Richard Crume, Editor

ENVIRONMENTAL HEALTH IN THE 21ST CENTURY

From Air Pollution to Zoonotic Diseases

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Environmental Health in the 21st Century

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From Air Pollution to Zoonotic Diseases

Volume 1: A–K

RICHARD CRUME, EDITOR

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Dedicated to the civil servants of the U.S. Environmental Protection Agency, who have devoted their careers to solving the most challenging environmental health issues while providing global leadership and making the world a better place for future generations. Their hard work, professionalism, and commitment to public service often go underappreciated.

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Contents

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Alphabetical List of Entries

Topical List of Entries

Environmental Pollution

Health Sciences

Energy and Climate

Waste Management

Built Environment

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Preface

The environmental health landscape is changing quickly and dramatically, with new issues arising almost daily. Toxic chemicals, infectious diseases, hazardous waste, climate change, genetically modified foods—the list of environmental health issues is almost endless. Yet, there are surprisingly few encyclopedias and other references covering the field of environmental health that are up to date and relevant to the concerns of today. The decision to publish *Environmental Health in the 21st Century: From Air Pollution to Zoonotic Diseases* was born from a desire to provide a comprehensive and concise resource for students, teachers, researchers, and the general public that presents the latest information in a convenient, encyclopedic format.

The field of environmental health is increasingly complex, interdisciplinary, and multifaceted, so much so that it is impossible for any one person, no matter how brilliant, to know everything there is to know about the field. For this reason, we have brought together a team of experts in various aspects of environmental health to share their knowledge by preparing entries relevant to their expertise. These experts include college and university professors, public health practitioners, physicians, research scientists, and other healthcare and environmental professionals. Additionally, lawyers prepared entries on relevant legislation, and environmental librarians and journalists contributed entries about important historical events and personalities in the environmental health field.

In addition to cross-referenced entries on a wide range of topics related to human health and the environment, the text includes a history of environmental health, interviews with leading figures in the field, a section on steps individuals can take to reduce their own environmental exposure, and a glossary. Also, a directory of resources is provided, and every entry includes a list of references for further reading. As an aid to locating entries related to the broader topics of environmental pollution, health sciences, energy and climate, waste management, and the built environment, entries are tagged with icons representing these topic areas. All interviews that appear in the text were conducted by the editor, Richard Crume.

One of the challenges in compiling the text was arriving at a definition of environmental health to guide us in selecting subject matter. Unfortunately, there is no single definition that everyone agrees on. Instead, because of the breadth of the field and overlap with public health, there is considerable variation in definitions among environmental health professionals and health agencies. After review of these definitions and consultation with experts, we selected the following World Health Organization definition as our starting point:

> Environmental health addresses all the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviours. It encompasses

> the assessment and control of those environmental factors that can potentially affect health. It is targeted towards preventing disease and creating health-supportive environments. This definition excludes behaviour not related to environment, as well as behaviour related to the social and cultural environment, and genetics.

We expanded upon this definition in several ways. For example, we included several relevant social and societal concerns, such as children's environmental health, e-cigarettes, environmental justice, health implications of population trends, socioeconomic status and health, and secondhand and thirdhand tobacco smoke. We also added natural disasters, such as earthquakes and hurricanes, because these events sometimes are accompanied by the spread of disease, and cleanup often presents environmental health hazards. Several topics related to genetics (epigenetics, genetic engineering and GMOs, and toxicogenomics) were included, as were biographical sketches of important figures in the field and descriptions of several environmental disasters that led to new environmental activism and legislation. Green buildings, renewable energy, and energy efficiency were added because they help reduce climate change-causing gases, and we addressed recycling and waste management topics because of their role in reducing environmental toxicants in the environment.

We gave careful consideration to which human diseases to cover, eventually arriving at a list of the more common infectious and communicable diseases that are transmitted by agents in the environment, for example, mosquitoes, ticks, and fleas. Thus, we added entries on bubonic plague, cholera, Ebola virus, *Escherichia coli* infection, Guinea worm disease, Lyme disease, lymphatic filariasis, malaria, norovirus infection, river blindness, Rocky Mountain spotted fever, schistosomiasis, tetanus infection, trachoma, West Nile virus, yellow fever, and Zika virus. To go beyond this list would have entailed adding many entries more appropriate for a treatise on public health than environmental health. In addition to specific diseases and viruses, entries address communicable, foodborne, infectious, insect-borne, waterborne, and zoonotic diseases. Healthcare-associated infections, Legionnaires' disease, and sick building syndrome are also covered.

Environmental Health Topic Areas

Each entry in the text includes at least one icon representing one of five topic areas: environmental pollution, health sciences, energy and climate, waste management, and the built environment. For entries that cross over topic areas, more than one icon is included. For example, the entry on hazardous air pollutants involves not only pollution but also health sciences research on toxic health effects. Thus, the entry includes icons for both environmental pollution and health sciences. Here is what each icon means:

Environmental pollution is the introduction of contaminants into the environment that have the potential to threaten the health of humans and endanger all the diverse forms of life found in our biosphere. We often think of environmental contaminants as toxic chemicals from manufacturing operations, but the definition is actually far broader. For example, pollution can include noise, light, and heat, and it can originate from motor vehicles, landfills, marine vessels, lead pipes, consumer products, hydraulic fracturing, and natural sources such as volcanos. Additionally, gases like carbon dioxide, which are nontoxic and do not directly threaten human health, are implicated in climate change, which may have dramatic consequences for human life.

The health sciences field covers a broad range of disciplines concerned with all dimensions of human health. Practitioners in the field could be physicians and nurses, public health professionals, professors and research scientists, health agency personnel, and a variety of other professionals in the sciences and engineering. The health sciences also include mental health specialists, practitioners of alternative and folk medicines, and innovators of new technologies and treatments. Equally broad are the settings where health science professionals work, such as state and local health departments, hospitals, research universities, federal agencies, and nonprofit organizations. One of the most important environmental health concerns in the health sciences is the control of infectious diseases.

Energy production and use have probably contributed more to environmental degradation over the years than any other human activity. In particular, the combustion of fossil fuels—coal, oil, and natural gas—to run our electric power plants has resulted in widespread air and water pollution and increasingly high levels of greenhouse gases in the atmosphere. Additionally, processes for extracting fossil fuels damage the natural environment, and recent contamination of waterways with coal ash has further raised the public's concern about the health impacts of traditional power generation. Renewable energy and green buildings hold promise for reducing humanity's dependence on fossil fuels, although progress has been slowed by political inertia and infrastructure needs. Nevertheless, energy-efficient appliances are as popular as ever, as are electric and hybrid automobiles that help reduce urban pollution and cut greenhouse gases.

America is running out of options for managing the huge amount of waste generated every day. Many urban area landfills are filling up, and communities are often resistant to building new ones nearby. This means that wastes are often trucked long distances to rural landfills, creating more pollution and risking spills along the way, and some wastes are even shipped overseas. Waste incineration is an option to landfills, but it has never caught on in a big way in America due to costs and concern over air pollution. Hospital and medical waste disposal presents special problems due to potential contamination with infectious agents, and the disposal of radioactive wastes from nuclear power plants has never been satisfactorily addressed on a national scale. Fortunately, recycling and pollution prevention programs are now commonly accepted in many communities, helping to reduce the volume of waste produced and sometimes achieving economic benefits for companies that have learned to waste less raw material.

The built environment comprises the physical areas where we live, work, shop, study, and play—our homes, schools, libraries, community centers, office buildings, hospitals, stores, restaurants, streets, and parks. Also included in the built environment is urban infrastructure, such as electricity and cable TV lines, as well as cell phone towers, sewer and stormwater drainage systems, and urban transportation systems. The built environment provides many conveniences we cannot live without, but it also creates pollution from factories and motor vehicles, increases greenhouse gases, and subjects residents to higher temperatures due to the heat island effect. Furthermore, it increases our risk of infectious disease because of our close proximity to other people. Recent innovations and initiatives, such as electric subways and trains, buses powered with clean fuels, low-emission automobiles, industrial pollution controls, bicycle lanes, green buildings, and more parks and trees, are helping to make the built environment healthier and more environmentally friendly.

Nearly two years in the making, our objective was to bring together leaders in the environmental health field to prepare a work of unequaled scope and content, one that will remain a valuable resource for home, office, research lab, and classroom for years to come. We would be most pleased if *Environmental Health in the 21st Century: From Air Pollution to Zoonotic Diseases* came to be counted among your most trusted reference materials.

Acknowledgments

Over 80 professionals from the environmental health field contributed entries and interviews to this work, giving freely of their time and expertise. Maxine Taylor of ABC-CLIO was a source of expert guidance and steadfast encouragement, without which this project would never have come to fruition. Finally, my wife, Yoko, and daughter, Hana, provided unending support and encouragement all along the way. I am indebted to you all.

Introduction to Environmental Health

What Is Environmental Health?

Environmental health is a field of science concerned with how the environment influences human health and disease. These environmental influences include air and water pollution, toxic substances, hazardous wastes, infectious diseases, climate change, contaminated food, radiation, and natural disasters. Environmental health professionals perform a variety of tasks, such as monitoring pollution levels, conducting research into the toxicity of pollutants, cleaning up hazardous material spills, investigating disease outbreaks, developing policies and regulations, and educating the public on environmental health risks.

Americans are preoccupied with their health. Organic foods have never been more popular, supermarkets are full of dietary supplements and healthy living magazines, and TV commercials tout the benefits of the latest miracle pharmaceuticals. Exercise and dieting have become part of the daily routine for millions of Americans, as more people are kicking the smoking habit or never starting in the first place. Why all the interest in health?

We have learned that being healthy makes you feel better, enjoy life more, and be more productive at work. However, sometimes our preoccupation with health is driven more by fear that if we do not take good care of ourselves, we may develop some dreaded, life-threatening disease. Despite our efforts to live healthy lives and have regular checkups at the doctor's office, heart disease, cancer, chronic lower respiratory diseases, and stroke are all too common in America, and many people also suffer from diabetes, Alzheimer's disease, influenza and pneumonia, and kidney disease.

No matter how healthy our eating habits are and how many trips we make to the gym, some diseases are going to happen anyway—they are hereditary or due to other factors beyond our control. But we often do have control over diseases brought about by environmental factors, that is, factors in our immediate surroundings that we can modify or avoid. For example, we can remove toxic chemicals from drinking water, avoid areas high in air pollution, eat pesticide-free foods, and support the work of local health officials to prevent the spread of infectious diseases. These are choices we can make as individuals and as a society.

The overall health of a population is often characterized by its life expectancy—basically, how long we can expect to live. Many Americans are surprised to learn that compared with other developed nations, we rank relatively low when it comes to life expectancy. This is a complex issue related to a number of circumstances, such as access to quality health care, family support, and a stressful work environment. However, it is no coincidence that Americans have higher exposure to pollution than people in many other countries. Toxic pollutants in our air, water, and food are known to cause cancer, heart and lung disease, and other adverse health conditions that shorten our lives, and in our major cities, it is common for the incidence of disease to be higher for people living in close proximity to polluted industrial areas and freeways.

The field of environmental health is concerned with the environmental factors, external to the human body, that are a threat to public health. These environmental factors can be physical, chemical, or biological, and either created by humans or found in nature. They can directly cause diseases or make existing illnesses worse, and the effects can be as minor as a headache or as serious as debilitating illness and even death. The goal of the environmental health profession is to identify the environmental factors that present a risk to our health and to manage or eliminate this risk.

Environmental health is occasionally misunderstood as being about protecting the health of plants and animals, as opposed to that of humans. However, plant and animal health is more aptly covered by other disciplines, such as ecology, biology, and environmental conservation. Nevertheless, most scientists believe that all forms of life are interrelated and that a healthy biosphere is essential for human survival. Some scientists even conceptualize the earth as one giant living organism, with all life forms interdependent and contributing to the overall health of the planet.

Although environmental health is usually associated with the out-of-doors, understanding the indoor environment is just as important because average adults spend up to 90 percent of their time indoors while at home, work, school, restaurants, and shops. The environmental contaminants inside a building can build up to levels much higher than outside. Additionally, workplace safety is a major concern for manufacturing facilities and other businesses where workers are exposed to physical, chemical, or biological hazards. Thus, the field of environmental health encompasses exposures both inside and outside, 24 hours a day.

Protecting Health Is Priority Number One

Protecting public health may be the greatest challenge of the modern world. Environmental health, which evolved from the public health field, has grown in importance as pollution has increased with industrialization, as a large number of man-made chemicals have entered the environment, and as people have become more aware of the benefits of good hygiene and a clean environment. One of the newest environmental health concerns, climate change, has the potential to substantially and irreversibly alter the atmosphere, with potentially devastating consequences for human health and the biosphere.

The World Health Organization estimates that nearly one-quarter of all deaths throughout the world can be attributed to environmental factors, and for children, this estimate exceeds one-third. Of course, we all die eventually, but because of environmental factors, people die sooner than would otherwise be expected, a phenomenon called premature mortality. For example, environmental factors are implicated in a number of global, life-threatening diseases, including malaria (associated with land use practices, deforestation, and poor water resource management), diarrhea (associated with contaminated drinking water and poor sanitation and hygiene), and lower respiratory infection (associated with both indoor and outdoor air pollution).

There are large regional differences in environmental health due to differing environmental exposures and the availability of health care. Poor environmental quality is a major concern for people in developing nations, who are already at risk due to poverty, malnutrition, poor sanitation, and limited medical services. However, environmental quality is also a problem in developed countries such as the United States, where many are sickened each year from exposure to contaminants in the air and water. Additionally, compared with developing nations, developed countries generally have higher per capita rates of cardiovascular disease and cancers caused by environmental factors. In the United States, about 120 million people live in areas where national ambient air quality standards are exceeded, and millions more drink from tainted water supplies.

Unfortunately, it is often difficult to establish a causal pathway between environmental exposure and disease. We know certain toxic environmental contaminants can cause cancer, but we do not always know whether specific cancers were likely caused by environmental factors, genetics, or some combination. And this same dilemma also holds true for other adverse health conditions and diseases. Consequently, the full extent to which environmental factors contribute to disease in humans is unclear.

Dimensions of Environmental Health

While there is no standard definition of environmental health, most environmental health professionals and agencies address a broad spectrum of environmental factors that threaten public health. This includes air and water pollution, toxic substances, hazardous wastes, infectious diseases, climate change, contaminated food, radiation, and natural disasters. Genetics are often excluded from the environmental health field, as are behaviors not related to the environment, social, and cultural aspects of a community that are independent of the environment, and environmental risks not amenable to environmental management intervention.

Another way to understand the environmental health field is to examine the specific challenges faced by environmental health professionals. These include:

- Ensuring drinking water supplies are safe, and protecting aquifers, watersheds, and estuaries
- Minimizing adverse health and environmental effects from contaminants in the atmosphere, including air pollution, greenhouse gases, and pollutants leading to acid deposition and stratospheric ozone depletion
- Treating and disposing of a vast array of solid, liquid, and radioactive wastes, and protecting the public from the harmful effects of toxic chemicals
- Investigating communicable and infectious diseases, and defending the public against pathogens in the environment that cause these diseases
- Ensuring the food supply remains safe and plentiful
- Preventing the loss of species. (Most medicines come from plants, animals, and microbes.)
- Maintaining a healthy indoor home and work environment, and preventing workplace injuries
- Responding to natural disasters like earthquakes, hurricanes, and tornadoes in a timely and effective manner

With such a wide variety of challenges, a multidisciplinary approach among environmental professionals is needed. This explains why it is common for environmental scientists, engineers, toxicologists, epidemiologists, biologists, physicians, and other health professionals to work collaboratively to address environmental health issues. When these and other specialists come together to solve a problem, a high level of teamwork results, and often innovative solutions that benefit the entire environmental health field emerge.

Achieving an Acceptable Level of Risk

Fortunately, many steps can be taken to reduce the risk of injury and disease from environmental factors. These include providing safe drinking water, improved hygiene, cleaner fuels, and better management of toxic substances. Additionally, government agencies have developed automobile emission standards and require environmental controls for various industries, including electric power generation, oil and gas extraction and refining, iron and steel manufacturing, agricultural production, transportation, and mining. Other actions to reduce environmental risk include promoting renewable energy and green buildings and encouraging more physical exercise and healthy lifestyles. Many of these steps have already been taken, but there is always room for improvement, and more work is needed to achieve an acceptable level of environmental risk for all the inhabitants of our planet.

Implementing procedures to reduce environmental risk is a tedious process, involving many partners. Government agencies, community leaders, university researchers, hazard control specialists, nonprofit agencies, and the private sector must all work together to find solutions. Public education is often key to recognizing and preventing environmental exposures, as is emergency response capability when hazardous substances are unexpectedly released into the environment. An ongoing need in the environmental health field is to improve coordination and input among all interested parties, particularly minority, low-income, and tribal communities, which are often disproportionately affected by toxic releases and infectious diseases.

The environmental health field is constantly evolving as new agents are introduced into the environment and better options are identified to reduce exposure. Every year, hundreds of new chemicals enter the U.S. market, often with unknown environmental consequences. At the same time, new technologies, such as the production of nanomaterials, may contaminate the environment in novel and unexpected ways. And the growing array of hazardous waste materials, including the toxic metals in cell phones and other throwaway electronics, requires more sophisticated disposal and recycling options. This dynamic nature of the environmental health field presents many challenges to health officials, researchers, and government policymakers, but it is also immensely satisfying when solutions are found. In this regard, few professions are more rewarding.

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Environmental Health: A Historical Perspective

There is nothing new about environmental health. From the beginnings of human civilization, people have struggled to secure food and water supplies, and they have suffered from floods, drought, disease, and hunger. The first environmental pollution may have occurred when *Homo sapiens* made fire for heating and cooking that created smoke and soot. The walls of some caves inhabited by humans thousands of years ago are covered with layers of soot, presumably from fires burning inside, and the lungs of ancient mummified bodies sometimes appear darkened from the polluted air. Some researchers speculate that early mining, and metallurgy activities may have caused silicosis and lead poisoning.

As cities developed and grew in size, air pollution, unsanitary drinking water, and sewage disposal were often problems. The ancient Romans complained of smoke, odors, and polluted water from the mining and quarrying of stones and from local workshops involved with brick and glass production, pottery-making, smelting, blacksmithing, and fish processing. Public health improved as the Romans built clean water aqueducts, sewers, and public latrines, although there is some doubt that these infrastructure projects improved sanitation all that much.

Hippocrates (460–375 BCE), the ancient Greek physician regarded as the father of medicine, might also be considered the father of environmental health. He observed that it was often contaminated air and water that make people ill and that food, climate, and occupation were associated with disease. And Hippocrates famously remarked that to learn about the health of a population, you should examine the air they breathe, the water they drink, and the places where they live. The citizens of his time came to realize that by paying attention to environmental factors such as clean water, they could play an active role in protecting their own health, rather than depending on the whims of gods and goddesses.

Infectious diseases were rampant during the Middle Ages, often due to contaminated drinking water and poor hygiene. Today it is hard to imagine the suffering caused by the Black Death, a mid-14th-century epidemic of bubonic plague caused by the bacterium *Yersinia pestis*, which circulates among wild rodents, particularly rats. The disease is usually transmitted to humans when they are bitten by an infected flea that has left its recently dead rat host and is looking for a new meal of blood. Estimates vary on the number of deaths attributed to the disease, but it is believed that more than half the population died in some European cities, so many that there were insufficient numbers of survivors to bury the dead. Estimates of plague deaths in Europe range from 25 to 50 million, and another

25 million may have died in Asia and Africa. Other outbreaks of plague and other infectious diseases have occurred, but the Black Death appears to have had the most far-reaching consequences for human health and society.

As industrialization took hold in the civilized world in the eighteenth and nineteenth centuries, environmental health concerns multiplied. Smog blanketed many cities as people burned wood and coal to heat their homes and run factories. Water pollution was common, leading to the spread of infectious diseases and eventually the development of sanitary systems to protect drinking water from sewage. Many cities instituted trash removal programs, including the first landfills, to reduce breeding sites for rats that carry diseases. Around the middle of the 19th century, John Snow (1813–1858), recognized as the father of modern epidemiology, traced the source of cholera outbreaks to contaminate drinking water. And later John Leal (1858–1914), another pivotal figure in the environmental health field, performed the first disinfection of a drinking water supply system using chlorine.

In the United States, environmental health concerns surfaced as early as 1652, when Boston established a public water system to supply clean water for domestic use and firefighting. (Water supply lines were made of wood.) Other cities would follow suit in the next century, and in 1804, Philadelphia became the first city to use cast iron water lines. In 1854, Henry David Thoreau (1817–1862) published *Walden*, an account of his two-year stay on Walden Pond that earned him recognition as the father of environmentalism and continues to inspire naturalists and environmentalists today. John Muir (1838–1914), the famous naturalist and conservation advocate whose activism gave birth to our national park system, helped found the Sierra Club in 1892. Believing in the healing power of nature, Muir wrote, "Everybody needs beauty as well as bread, places to play in and pray in, where nature may heal and give strength to body and soul alike."

While the modern beginnings of the environmental health field cannot be attributed to any one occurrence, several 20th-century events were instrumental in helping the field gain momentum. One was the 1962 publication of *Silent Spring*, the seminal book by Rachel Carson (1907–1964) demonstrating that pesticides like DDT can bioaccumulate in the food chain, threatening wildlife and human health. *Silent Spring* first brought to light the hazards of environmental contamination for millions of Americans, and it strongly influenced the emerging environmentalism movement and subsequent formation of the U.S. Environmental Protection Agency (EPA).

Along with Rachel Carson, other Americans were influential in the nation's nascent environmental health movement. Frances Moore Lappé (1944–), author of the 1971 best seller *Diet for a Small Planet*, demonstrated how healthy eating habits are not only good for the individual but can also alleviate world hunger. Albert Gore Jr. (1948–), the 45th vice president of the United States and an ardent climate change activist, won the Nobel Peace Prize in 2007 (sharing it with the Intergovernmental Panel on Climate Change), and his climate change awareness movie, *An Inconvenient Truth*, won an Oscar the same year. Luther L. Terry (1911–1985), the surgeon general of the United States from 1961 to 1965, is known for his groundbreaking work in warning the public about the dangers of tobacco use. R. Buckminster Fuller (1895–1983) invented the geodesic dome (patented in 1954), based on the principle of doing more with less, and to inspire responsible stewardship of our planet's limited resources, coined the phrase *spaceship earth*. Alan Chadwick (1909–1980), although an Englishman, pioneered sustainable organic gardening in the United States.

In addition to these remarkable individuals, a number of environmental calamities since the mid-20th century helped define the modern boundaries of the environmental health field. The following timeline identifies some of the more notable events:

1948: A deadly smog that occurred in the steel and zinc town of *Donora, Pennsylvania*, killed 20 people, sickened many more, and led to greater public awareness about air pollution and the need for clean air legislation.

1952: About 4,500 excess deaths occurred following an unusually severe *London smog* event, and many more deaths were reported in the following weeks as the sooty smoke persisted, resulting in newfound international awareness about association between air pollution and public health.

1956: An investigation of neurological symptoms experienced by some residents of Minamata City, Japan, led to the discovery of what came to be known as *Minamata disease*, a form of severe mercury poisoning caused by eating fish and shellfish contaminated by methylmercury in factory wastewater.

1957: A Japanese physician first linked *Itai-Itai disease*, a painful kidney and bone condition seen in residents of the Jinzu River Basin, to the presence of cadmium in the water, originating with a zinc mining and smelting company. (Itai-Itai means "it hurts, it hurts" in Japanese.)

1967: The supertanker *Torrey Canyon* ran aground near Cornwall, England, and eventually spilled its entire load of oil into the sea, fouling beaches, killing thousands of seabirds, and drawing international attention to the hazards of oil transport and the challenges of oil spill cleanup.

1969: The pollution was so bad in Cleveland's *Cuyahoga River* that the river caught fire at least a dozen times, including an incident in 1969 that was featured in *Time* magazine, a story that helped spur the nascent environmental movement.

1976: Following an explosion at a chemical plant, a cloud of toxic dioxin gas descended on *Seveso, Italy*, and other nearby towns, sickening local residents, killing several thousand farm animals, and resulting in the slaughter of thousands more farm animals to keep dioxin out of the food chain.

1978: About 20,000 tons (18,100 metric tons) of toxic chemical wastes in the abandoned *Love Canal* waste dump began affecting the health of local residents, prompting President Jimmy Carter to declare a federal health emergency and providing a major incentive for passage of the Comprehensive Environmental Response, Compensation, and Liability (Superfund) Act.

1979: An accident at the *Three Mile Island* nuclear plant caused a partial meltdown of a reactor, and although there were no detectable health effects associated with the subsequent small release of radiation, the accident resulted in major improvements to emergency response planning and safety protocols for the nuclear power industry.

1982: At the Union Carbide pesticide plant in *Bhopal, India*, an accident resulted in the release of deadly methyl isocyanate and other toxic gases, possibly exposing over 600,000 people and killing 15,000, by some estimates.

1986: A reactor design flaw and operator error at the *Chernobyl* nuclear power plant in Ukraine led to a violent explosion that contaminated a wide area, resulting in 30 deaths and over 100 cases of acute radiation sickness among plant workers and firefighters and causing an increase in childhood thyroid cancer in the surrounding community.

1989: The *Exxon Valdez* oil tanker ran aground in Prince William Sound, Alaska, spilling nearly 11 million gallons (42 million liters) of crude oil into a scenic and biological sensitive area, representing the largest single oil spill up to that time.

1991: As the Iraqi military retreated toward the end of the Persian Gulf War, a major environmental disaster ensued as a team of Iraqi engineers set fire to the *Kuwaiti oil fields* and millions of barrels of oil were dumped into the sea.

2010: The *Deepwater Horizon* drilling platform exploded, killing 11 workers and causing millions of barrels of oil to be released into the Gulf of Mexico, creating an oil plume extending 22 miles (35 kilometers), and doing untold damage to ecosystems that are still struggling to recover.

2011: Following a massive earthquake off the Pacific coastline of northeastern Japan and subsequent 50-foot (15-meter) tsunami, a meltdown occurred at three reactors of the *Fukushima Daiichi* nuclear power plant, releasing a radiation cloud and causing the evacuation of over 100,000 local residents.

2014: When city officials switched the water supply of *Flint, Michigan*, to the Flint River without implementing proper anticorrosion measures, corrosion in water pipes resulted in high lead concentrations in drinking water that in some homes were 10 times higher than the safe limit set by the EPA.

A discussion of the origins of the modern environmental health field would be incomplete without mentioning the day American environmentalism became a popular movement. On April 22, 1970, the nation held its first Earth Day—a celebration of clean air, clean water, and clean land. In New York City, Fifth Avenue was shut down as more than 100,000 people amassed in Union Square and Central Park to hear speeches, sing songs, and participate in environmental "teach-ins." Crowds also gathered in Washington, D.C., as Congress suspended business so that its members could meet with constituents on the National Mall. This first Earth Day may have been prompted by the recent moon landings and photographs of our fragile blue planet from outer space, and the 20 million participants nationwide far surpassed the wildest expectations of organizers.

Later that same year, the EPA was formed and given broad responsibility for protecting public health and the environment. This was a significant event in the history of environmental health in America because it represented the first governmental separation between public health and environmental health concerns, which had previously been combined within single agencies like the Public Health Service. One of the EPA's top priorities was to address the nation's serious air and water pollution problems by implementing the newly passed Clean Air Act and two years later the Clean Water Act. Additionally, other federal legislation was enacted during the latter part of the 20th century to assist the EPA and other federal agencies in cleaning up the environment and protecting public health. This legislation included:

- Comprehensive Environmental Response, Compensation, and Liability Act
- Emergency Planning and Community Right-to-Know Act
- Endangered Species Act
- Federal Insecticide, Fungicide, and Rodenticide Act
- Marine Protection, Research, and Sanctuaries Act
- National Environmental Policy Act
- Occupational Safety and Health Act
- Pollution Prevention Act
- Resource Conservation and Recovery Act
- Safe Drinking Water Act
- Superfund Amendments and Reauthorization Act
- Toxic Substances Control Act

In addition to the EPA, other federal entities were given major responsibilities for environmental research and education (including workplace hazards and indoor air quality). These include the National Center for Environmental Health, National Institute for Occupational Safety and Health, National Institute of Environmental Health Sciences, National Oceanic and Atmospheric Administration, and Occupational Safety and Health Administration. At the same time, professional associations like the American Public Health Association expanded their environmental health agenda, and nonprofit organizations like the Carter Center raised funds to study and control the transmission of infectious diseases overseas. The Federal Emergency Management Agency was formed to respond to natural disasters and human-caused health emergencies, such as hurricanes and industry chemical leaks.

Over the history of environmental health, children have been particularly at risk and often suffered the most. The natural defenses of young bodies, especially their immune systems, are not yet fully developed. Additionally, children often have greater exposure to environmental toxicants because they spend more time playing outside in polluted air and ingesting contaminated dirt as they put their hands and other objects in their mouths. And unlike many adults, children have little control over their social and physical environments and the potentially detrimental behavior of those around them (e.g., adults who smoke cigarettes). Similar to children, older adults have historically been at greater risk from environmental hazards, often due to weakened natural defenses and chronic health conditions.

Environmental health history is also replete with examples of how the greatest exposure to toxicants tends to occur among low-income and minority populations, a trend that continues today. These people often live closest to the industrial sources of pollution and have limited options to move away from the contamination and to seek out the best health care. For example, the World Health Organization reports that currently over 80 percent of people living in urban areas that monitor air pollution are exposed to air quality levels higher than acceptable limits, and low-income cities are the most impacted. Similarly, low-income and minority populations in many countries often disproportionately contend with poor drinking water, inadequate sewage disposal, and the spread of infectious diseases.

Great progress has been made over the past century in reducing environmental health risks, particularly in providing clean water supplies and curbing the spread of infectious diseases. However, serious challenges remain. The World Health Organization reports that today about a quarter of diseases and deaths globally are linked to environmental hazards and that air pollution represents the world's largest single environmental health risk. Nearly 7 million premature deaths each year are attributed to air pollution, spilt almost evenly between outdoor and indoor air pollution exposure. Additionally, unsafe water and poor sanitation and hygiene result in about 1.7 million deaths annually, and malaria kills over 1.2 million people every year, mostly young children in Africa. Inadequate drinking water and waste disposal, poorly designed irrigation, deforestation, and loss of biodiversity all contribute to the spread of vector-borne diseases.

There is little history to guide us with regard to the newest threat to environmental health—climate change—which experts tell us will cause stronger and longer droughts, more intense storms and heat waves, the spread of infectious diseases, worse air pollution episodes, food shortages, and eventually, the mass migration of people to more inhabitable areas. However, perhaps we can learn from past successes in the environmental health field, such as the importance of good science and international cooperation. The environmental health challenges of the future, like climate change, will be complex, multidisciplinary, and multinational, crossing international borders and requiring geopolitical solutions. The environmental health profession will be needed more than ever.

A

AIR POLLUTION

Having clean air to breathe is essential to maintaining good health. Yet, we often take for granted our air quality, perhaps because air pollution is usually invisible, except on days when the pollution is particularly bad. Although we may not always be aware of polluted air, it can affect our health by causing burning eyes, irritated throat, coughing, and breathing difficulties. Long-term exposure to air pollution can damage our immune, neurological, reproductive, and respiratory systems and even cause cancer. And during extreme episodes, people have died from breathing the polluted air.

Are We Surrounded by Air Pollution?

With all the talk about air pollution, you would think the air we breathe is full of nasty gases and particles. While it is true that the atmosphere contains concentrations of air pollutants often high enough to cause respiratory discomfort and sometimes make us sick, air pollution is hardly a major component of the air we breathe. In fact, 99 percent of the atmosphere consists of just two gases: nitrogen at 78.1 percent and oxygen at 20.9 percent (by volume in dry air). And another 0.9 percent is argon. That leaves just 0.1 percent for everything else—ammonia, carbon dioxide, carbon monoxide, helium, hydrogen, iodine, krypton, methane, neon, nitrogen dioxide, ozone, xenon, and various pollutants that are often present in only the part-per-million (ppm) range or less. (1 ppm is just 0.0001 percent.) The air also contains water vapor, which can vary from 1 to 5 percent, and particles, such as dust, smoke, acid droplets, and pollen. Despite the relatively low concentrations of pollutants in the air we breathe, the health effects associated with air pollution are well documented. For example, it is common for hospital emergency room visits to increase on days when particulate and ozone concentrations are elevated, and very low concentrations are hazardous air pollutants have been shown to cause cancer and other serious health problems.

In addition to these adverse health effects, air pollution can degrade the environment in various ways. For example, it causes acidic rainfall, attacks the stratospheric ozone layer, and reduces visibility in our national parks. Acidic forms of air pollution can etch automobile windows and cause the surfaces of buildings and

What Is the World's Greatest Environmental Health Risk?

Air pollution is not just a problem of industrialized nations like the United States. The World Health Organization estimates that in 2012 (the most recent year they analyzed), about 7 million people around the world died prematurely due to air pollution exposure, making air pollution the world's largest single environmental health risk. Over half of these deaths were related to indoor exposure in households using coal, wood, or biomass for cooking. About 82 percent of the indoor exposure deaths and 91 percent of outdoor exposure deaths were caused by stroke, ischemic heart disease, and chronic obstructive pulmonary disease. Other causes of death included lung cancer and acute lower respiratory infections in children. A 2016 study published by researchers at the University of British Columbia estimated the number of premature deaths from both indoor and outdoor air pollution at 5.5 million, more than half occurring in China and India.

monuments to deteriorate. And through a mechanism called deposition, mercury and other pollutants in the atmosphere (e.g., sulfates, nitrates, nitrogen dioxide, sulfur dioxide, and nitric acid) can contribute to poor water quality in lakes and streams. (Dry deposition is where air pollutants contact the water surface through the processes of molecular diffusion, impaction, and gravitational settling, while wet deposition is where raindrops drag air pollutants down with them as they fall. Snowfall and fog can also contribute to wet deposition.)

There are many sources of air pollution. These include motor vehicles and a variety of commercial and industrial activities, such as burning fossil fuels in power plants to produce electricity, operating oil refineries and iron and steel plants, manufacturing plastics and chemicals, mining for metals and other raw materials, and smaller everyday activities like dry cleaning, auto body shop painting, and pumping gas. Additionally, there are natural sources of air pollution, like the gases and particles coming from volcanos and forest fires and the wind-blown dust common in dry areas of the southwestern United States. We can also be exposed to air pollutants while indoors, for example, from gas appliances, cleaning agents, pesticides, and personal-care products. (See the entry on Indoor Environment for more information.)

There are different ways of classifying air pollution sources. For example, cars, trucks, buses, trains, and airplanes are called mobile sources, whereas industrial and commercial operations are called stationary sources. Stationary sources are further broken down as point sources, where the pollution is emitted from a specific point like a smokestack, and area sources, where the pollution emanates from a large number of smaller sources, such as all of the dry cleaners or auto body paint shops in a city. Individually, an area source may not emit much air pollution, but when all the area sources in a city are taken together, the pollution they cause can be substantial.

Smoke billows from factory smokestacks. We often take for granted the air we breathe, but clean air is essential to good health. (Rusty Elliott/Dreamstime.com)

Air pollution is also categorized according to the type of pollutant. The criteria pollutants (i.e., carbon monoxide, nitrogen dioxide, lead, ozone, particulate matter, and sulfur dioxide) are widespread and often associated with respiratory discomfort and distress, whereas the hazardous air pollutants (e.g., asbestos, benzene, cadmium, chromium, dioxin, mercury, methylene chloride, and toluene) are more localized and can cause serious, sometimes life-threatening health conditions such as cancer. (Hazardous air pollutants are also known as toxic air pollutants, or simply, air toxics.) Under the Clean Air Act, the U.S. Environmental Protection Agency (EPA) is required to work with state and local environmental agencies to reduce emissions of 187 hazardous air pollutants. (See the entries on Ambient Air Quality and Hazardous Air Pollutants for more information.)

Carbon dioxide (CO_2) is another type of air pollutant, although some scientists question whether it should be considered air pollution because CO_2 is naturally present in the atmosphere as part of the earth's carbon cycle, and it does not, by itself, adversely affect human health. Concentrations of CO_2 in the atmosphere have increased by more than 40 percent since preindustrial times, largely due to the vast quantities of CO_2 emitted from electric power plants that burn fossil fuels. This large increase in atmospheric CO_2 concentrations, occurring over a brief period of human history, is considered the primary cause of climate change. (See the entries on Climate Change and Human Health and on Carbon Dioxide and the Carbon Cycle for more information.)

How people react to air pollution depends not only on the type of air pollutant but also on the concentration of the pollutant in the air, the duration of exposure, and whether other pollutants that cause synergistic effects are present. Elevated temperature and humidity can also add to the discomfort and worsen symptoms. To help protect people when the air quality is poor, the EPA issues Air Quality Index alerts for days when the air pollution is high enough to cause adverse reactions. (See the entry on AirNow and the Air Quality Index for more information.)

Because many pollutants remain in the atmosphere for long periods and can be carried by the winds to remote locations, you do not have to live in a big city to experience poor air quality days. In fact, air pollution over the United States has been tracked from as far away as China. Also, some remote areas in the United States have large air pollution sources, such as electric power plants, smelters, and mining operations, that can cause localized pollution problems. Some valleys where woodstoves are used for heating homes are particularly prone to air pollution from the particles in woodstove smoke.

In the United States, air pollution is regulated at the federal level under the Clean Air Act. The act has been highly effective in reducing air pollution emissions. For example, between 1970 (the year the act was enacted) and 2016, emissions of the criteria pollutants decreased by 73 percent, while over the same period, energy consumption, population, vehicle miles traveled, and gross domestic product (factors that would be expected to worsen air pollution) increased 44, 58, 190 and 253 percent, respectively. (CO_2 emissions, which are associated with energy consumption, also increased.) Despite falling emissions, over 120 million people in 2016 lived in areas with air pollution levels above one or more of the national ambient air quality standards (NAAQS) for the six criteria pollutants.

In addition to the NAAQS, which address pollutants in the ambient air, federal regulations limit air pollution emitted from motor vehicles and certain industrial and commercial facilities. Many of the industrial and commercial regulations are for hazardous air pollutants and require the facilities to install the best pollution-reduction technologies that are currently available. The states and many cities also have their own air pollution emission regulations, which generally must at least as stringent as any federal regulations covering the same emission sources.

Because the average person breathes over 3,000 gallons (11.4 cubic meters) of air each day, and children breathe even more proportional to their body weight, there is a good chance any air pollutants in the surrounding air will find their way into our lungs and blood stream. (Air pollution can also be absorbed through the skin.) Thus, we need to be careful to avoid polluted areas and stay indoors on days when the Air Quality Index is elevated. We can all help reduce air pollution by driving hybrid or electric automobiles, using public transportation whenever possible, buying energy-efficient appliances, powering our homes with renewable energy, and supporting legislation, like the Clean Air Act, aimed at reducing air pollution and protecting the environment.

The Air We Breathe

Cleaner air leads to better health and productivity for American workers as well as savings on medical expenses for air pollution–related health problems.

An Interview with Jenny Noonan

Director, Policy Analysis and Communications, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency

As director for the Policy Analysis and Communications Staff in the U.S. Environmental Protection Agency's Office of Air Quality Planning and Standards, Noonan's team prepares communication materials for the public, responds to questions from the media, and addresses concerns from members of Congress, the White House, state governors, and local governments. These concerns typically involve the agency's national air quality standards, air pollution emissions from commercial and industrial facilities, and nationwide air pollution databases and monitoring systems.

Although the United States has made great progress in reducing air pollution emissions, many Americans still live in areas not meeting ambient air quality standards. What is the EPA doing to ensure every American enjoys clean air?

The Clean Air Act is one of the most successful pieces of federal legislation in history, as measured by improvements in air quality over time. Between 1980 and 2014, gross domestic product increased 147 percent, vehicle miles traveled increased 97 percent, energy consumption increased 26 percent, and the U.S. population grew by 41 percent—all factors that should have increased air pollution. Yet, during the same period, total emissions of the six principal air pollutants dropped by 63 percent. Despite this great progress in air quality improvement, approximately 57 million people nationwide lived in counties with pollution levels above the National Ambient Air Quality Standards in 2014. The Clean Air Act establishes a system of continual improvement, for example, by requiring the EPA to review, and if necessary, revise the Standards, putting into motion a series of steps that result in incremental improvements in air quality over time. The Act also requires improvement over time in the program addressing toxic air pollutants, mandating periodic review of emission control technologies and practices for key industrial sectors.

Environmental rules can be costly to implement, especially to the industries that must install pollution control equipment. Do the public health benefits resulting from these rules justify the costs?

Yes, and the EPA is required to periodically review the impact of the Clean Air Act on public health, the economy, and the environment. The most recent of these studies was released in 2011 and concluded that the benefits of the Clean Air Act outweigh the costs by more than thirty-to-one. Most of these benefits result from avoided premature deaths—230,000 in 2020 estimated as a result of the Clean Air Act. Other benefits include avoided asthma attacks (2.4 million), lost workdays (17 million), and heart attacks (200,000), all of which have costs associated with them. As the report concluded, "cleaner air leads to better health and productivity for American workers as well as savings on medical expenses for air pollution-related health problems."

Low income and minority populations are sometimes disproportionately exposed to environmental pollution. What is the U.S. government doing to address this problem?

The EPA's goal is to provide an environment where all people enjoy the same degree of protection from environmental and health hazards and equal access to the decision-making process to maintain a healthy environment in which to live, learn, and work. The EPA has a dedicated Office of Environmental Justice responsible for ensuring that Presidential Executive Orders and other environmental justice related mandates extend to all of the Agency's work. The EPA air program has been a leader in this regard. For example, our regulations for the petroleum refinery sector reflect the EPA's long-term engagement with affected communities and commitment to environmental justice. These regulations will reduce cancer risk for millions of people and provide important information about refinery emissions to the public and neighboring communities by requiring refineries to monitor emissions at key emission sources within their facilities and around their fence lines.

What is a good federal government career path for a recent college or university graduate committed to protecting public health and the environment?

Many options are available to those interested in protecting public health and the environment. There are career paths at the EPA available to scientists, engineers, as well as lawyers and liberal arts majors, who may find work in administration, contracting, or facilities management. Another common entry point for government employment is through military service or through the Peace Corps. Other options include obtaining experience in state or local environmental agencies or with environmental contracting firms and then moving into the federal government mid-career. There is no single ideal career path, but rather there are many options for arriving at a career at the EPA or one of the many other federal organizations working to protect public health and the environment.

Richard Crume

See Also: AirNow and the Air Quality Index; Ambient Air Quality; Asbestos; Asthma; Automobile and Truck Emissions and Controls; Cancer Clusters; Cancer Risk from Environmental Exposure; Carbon Dioxide and the Carbon Cycle; Clean Air Act; Climate Change and Human Health; Crops and Vegetation, Air Pollution Damage to; Dioxin Pollution; Electric Power Generation, Health Implications of; Energy Star; Environmental Protection Agency; Fugitive Dust; Hazardous Air Pollutants; Hexavalent Chromium; Hybrid and Electric Automobiles, Health Benefits from; Indoor Environment; Lead Poisoning Prevention; Mercury Pollution; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Public Transportation and Environmental Health; Regional Haze Pollution; Renewable Energy, Health Implications of; Respiratory Disease and Air Pollution; Stratospheric Ozone Depletion; Volatile Organic Compound Pollution; Woodstove Air Pollution

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AIRNOW AND THE AIR QUALITY INDEX

AirNow is an Internet-based service of the U.S. Environmental Protection Agency (EPA) that provides daily information to the public on air quality in communities across the United States. High levels of air pollution can cause coughing, shortness of breath, and other breathing difficulties, and long-term exposure to polluted air can damage the immune, neurological, reproductive, and respiratory systems. By

Air Quality and Older Adults

Many older adults, especially those with lung disease, are particularly sensitive to poor air quality. For example, ozone and particulate air pollution can aggravate asthma, chronic obstructive pulmonary disease (COPD), and other health conditions affecting older adults, leading to hospitalization and even premature death. People generally become more sensitive to air pollution in their mid-60s, although the risk of heart attack associated with particle pollution may begin as early as the mid-50s for women and mid-40s for men. On days when the air quality is poor, daily monitoring of the Air Quality Index can help older adults avoid outdoor activities and stay healthy. Because many older adults spend up to 90 percent of their time indoors, a clean indoor environment is also important for good health. The indoor contaminants that can trigger asthma attacks, COPD, and other health conditions include animal dander, building materials made from pressed wood, cleaning chemicals, cockroaches, dust and dust mites, fumes from cooking and space heating, molds, pesticides, pollen, and tobacco smoke (including exposure to secondhand and thirdhand smoke associated with other smokers in the household).

being aware of outdoor air quality, people can modify their daily routines, such as staying indoors and limiting exercise, when the air quality outside is poor.

The principal service offered by AirNow is the Air Quality Index (AQI), which provides air quality information to the public using a numerical and color-coded scale. The AQI is concerned with the health problems people may experience from breathing polluted air over a few hours or days, and it does not predict health effects from exposure over longer periods. If you live in the United States, you may have seen AQI reports during your local TV weather forecasts, especially when poor air quality is a concern for people spending time outdoors. The Weather Channel and other national media outlets carry AQI reports, and the AQI is also available on the Internet.

The AQI ranks air quality from 0 to 500. As the index number gets higher, the potential health concerns become more severe and affect more people. For example, a value of 50 (color code green) indicates good air quality, while a value over 300 (color code maroon) represents hazardous air quality, as shown in Table 1. Generally, values below 100 are considered satisfactory for most people, whereas values above 100 are unhealthy, particularly for the most sensitive individuals as well as for everyone else as AQI values increase.

The AQI is calculated and reported separately for five major air pollutants: ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide. (Among these pollutants, ground-level ozone and particulate matter represent the greatest health risks.) An AQI value of 100 generally corresponds

Table 1. AQI value, color, and level of health concern.

AQI Value	Color	Level of Health Concern
0 to 50	Green	Good—Air quality is satisfactory and poses little or no health risk.
51 to 100	Yellow	Moderate—Air quality is acceptable; however, pollution in this range may pose a moderate health concern for a very small number of individuals. People who are unusually sensitive to ozone or particle pollution may experience respiratory symptoms.
101 to 150	Orange	Unhealthy for Sensitive Groups—Although the general public is not likely to be affected at this AQI range, people with lung disease, older adults, children, and people who are active outdoors are at a greater risk from exposure to ozone; and people with heart and lung disease, older adults, and children are at greater risk from the presence of particles in the air.
151 to 200	Red	Unhealthy—Everyone may begin to experience some adverse health effects, and members of sensitive groups may experience more serious effects.
201 to 300	Purple	Very Unhealthy—AQI levels in this range would trigger a health alert, signifying that everyone may experience more serious health effects.
301 to 500	Maroon	Hazardous—AQI levels in this range would trigger health warnings of emergency conditions. The entire population is even more likely to be affected by serious health effects.

to the National Ambient Air Quality Standard for the pollutant. This is the ambient air concentration level the EPA has set to protect public health.

Other services provided by AirNow include AirNow International (an international version that helps countries manage their air quality), Enviroflash (daily air quality forecast e-mails), and the Flag Program (using colored flags to help schools, organizations, and the community be informed about air quality conditions).

Richard Crume

See Also: Air Pollution; Ambient Air Quality; Asthma; Environmental Protection Agency; Indoor Environment; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Pesticides and Herbicides; Respiratory Disease and Air Pollution; Tobacco Smoke, Secondhand and Thirdhand

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ALLERGENS IN THE ENVIRONMENT

Allergens in the environment are substances in indoor or outdoor environments that (1) aggravate allergies; (2) increase the severity of asthma or other respiratory, sinus, and skin conditions; or (3) prompt other health problems in individuals who are sensitive to such substances. Some allergens and irritants are seasonal in nature, while others pose problems throughout the year. Allergens are the sixth leading cause of chronic illness in the United States, and many also cause acute conditions. Overall, allergies affect more than 50 million Americans each year.

Pet Allergies

Many people believe that the fur of dogs and cats is the cause of allergic reactions in people who are allergic to pets. However, the actual causes are certain proteins in the dander (dead skin cells), saliva, and urine of pets. These substances tend to accumulate on carpets, furniture, walls, clothing, and other materials that are encountered by the animals. The allergens typically trigger adverse reactions in sensitive people after they become airborne and inhaled during the petting or grooming of the pets or during dusting, cleaning, and other household activities.

Allergies, also known as hypersensitivities, are conditions in which a person's immune system overreacts to substances that do not normally provoke such reactions in healthy people. In most hypersensitivities, the malfunctioning immune system produces an excess amount of immunoglobulin E (IgE) antibodies to attack relatively harmless substances that are mistakenly identified as dangerous foreign invaders. The IgE antibodies travel through the circulatory system to various cells and tissues in the body (e.g., in the eyes, nose, skin, sinuses, lungs, and stomach), where chemicals that cause inflammation or other pathologic reactions are released.

Individuals are generally sensitive to certain environmental allergens but not to others, and the nature and severity of hypersensitivities vary from person to person. Some individuals are born having particular allergies, such as an allergy to cow's milk. Other allergic reactions may develop later in life, such as the hives that develops in an adult in response to receiving a certain medication. Inherited genetic factors raise the risk of many forms of hypersensitivity.

Common, relatively minor symptoms caused by environmental allergens include sneezing, a runny nose, red and watery eyes, coughing, skin rashes, and itching. These symptoms may be temporary, such as in hay fever or poison ivy rashes, becoming resolved soon after exposure to the allergen is stopped. In other cases, allergens are associated with serious, chronic conditions, such as asthma, bronchitis, and sinusitis. The most severe symptoms caused or aggravated by allergens, such as chronic breathing difficulties and acute anaphylaxis, are life-threatening.

There are numerous kinds of environmental allergens and irritants. Among the more common ones are cigarette smoke and other particulate air pollution, household molds, plant pollens, pet dander and saliva, dust mites, cockroaches (especially their saliva and droppings), insect stings (mainly those from bees, wasps, and ants), and latex (e.g., in gloves and condoms). There are also allergens in some drugs (e.g., penicillin and animal insulin) and foods (e.g., peanuts and shellfish), which can lead to pathologic conditions in different tissues and organs of the body.

According to the American Academy of Allergy, Asthma, and Immunology (AAAAI), roughly 8 percent of adult Americans have pollen-caused hay fever, which is the most prevalent form of allergic rhinitis (constituting a group of widespread allergies). Approximately 8 percent of American children have a food allergy, the most widespread being hypersensitivities to peanuts, followed by milk and shellfish. Worldwide, notes the AAAAI, the prevalence of allergy-related diseases has been increasing in industrialized countries since the 1960s. As of 2015, from 40 to 50 percent of school-age children around the world had hypersensitivities to one or more allergens.

Public health experts recommend several strategies for avoiding exposure to environmental allergens and preventing allergic reactions. For example, adverse reactions to pollen, or hay fever, can be prevented by minimizing time spent outdoors (staying in air-conditioned, air-filtered indoor environments) during the seasons in which the problematic pollens are most abundant. In the spring, tree pollens are the typical culprit behind hay fever reactions, while grass and weed pollens are the usual causes in the summer. Face masks worn when mowing the lawn, gardening, or raking leaves will also help to prevent allergic reactions to pollens.

Dust mite allergies can be minimized by keeping the house clean and dust-free; animal dander allergies may require that dogs and cats be avoided as pets or restricted to certain rooms, and certain food allergies may necessitate the avoidance of those foods. Skin irritants, such as poison ivy leaves, can be avoided by wearing protective clothing, such as gloves worn while doing yard work. Household molds can be minimized by maintaining low levels of humidity, regularly cleaning bathrooms with mold-killing solutions, limiting the number of houseplants, and other simple acts.

Medications are available to minimize or counteract allergic reactions to various kinds of allergens. Physicians may conduct skin tests to first pinpoint a patient's specific allergens before prescribing an anti-allergy medication. The most severe allergies may require administration of immunization injections to prevent hypersensitivity reactions. Severe reactions that do occur, such as the anaphylaxis resulting from a bee sting, can be counteracted by the prompt administration of an epinephrine injection.

Over-the-counter decongestant and antihistamine drugs, including diphenhydramine hydrochloride (an active ingredient in such drugs as Benadryl), are available to relieve general allergy symptoms, such as sneezing, runny nose, and watery eyes.

A. J. Smuskiewicz

See Also: Asthma; Indoor Environment; Mold and Dampness; Particulate Matter and Bioaerosols Pollution; Tobacco Smoke, Secondhand and Thirdhand

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AMBIENT AIR QUALITY

Every day the average person breathes over 3,000 gallons (11.4 cubic meters) of air, and if air pollutants are present, each breath increases the risk of some adverse health effect. To protect the public from the risks of exposure to air pollution in the ambient air (i.e., the surrounding air that we breathe), the U.S. Environmental Protection Agency (EPA) has established national ambient air quality standards (NAAQS) for the following six common pollutants: carbon monoxide, nitrogen dioxide, lead, ozone, particulate matter (PM), and sulfur dioxide.

How Small Are Air Pollution Particles?

Particulate air pollution comes in a variety of shapes and sizes. Some particles are large enough to be seen with the naked eye, but the particles we are most concerned with are much smaller, requiring the aid of an electron microscope. It is these very small particles, less than 2.5 micrometers in diameter, that we are most concerned with because they can reach the most remote regions of the lungs. How small is 2.5 micrometers? By comparison, the width of a strand of human hair, which is about the smallest size that can be seen by the unaided human eye, averages 70 micrometers (almost 30 times larger)!

Millions of Americans are exposed to criteria air pollutants on a daily basis, particularly in large metropolitan areas where pollution levels tend to be highest. Short-term exposure to criteria pollutants can cause non-life-threatening problems such as burning eyes, irritated throat, coughing, aggravated asthma symptoms, and breathing difficulties, while long-term exposure can damage the immune, neurological, reproductive, and respiratory systems. Criteria air pollutants are different from hazardous air pollutants, which tend to be more localized and can cause serious, irreversible, life-threatening conditions, such as cancer. (See the entry on Hazardous Air Pollutants for more information.)

Among the six criteria air pollutants, perhaps the two most egregious are ozone and PM. In contrast with most other forms of air pollution, ozone is not emitted directly into the air. Instead, it is the result of chemical reactions between two other pollutants: oxides of nitrogen and volatile organic compounds. These pollutants originate from a variety of air pollution sources, including industrial facilities, electric power plants, chemical solvent use, and motor vehicles. Ozone can trigger respiratory discomfort and distress, particularly for children, older adults, and people with lung diseases like asthma. Additionally, ozone can damage sensitive vegetation and ecosystems. The ozone discussed here, which is found near ground level and is widespread in many metropolitan areas, should not be confused with the ozone found in the stratosphere (up to 31 miles, or 50 kilometers, above the earth's surface), which is important in blocking harmful ultraviolet radiation from the sun.

Like ozone, PM is a widespread problem in many metropolitan areas, particularly for children, older adults, and people with existing heart or lung disease. PM is a complex mixture of particles and liquid droplets often originating from industrial operations, electric power plants, and motor vehicles. Most PM small enough to enter the lungs results from chemical reactions in the atmosphere involving gases such as sulfur dioxide and nitrogen oxides, and some small PM also originates with fires, unpaved roads, and construction sites. PM with a diameter of 10 micrometers and smaller (often called PM_{10}) is of particular concern because it can be inhaled directly into the lungs without being captured by the throat and nose, and fine PM, having a diameter of 2.5 micrometers and less (often called $PM_{2.5}$), can reach the most remote regions of the lungs. Many scientific studies have linked

PM to (1) premature death in people with heart or lung disease; (2) nonfatal heart attacks; (3) irregular heartbeat; (4) aggravated asthma; (5) decreased lung function; and (6) increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing.

The other four criteria pollutants—carbon monoxide, lead, nitrogen dioxide, and sulfur dioxide—can also cause health problems. Exposure to carbon monoxide, a colorless, odorless gas emitted from combustion processes, reduces oxygen delivery to the heart, brain, and other tissues, and extremely high levels can cause death. Most carbon monoxide in the ambient air comes from motor vehicles. Lead air pollution can affect kidney function and the nervous, immune, reproductive, developmental, and cardiovascular systems; it diminishes the oxygen carrying capacity of the blood; and it may cause behavioral problems and lower IQ in infants and young children. Sources include lead smelters and other ore-processing facilities, waste incinerators, and lead-acid battery manufacturers. Nitrogen dioxide is used as an indicator for the presence of a group of highly reactive gases known as nitrogen oxides, which cause respiratory problems and contribute to ground-level ozone and fine PM formation. Nitrogen dioxide forms from the emissions of motor vehicles, electric power plants, and off-road equipment. Sulfur dioxide, which also causes respiratory problems and contributes to fine PM formation, is emitted from electric power plants and other operations that burn fossil fuels, industrial operations like ore extraction, locomotives, ships, and natural sources like volcanos.

The EPA is mandated by the Clean Air Act to develop NAAQS for the criteria pollutants at levels sufficient to protect public health and the environment. The act establishes two types of standards. Primary standards protect the public against adverse health effects, including protection of sensitive populations like asthmatics, children, and older adults. Secondary standards protect against so-called welfare effects, such as reduced visibility and damage to animals, crops, other vegetation, and buildings. If the concentration levels of criteria pollutant in the ambient air are higher than the NAAQS for any of those pollutants, the potential exists for adverse health or welfare effects. Depending on the pollutant, the NAAQS are specified in units of parts per million by volume, parts per billion by volume, or micrograms per cubic meter of air.

Areas of the country where concentration levels of the criteria pollutants are below the NAAQS are called attainment areas, and areas where the NAAQS are exceeded are called nonattainment areas. Over 120 million people live in nonattainment areas where one or more of the NAAQS are exceeded. Although the EPA is charged with establishing the NAAQS, it is the responsibility of each state to design and implement a plan to attain the NAAQS in their state. This plan, called a state implement plan, is intended to show that the state has implemented the appropriate emission-control requirements and air quality management systems to ensure that (1) air quality does not deteriorate in attainment areas and (2) steps are taken in nonattainment areas to reduce air pollution emissions to levels that will ensure compliance with the NAAQS. (Tribal governments have the option of developing their own tribal implementation plans.) The EPA is required to review and update the NAAQS periodically, taking into account the latest health effects research and other new information relevant to setting the levels of the NAAQS.

The EPA has several programs for monitoring ambient air quality, the most basic one being the Ambient Air Monitoring Program. Under this program, air quality samples are collected and analyzed to determine whether the NAAQS are being achieved. Additionally, the air quality samples are useful in observing air quality trends; detecting poor air quality episodes; and evaluating the effectiveness of urban, land-use, and transportation planning related to air quality. This program is conducted by the EPA in partnership with state and local air pollution agencies, with oversight provided by the EPA. When air quality is expected to be poor enough to cause adverse reactions, the EPA issues Air Quality Index alerts. (See the entry on AirNow and the Air Quality Index for more information.)

Richard Crume

See Also: Air Pollution; AirNow and the Air Quality Index; Asthma; Automobile and Truck Emissions and Controls; Clean Air Act; Crops and Vegetation, Air Pollution Damage to; Electric Power Generation, Health Implications of; Environmental Protection Agency; Hazardous Air Pollutants; Indoor Environment; Lead Poisoning Prevention; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Public Transportation and Environmental Health; Regional Haze Pollution; Respiratory Disease and Air Pollution; Stratospheric Ozone Depletion

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AMES TEST

Humans are surrounded by a variety of both naturally occurring and manufactured chemical substances in our food and water supplies, the air we breathe, and many other products that we come into contact with on a daily basis. These substances have the potential to act as mutagens, which are agents that can alter DNA sequences within their respective genomes. Because the genome contains the information necessary to build an organism, alterations can have disastrous effects, sometimes even causing cancer.

To determine whether or not a chemical is a mutagen, Bruce Ames developed the Ames test in the 1970s. In this test, bacterial organisms, like the prokaryote *Salmonella typhimurium*, are exposed to potentially mutagenic compounds. The bacteria are then evaluated to determine whether the potential mutagen caused a mutation in the bacteria's genome. If so, the data are extrapolated to say that the chemical is potentially harmful for humans and other animals. This test is invaluable across markets that research chemical compounds produced by industrial and sewage treatment plants, medical and cancer research facilities, cosmetic laboratories, and more.

In the United States, the Ames test is one of the tests mandated by the Pesticide Act and the Toxic Substance Act to screen for possible carcinogens among drugs and manufactured chemicals. These laws have led to further testing of many potentially mutagenic agents, evaluating their potential harm prior to release in the commercial market. After the introduction of the Ames test, it notably identified many mutagens that were previously thought to be safe. One example of a successful study is the identification of tris(2,3-dibromopropyl) phosphate, which was used for many years as a commercial flame retardant in children's clothes. It also showed that furylfuramide, an antibacterial additive for food products in Japan that had previously passed animal testing, was mutagenic and may cause cancer.

This breakthrough in laboratory research has accelerated studies and experiment completion times for many safe agents and identified harmful chemical agents with mutagenic and carcinogenic (cancer-causing) properties. The timeline to complete the Ames test by using bacterial organisms is between 24 and 72 hours, while animal studies with mice and rats are more time-consuming. Depending on the life cycle of the animal used during the study, an animal study can take weeks to months to complete. The Ames test is also notably less expensive than animal studies and decreases unnecessary exposure and risk of exposure by avoiding the study of humans and animals directly.

However, as with every scientific study, there is a potential for false positives and false negatives. Prokaryotic bacteria are much simpler organisms than humans or other animals, so there may be false positives in which the bacteria were harmed but animals would not be. There have also been false negative results, in which the chemical did not harm the bacteria being studied but was later found to be harmful to humans or other animals. Historically, the test has been viewed as 90 percent accurate. However, in recent years the test has become less effective at identifying potentially harmful substances.

Howard W. MacLennan Jr.

See Also: Cancer Risk from Environmental Exposure; Environmental Toxicology; Pesticides and Herbicides

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ANTIBIOTIC RESISTANCE

When bacteria adapt the ability to resist the effects of an antibiotic, they are considered resistant. This can be a major problem because illnesses that were once treatable by antibiotics become dangerous infections. These resistant bacteria can then travel to other people, spreading the immunity to antibiotics and certain other drugs. The Centers for Disease Control and Prevention (CDC) reports that every year at least 2 million people become infected with antibiotic-resistant bacteria, and at least 23,000 die from these infections.

The CDC has designated numerous bacteria as urgent, serious, and concerning threats. Infections such as tuberculosis, gonorrhea, and pneumonia are becoming harder to treat due to bacteria that are immune to antibiotics. As these resistant bacteria impact more and more humans, healthcare costs will increase, as will mortality rates. Also, illnesses will become more complex and longer lasting,

Overuse of Antibiotics

Studies show that the overuse of antibiotics has contributed to antibiotic resistance, a growing problem in America. According to the CDC (cdc.gov/drugresistance), as much as 30 to 50 percent of the antibiotics prescribed in hospitals are unnecessary and even inappropriate. The good news is that when hospital prescribing practices are improved, rates of infection and antibiotic resistance decline and so do healthcare costs. Antibiotic resistance is also a problem in nursing homes, where up to 70 percent of residents may receive at least one course of systemic antibiotics over a year, and between 40 and 75 percent of these antibiotics may be unnecessary. The overuse of antibiotics in nursing homes is a particular problem for some older adults who may be frail, have weakened immune systems, and are suffering from other medical conditions.

and stronger and more expensive drugs will be required. Antibiotic resistance is quickly becoming a major issue for Americans, as these common infections, once treatable, could once again become widespread killers.

The path to resistance starts when just a few bacteria are resistant to a drug. Although the antibiotic eradicates the bacteria causing the illness, it also kills the good bacteria protecting our bodies. Without the good bacteria present, the surviving resistant bacteria are free to grow and attack the body. Some bacteria can transfer the antibiotic resistance to other bacteria, making the body all the more vulnerable to disease.

Overuse and misuse, improper prescribing, widespread presence in food animals, lack of new antibiotics, and complex regulatory processes are all key causes of this issue. It is up to physicians, healthcare companies, government agencies, and consumers to work together to prevent antibiotic resistance from becoming a larger problem. The Food and Drug Administration is addressing the antibiotic resistance problem by implementing regulations surrounding the labeling of drugs used to treat bacterial infections, launching public awareness campaigns, and developing new antibiotics. The CDC and other agencies are also deeply involved in researching this problem and in educating consumers, physicians, and medical facility personnel.

Hana Elliott

See Also: Centers for Disease Control and Prevention; Infectious Diseases; Pharmaceuticals in the Environment

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ARCTIC ENVIRONMENT AND HUMAN HEALTH

The Arctic environment is sparsely populated because of its seasonal extremes of temperature and light. The diverse people of Alaska, America's arctic state, inhabit a wide variety of environments. The health and survival of rural Alaskan native populations has historically depended on an extensive knowledge of the plant and animal species in their local environment. Seasonal harvest patterns have historically been a major community activity and are closely linked to a holistic culture and worldview. The Arctic and subarctic environment fosters a high degree of traditional ecological knowledge related to terrestrial, coastal, and marine resources that supply natural nutrients for preventing diseases and potentially mitigating metabolic syndromes such as diabetes. This closeness to the land has led to a "one health" approach to understanding disease processes, allowing the development of interdisciplinary collaborations that focus on interactions between the physical environment, plants, animals, and human social systems.

Health risk assessment (i.e., quantifying the risk of disease) in the Arctic environment is difficult due to small populations, short and poorly characterized natural and global food systems, unknown levels of pollution, and a rapidly changing climate. This uncertainty leads to highly speculative and controversial predictions. Research has indicated the need to understand the Arctic physical environment (seasonality and pollution), biological phenomena (nutrition and pathogens), and socioeconomic factors in a holistic way. Understanding these complex processes is key to understanding the disease processes for people living in this changing and marginal environment.

According to the Intergovernmental Panel on Climate Change and the Carter Center, certain Arctic regions and their populations are more vulnerable to increases in respiratory and infectious diseases, allergies, and mental health issues, such as seasonal affective disorder and alcoholism. Heat stress, water cycle and quality, and food security are other systemic issues impacting health in the Arctic, and the U.S. Centers for Disease Control and Prevention and Environment Canada are supporting active monitoring programs in water and food security. Growing

What's Happening in the Arctic?

The National Oceanic and Atmospheric Administration reports that the persistent warming of the arctic and loss of sea ice are causing extensive changes to the region. Records are routinely set for surface air temperature, sea ice extent, spring snow cover, and the onset of spring melting for the Greenland Ice Sheet. Because of cold water temperatures and the ongoing formation and melting of sea ice, the Arctic Ocean is especially susceptible to acidification from human-derived carbon dioxide, a process that disrupts the ecosystem and food chains. Furthermore, the thawing permafrost is a net source of carbon released to the atmosphere, and there is evidence of a northward shift of subarctic species. Scientists continue to monitor these changes because the Arctic is an integral part of the biosphere, and physical and biological changes in the Arctic region can affect global weather patterns, ocean currents, and sea life.

industrial development in Asia and associated polar transport of air pollutants will lead to an increase in water acidity and contaminants.

Environmental pollutants are another risk that is particularly pertinent in the Arctic. Many environmental pollutants, such as mercury and persistent organic pollutants, originate at lower latitudes and are systemic in their action. Because these pollutants are inhaled or ingested with food and water, they are more widely distributed and impact Arctic public health services and budgets. Dichlorodiphenyltrichloroethane (DDT) and toxaphene have been reported in the high Arctic, and legacy chemicals from early development efforts, like polychlorinated byphenyls and polycyclic aromatic hydrocarbons, have been reported in the milk of Arctic women. Industrial accidents related to fossil-fuel development, as in the case of the *Exxon Valdez*, has led to immediate loss of wildlife and fish as well as human psychological impacts.

Climate change is expected to increase the spread of disease in the Arctic, especially biologically transmitted pathogens. As temperatures increase, human, wildlife, and plant diseases will advance northward through insect, bacterial, and viral vectors (organisms that transmit disease). Recent predictions also suggest the Arctic will become drier over the next century, leading to drought-related illness. Declines in sea lion and walrus populations have been reported, and explanations related to both environment and disease are being investigated. Loss of marine mammals and fish can lead to malnutrition and the dislocation of communities, and the disruption of local culture will likely increase mental illness.

Lawrence K. Duffy

See Also: Carter Center; Centers for Disease Control and Prevention; Climate Change and Human Health; DDT Exposure; *Exxon Valdez* Incident; Intergovernmental Panel on Climate Change; Mercury Pollution; One Health; Persistent, Bioaccumulating, and Toxic Chemicals; Polychlorinated Biphenyls; Polycyclic Aromatic Hydrocarbons

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ARSENIC POLLUTION

Arsenic is an element with an atomic number of 33 and a standard atomic weight of 74.9216 that belongs to subgroup V of the periodic table. Arsenic poisoning affects millions of individuals globally.

Arsenic is a highly toxic substance that occurs naturally in many environments at relatively low concentrations. It commonly can be found in soil and in several minerals, such as arsenopyrite ($AsFeS$), eargite, orpiment, and realgar. Arsenic in soil is slowly depleted through erosion, leaching, methylation, and uptake by plants. Most arsenic is produced as a by-product of refining various metal ores, particularly copper, lead, and zinc. About 50,000 tons (45,360 metric tons) of arsenic are produced each year from mining activities, and global reserves are estimated to be approximately 10 million tons (9.1 million metric tons). Arsenic is also found in the atmosphere: microorganisms release about 20,000 tons (18,140 metric tons) of atmospheric arsenic annually, volcanoes release about 3,000 tons (2,720 metric tons) per year, and the burning of fossil fuels releases about 80,000 tons (72,570 metric tons) into the atmosphere annually. In addition to the soil and air, arsenic can be found in water and in crops that absorb it from the soil, air, or water. The removal of arsenic from water is a widespread problem, particularly in developing countries.

Arsenic has a tendency to build up in the environment. Consequently, bioaccumulation of arsenic is a serious environmental concern. Because arsenic is absorbed fairly readily by plants, aquatic organisms that eat plants can accumulate higher concentrations of arsenic. Higher ranking animals, such as birds that eat fish having a diet of arsenic-laden plants, can accumulate fatal concentrations.

There are both organic and inorganic forms of arsenic. Organic arsenic is generally less of a health concern to humans, whereas inorganic arsenic is potentially more dangerous. Exposure to arsenic can cause irritation to the stomach and intestines, decreased red and white blood cell production, rashes and skin changes, and irritation to the lungs. High levels of exposure are known to lead to infertility and miscarriages as well as to brain damage, heart problems, and lowered resistance to infection. There are also concerns that high levels of arsenic exposure can increase the likelihood of cancer, particularly skin, liver, lung, and lymphatic cancers. A 0.0035-ounce (100 milligram) dosage of arsenic oxide is generally regarded as lethal.

In the 1990s, the indiscriminant use of pesticides containing arsenic led to contamination of soils around the world. Thousands of people in West Bengal, India, have reported symptoms of arsenic poisoning, probably resulting either from drinking contaminated groundwater or from consuming crops irrigated with such water.

Victor B. Stolberg

See Also: Bioaccumulation of Environmental Contaminants; Cancer Risk from Environmental Exposure; Drinking Water Quality and Regulation; Electric Power Generation, Health Implications of; Food Supply, Environmental Threats to; Persistent, Bioaccumulating, and Toxic Chemicals

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ASBESTOS

"Asbestos" is a term for six minerals recognizable for their appearance as a bundle of thin strands of fibers. Their primary properties—resistant to heat, chemically unreactive, and nonconductive to electricity—once made them ideally suited for a variety of commercial and industrial purposes, and asbestos was mined and processed on a large scale beginning in the 19th century. In particular, asbestos became very prevalent in construction projects. Today, we know that asbestos represents a serious inhalation health risk.

There are two general categories of asbestos: (1) amphibole, which has straight and brittle fibers in a chain-like structure; and (2) serpentine (the mineral name is chrysotile), which has curved and flexible fibers that tend to occur in layers. Both can be molded into materials such as insulation, brake linings, and ceiling, floor, and roof tiles. The usefulness of asbestos led to extensive use following World War II, until the health hazards related to airborne asbestos became well known.

Undisturbed asbestos materials are not a health hazard. However, problems occur when the asbestos fibers become airborne, for example, due to weathering or during building renovation projects. Asbestos fibers are thin but sturdy, and they do not break down easily in the human body. Thus, when inhaled, the fibers collect in the lungs and remain there over long periods, causing serious health problems. While the different types of fibers have different toxicity levels, the U.S. Environmental Protection Agency considers all asbestos fibers carcinogenic.

In the 1970s, asbestos became increasingly linked to lung cancer and mesothelioma. The latter is a form of cancer in the thin layer of tissues covering the lungs, abdomen, and other organs. Long-term exposure can also lead to asbestosis, which is noncancerous but involves scarring of the lungs. Although not necessarily fatal, asbestosis victims have breathing difficulty and chest pain, particularly during exercise.

There is often significant lag time between exposure to asbestos and the onset of symptoms. This explains why it took several decades before widespread use of asbestos in the United States became associated with the aforementioned diseases. Health officials are concerned about asbestos exposure after the collapse of the World Trade Center towers in New York City following the September 11, 2001,

A technician in protective gear removes asbestos from an old industrial site. When asbestos fibers become airborne, they can collect in the lungs, causing serious health problems, such as lung cancer and mesothelioma. (Bernard Maurin/Dreamstime.com)

terrorist attacks. In particular, firefighters and other emergency response personnel team are at risk of developing mesothelioma in the coming years.

Although asbestos was technically never banned in the United States, actual manufacturing of asbestos-containing materials has declined significantly. Beginning in the 1980s, asbestos in many existing buildings was sealed in place or removed, and various health and safety laws and guidelines have prevented asbestos from being used in construction materials.

Aaron Dorman

See Also: Cancer Risk from Environmental Exposure; Environmental Protection Agency; Occupational Safety and Health; September 11 World Trade Center Attack

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ASTHMA

Asthma is a chronic disease that is characterized by inflammation and narrowing of the airways of the lungs. This narrowing limits air flow and can cause shortness of breath and obstruction of the airways. Data obtained by the Centers for Disease Control and Prevention (CDC) indicate that nearly 8 percent of the population in the United States in 2014 was afflicted with asthma, 26 percent of whom were children younger than age 18. Forty-five percent of those afflicted with asthma in 2014 reported having one or more asthma attacks. While genes play an important role in whether a person will contract asthma, there has been an increase in the prevalence of asthma over the years, especially among African American children in the United States.

Inflammation of the airways of the lungs results in an increased sensitivity to the inhalation of irritants and allergens that can lead to an asthma attack. Signs and symptoms of an asthma attack can vary but generally include wheezing, coughing, shortness of breath, and chest tightness. Doctors prescribe medications to both treat and reduce the prevalence of attacks (e.g., quick-acting corticosteroid inhalants to open the airways by decreasing inflammation).

An asthma attack can be minor or life-threatening. Emergency room visits and hospitalizations are necessary when people are unable to obtain relief from quick-acting asthma medications. The CDC reports that asthma attacks have resulted in more than 1.8 million emergency department visits (2011), 10.5 million physician office visits (2012), 1.3 million hospital outpatient visits (2010), and about 440,000 hospitalizations (2010) annually in the United States. There were over 3,650 asthma-related deaths in the United States in 2014, according to the CDC.

Asthma attacks are caused by exposure to "triggers" that include, but are not limited to, dust mites, cockroach allergens, pets, mold, smoke from burning wood

Does Air Pollution Cause Asthma?

Research studies by epidemiologists in the United States and other countries have found an association between increased air pollution levels and the prevalence of asthma attacks. Additionally, they have discovered that asthma-related medication use, emergency room visits, and hospitalizations all increase when air pollution levels are higher. Ground-level ozone and particulates are the types of air pollution most often associated with asthma. Air pollution alone may not cause asthma, but it appears to contribute to the development of asthma in persons having a genetic predisposition.

or grass, tobacco smoke, and indoor and outdoor air pollution. Besides the use of medications to reduce the prevalence of asthma attacks, persons with asthma are educated to learn their triggers and other factors that may contribute to and exacerbate their asthma so as to reduce their risk of an attack.

Exposure to increased air pollution, particularly ground-level ozone and particulates, is associated with an increase in the prevalence of asthma attacks and may contribute to the development of asthma in persons with a genetic predisposition (especially children). Ozone and particulate pollution exposure can result in inflammation of the airways in people with and without asthma, but such exposure is particularly problematic for those with asthma who are also sensitive to air pollution. Additionally, there may be synergistic effects involving exposure to differing pollutant mixtures, and these effects may contribute to the increased incidence of asthma attacks.

Urban and industrial areas and locations near highways are generally associated with the highest ground-level ozone and particulate concentrations. Because of concern regarding the health effects associated with exposure to air pollutants, the U.S. Environmental Protection Agency and the states have developed and implemented regulations over the years to reduce the pollutants that contribute to the formation of ground-level ozone (i.e., volatile organic compounds and nitrogen oxides) and to reduce particulates and other pollutants. Additionally, air quality monitors collect data that are used to alert the public to air pollution levels of concern, for example, through AirNow and the Air Quality Index.

Joanne O'Loughlin

See Also: AirNow and the Air Quality Index; Allergens in the Environment; Centers for Disease Control and Prevention; Children's Environmental Health; Environmental Epidemiology; Environmental Protection Agency; Indoor Environment; Mold and Dampness; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Respiratory Disease and Air Pollution; Tobacco Smoke, Secondhand and Thirdhand; Volatile Organic Compound Pollution

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ATOMIC ENERGY COMMISSION

The Atomic Energy Commission (AEC) is an agency of the U.S. government authorized by the Atomic Energy Act (AEA) of 1946. The AEC was created at the dawn of the Cold War, a period of political tension between the United States and the Soviet Union. The AEC's primary mission during its initial years was to develop nuclear weapons. In 1954, the AEA was amended to authorize the AEC to both regulate and promote atomic (nuclear) power. During this period, the AEC built several experimental nuclear power plants in an effort to harness the power and utility of radioactive material.

During the 1960s, the AEC's mandate to regulate an industry it was also required to promote was seen as a conflict of interest, prompting discord within the agency. Pressures to encourage development of the nuclear industry led to lax regulations and insufficient oversight regarding where nuclear plants were sited, how they were operated, and how well workers, communities, and the environment were protected. This lack of regulations and oversight caused considerable concern about the safety of nuclear power and spurred strong citizen opposition to the AEC. Around the same time, people who had lived near some of the early atomic bomb test sites were alleging health problems from radioactive fallout (radioactive particles and gases from atomic testing that fall back to the earth, exposing people to the radiation).

The AEC was also charged with conducting basic research into the health effects of radiation. These experiments involved exposing subjects (including pregnant

J. Robert Oppenheimer

One of the pivotal moments in the AEC's history concerned a decision made by J. Robert Oppenheimer (1904–1967), chairman of the commission's General Advisory Committee, to oppose further nuclear weapons development. Prior to his role with the commission, Oppenheimer had been the head of the Los Alamos Laboratory during World War II and was responsible for directing the secret Manhattan Project, which was tasked with developing the first nuclear weapons. The project was successful, and in 1945, the United States detonated the first atomic bombs over Hiroshima and Nagasaki, Japan. The enormous destructive capacity of atomic weapons and horrific loss of life following their use over Japan influenced Oppenheimer to firmly oppose further proliferation of nuclear weapons, especially the more powerful hydrogen bomb. Following his fruitless attempts to end development of the hydrogen bomb, surveillance of Oppenheimer by the Federal Bureau of Investigation intensified. (This occurred during the McCarthy era, when Senator Joseph McCarthy of Wisconsin and a group of anti-Communist zealots falsely accused many prominent Americans of being Communist spies.) Ultimately, Oppenheimer's security clearance was revoked; he lost his position with the commission, and he was stripped of all prior political influence. Later, to make amends for this treatment, President Johnson awarded Oppenheimer the commission's highest honor, the Fermi Award.

women and children), without their knowledge or informed consent, to radiation levels that are now considered dangerous. Government records on these studies were declassified and released during the Bill Clinton administration, and subsequently, the Advisory Committee on Human Radiation Experiments was created to prevent future abuse of government power.

To address the public's growing concern about the AEC's practices, the commission was abolished in 1974 and replaced by two new government organizations: the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC). The ERDA was responsible for managing nuclear materials for military use (e.g., energy production and nuclear weapons), but the agency was disbanded after only a few months, making way for creation of the Department of Energy, which adopted ERDA's mission. The NRC is responsible for the oversight of nuclear materials used for commercial purposes (e.g., commercial nuclear power plants).

Adrienne L. Katner

See Also: Electric Power Generation, Health Implications of; Nuclear Regulatory Commission; Nuclear Safety; Radiation, Ionizing and Nonionizing; Radiation Sickness

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AUTISM AND ENVIRONMENTAL EXPOSURE

Autism is a developmental problem primarily affecting the brain that is characterized by developmental speech delays, reduced communication abilities, and the inability to maintain a stable relationship with peers. Affected children often exhibit ritualistic behaviors with increased resistance to change. Early symptoms of autism typically emerge by the age of three, with an estimated prevalence of one in 68 children in the United States. Worldwide, autism is estimated to affect more than 20 million people.

Is Environmental Pollution a Factor in Autism?

The genetic foundation of autism is very well established, but in contrast, the role of environmental exposure is still uncertain.

An Interview with Steve Silberman

Best-Selling Science Writer and Public Speaker

Steve Silberman is an award-winning science writer whose recent book, NeuroTribes: The Legacy of Autism and the Future of Neurodiversity, *is a* New York Times *best seller and was awarded the prestigious Samuel Johnson Prize for nonfiction. Silberman's article, "The Placebo Problem," won the 2010 Science Journalism Award for Magazine Writing from the American Association for the Advancement of Science and the Kavli Foundation. His writings have appeared in many publications, including the* New Yorker, Wired, Nature, Salon, *and* Shambhala Sun, *and his TED talk, "The Forgotten History of Autism," has been translated into 25 languages and viewed more than a million times.*

Some studies indicate that environmental pollution may be implicated in autism. And according to the National Institute of Environmental Health Sciences, a growing area of research suggests that autism may be caused by an interaction of genetic and environmental factors. Does environmental pollution explain the increasing rate of autism in the United States and elsewhere in the world?

It's crucial to note that, contrary to popular belief, the true rate of autism prevalence may not be increasing at all. According to a study published by Terry Brugha in 2011, the prevalence of autism among adults in England is the same as it is among children, indicating that the autism "tsunami" is a myth. Instead, what has changed is improved diagnostic criteria and screening instruments, which both have led to greater reporting of cases. This is not to say that environmental exposure to toxins is not a problem in other ways, but that the perceived increase in autism cases should not be attributed to environmental pollution before we've even determined if the increase is real or not.

If autism cases have not been increasing while pollution has been on the rise, doesn't this indicate that environmental exposure is not a factor?

Not necessarily. The genetic foundation of autism is very well established, but in contrast, the role of environmental exposure is still uncertain. We know that increasing parental age contributes to the likelihood that a child will be born with autism, and some studies suggest that air pollution exposure may also be implicated, but there is no research that has definitively established a causal relationship between autism and environmental contaminants. I'm not saying that pollution is not a factor, but the body of research is not yet convincing.

What about the mercury-containing preservative thimerosal in childhood vaccines? This has gotten a lot of press coverage, despite assurances from experts that it is not a concern.

Despite all the misinformation on the Internet, extensive research over the years has failed to show any link whatsoever between thimerosal and autism. In countries like Japan, when thimerosal was removed from vaccines, the rates of autism continued to climb because of broadened diagnostic criteria, greater public awareness, and other factors. Thimerosal has not been used in most vaccines for children in the United States since 2001, although it is still used in some flu vaccines. (Flu vaccines without thimerosal are also available.) Yet, the apparent rise in diagnoses continued unabated because of the other factors I mentioned.

Do you have any advice for recent college or university graduates who are interested in journalism and want to explore issues related to environmental health?

Maintain a healthy sense of skepticism about claims on every side. Don't believe a chemical is safe just because the corporation that makes it insists that it is, and don't believe a theory that X causes Y just because of widespread rumors on the Internet, no matter how earnest or well-intentioned the rumor-mongers seem to be. Toxicity in the environment is not a matter of "he said, she said" and shouldn't be portrayed that way in the media. Controlled studies and replication of data are the bottom lines to establish that something is safe, whether it's a new drug or a substance released into the environment.

In 2013, the American Psychiatric Association broadened the definition of autism in the *Diagnostic and Statistical Manual of Mental Disorders*, fifth edition, by incorporating psychosocial conditions that bear similarities to the above symptoms. These include Asperger's syndrome, childhood disintegrative disorder, and pervasive developmental disorder not otherwise specified. With that understanding, researchers reclassified autism as "autism spectrum disorder," a group of complex disorders of brain development characterized by difficulties in social integration, verbal/nonverbal communications, and repetitive behavior.

The exact causes of autism remain unclear. Scientists have identified a number of rare mutations (changes in DNA sequence) associated with autism as well as more than 100 autism risk genes. However, while there appears to be a significant genetic component to autism, the presence of certain environmental agents has also been strongly associated with autism. It is currently believed that genetic and environmental factors typically act in concert to trigger the development of autism. In other words, while the majority of the population may be exposed to potential autism-promoting environmental agents, people who are genetically predisposed to develop autism have a higher chance of responding to these environmental factors.

Fetuses (unborn children) are especially sensitive to environmental factors. Researchers have identified environmental agents that cause injuries to the brain of developing fetuses, resulting in the subsequent development of autism. These agents include lead, mercury, polychlorinated biphenyls, organophosphate pesticides, and some viruses. Research indicates that exposing a pregnant woman to these environmental agents may induce developmental changes in the brain of the fetus that can result in autism. These developmental changes may result from either direct toxicity to the brain or by interacting with the gene system of the susceptible fetal brain.

Scientists have also found chemicals that appear to reduce the risk of autism. In a study conducted in 2015, researchers found that populations with high levels of antioxidants, such as glutathione and vitamin E, are at reduced risk for developing autism compared to those with low concentrations of these antioxidants in their systems.

Whatever the specific causes are, there have been strong associations between the previously stated agents, including toxins that are widely available in the environment, and the development of autism. It is important to evaluate conditions in pregnancy that predispose expectant mothers to these agents and to find ways to minimize or eliminate their presence.

Ifeanyi Abuachi

See Also: Lead Poisoning Prevention; Mercury Pollution; Pesticides and Herbicides; Polychlorinated Biphenyls

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AUTOMOBILE AND TRUCK EMISSIONS AND CONTROLS

Automobile and truck emissions and controls refer to the pollution emitted by motorized vehicles and the industrial and governmental efforts to reduce that pollution. Gaseous and particulate emissions through vehicle tailpipes are hazardous to human health as well as to the environment. In addition to tailpipe emissions, vapors from gasoline are emitted into the air during the process of refueling at gas pumps and during normal vehicle operation from beneath the hood, especially when temperatures are high outside. Mechanical problems, such as leaking air-conditioning systems, result in additional emissions.

The primary hazardous chemicals in vehicle emissions are carbon monoxide, nitrogen oxides, hydrocarbons, particulate matter, and benzene, which are all generated when gasoline is burned in an internal combustion engine. Sunlight and high temperatures cause the hydrocarbons in emissions to react with the oxides of nitrogen in the air to create ground-level ozone, the main constituent of smog, in urban areas that have heavy traffic. Carbon dioxide (CO_2), a greenhouse gas, is also emitted by cars and trucks, as are hundreds of other chemicals, some of which are harmful to health or the environment to varying extents. The specific amount and nature of pollutants in emissions depend on a vehicle's age and mileage, the type of fuel used, weather conditions, and other factors. Older vehicles generally have more harmful emissions than newer vehicles.

In terms of human health, emissions pose the greatest danger to the respiratory system, where they can cause severe damage to lung tissue and lead to or worsen asthma and many other breathing and pulmonary conditions. Ozone, especially, is a major cause of such respiratory problems as shortness of breath, wheezing, and coughing as well as chronic lung conditions and permanent lung damage. Severe pulmonary problems can progress to serious cardiovascular conditions as the heart must work harder to compensate for reduced lung function. Carbon monoxide, in high concentrations, can affect mental and visual function and can even be fatal. Furthermore, car and truck pollution has been associated with developmental abnormalities in infants and children, including infants who are born prematurely and of low birth weight, children who have impaired lung development, and children with leukemia. Research has shown that people who live, work, or attend school close to busy high-traffic roads experience, on average, increased severity of health problems related to vehicle emissions as well as increased risk of premature death.

Regarding the environment, vehicle emissions are among the main pollutants that are associated with global warming and acid rain. More than 99 percent of the carbon in typical gasoline is emitted in car exhaust as the greenhouse gas CO_2. The small amounts of carbon monoxide and hydrocarbons in exhaust are chemically converted into CO_2 in the atmosphere, adding to the global warming effect. According to the U.S. Environmental Protection Agency (EPA), a typical passenger vehicle emits 5.2 tons (4.7 metric tons) of CO_2 per year. Other greenhouse gasses released into the atmosphere by cars and trucks include methane, nitrous oxides, and hydrofluorocarbons (from leaking air conditioners). Acid rain is created when nitrogen oxide and sulfur dioxide from exhaust react with water in the atmosphere.

The automobile industry and the U.S. government (primarily the EPA) have implemented technological and regulatory strategies, respectively, for reducing the health and environmental impacts of vehicle emissions. The Clean Air Act of 1970 was a crucial impetus prompting the industry to develop cleaner automotive technology. One of the main technologies stemming from the Clean Air Act was the catalytic converter, in which chemical reactions reduce the output of carbon monoxide, nitrogen oxides, and hydrocarbons. Emissions tests also were instituted as a result of government clean air regulations. Most states have instituted requirements for older vehicles to undergo regular inspections to ensure that their tailpipe emissions remain below acceptable limits. If a vehicle fails a state emissions test, it must be repaired to meet the limits or be designated as unfit to drive.

Improved fuel economy has been a high priority of auto manufacturers for many years, and much progress has been made in this area, with the overall effect of reducing harmful emissions. According to the EPA, these technological improvements led to reduced CO_2 emissions of 13 percent from 2007 to 2012. Automobile engineers have developed a number of zero-emission vehicles, which generate no or minimal harmful gasses and are increasingly attractive to U.S. consumers. Such vehicles include electric cars, hybrid electric cars, and hydrogen fuel-cell electric cars. Several states have committed themselves to the goal of placing 3.3 million zero-emission cars, trucks, and busses on the street by 2025.

Individual drivers can advance the goal of emissions reduction by adhering to certain driver and ownership practices. These practices include driving at moderate speeds, following proper maintenance procedures (including maintaining correct wheel alignment and tire pressure), avoiding fully filling (topping off) the car's gas tank during refueling, avoiding idling, participating in car pools, and using public transportation as frequently as possible.

A. J. Smuskiewicz

See Also: Air Pollution; Ambient Air Quality; Carbon Dioxide and the Carbon Cycle; Clean Air Act; Environmental Protection Agency; Hazardous Air Pollutants; Hybrid and Electric Automobiles, Health Benefits from; Ozone and Smog in the Urban Environment; Respiratory Disease and Air Pollution

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AVIATION EMISSIONS

Travel by aircraft has become so ubiquitous in our society that in 2015, over 3 billion passengers took to the skies. But aircraft run on fossil fuels, and the exhaust that is produced from increasing amounts of air travel has a measurable impact on both climate change and human health.

Do Airports Pollute?

It is well established that aircraft engines are major sources of air pollution and contribute to climate change. But what about the airports where aircraft take off and land? Airports can also be large sources of air pollution, including sulfur and nitrogen oxides, volatile organic compounds, and particulate matter that contribute to soot and smog in our cities. Also, airport operations generate carbon dioxide, the most prevalent global warming gas, and hazardous air pollutants like benzene, formaldehyde, toluene, xylene, acrolein, lead, and 1,2-butadiene. These pollutants come from a number of operations and facilities, including:

- aircraft refueling, auxiliary power units, and brake and tire wear;
- ground support equipment and service vehicles;
- airport on-site power stations;
- deicing of aircraft, runways, taxiways, and aprons;
- aircraft and airport facility maintenance, such as cleaning, painting, and engine servicing; and
- personal vehicles and public transportation like buses as they approach the airport.

Adding to this pollution mix are the emissions from the aircraft themselves. Air pollution scientists estimate that about 10 percent of aircraft emissions occur in the vicinity of airports during takeoff and landing. Airports can also have water pollution challenges, for example, wastewater management, runoff from deicing operations, and stormwater drainage. Many large airports have their own industrial wastewater treatment plants.

Jet fuel is a kerosene-based liquid that is similar to diesel fuel. A typical jetliner holds several thousand gallons of fuel and burns most of this during a flight. That sounds like a lot. However, a Boeing 757 aircraft, which burns about 5 gallons of fuel per mile (12 liters per kilometer), is actually more fuel-efficient on a per-person basis than a car. This is because the 757 can carry several hundred passengers.

Almost 99 percent of jet engine emissions are carbon dioxide and water. (The condensed water forms contrails, which appear as streaks of white cloud from the ground.) The remaining emissions include nitrogen and sulfur oxides and particulate matter. The interaction of these emissions can be complex as they move from the engine to the exhaust plume and mix with the surrounding atmosphere. Depending on the pollutant, 70 to 90 percent of emissions occur above 3,000 feet (914 meters).

Aviation's carbon footprint is small relative to other transportation sources. Only 2 to 3 percent of human-caused carbon dioxide emissions come from airplanes, and within the transportation sector, aviation accounts for just 12 percent. Airplane engines have become much more efficient in recent years, with continued improvements in design and fuel efficiency leading to less energy use, and thus, lower air pollution. However, aviation's contributions to climate change and health impacts are still a concern. Conservative estimates by the U.S. Environmental Protection Agency indicate that aviation emissions will account for about 6 percent of human-caused climate change by the year 2050, which is not an insignificant amount.

In addition to carbon dioxide, the aircraft contrails themselves may contribute to global warming, particular during night flights, by trapping heat in the earth's atmosphere. (This is similar to the way clouds prevent some of the earth's heat from radiating into outer space.) Some research suggests this contribution to climate change may actually be greater than that of the carbon dioxide from jet engines, although the effect of contrails has been difficult to quantify.

The other air pollutants emitted from aircraft engines are also concerning. For example, the nitrogen and sulfur oxides and particulate matter can contribute to ground-level smog and are associated with various adverse health effects, including exacerbated asthma and respiratory and cardiovascular disease. (Smog can also contribute to climate change.) Some of these pollutants can travel long distances and remain in the atmosphere for weeks. Recent research suggests that air pollution from aircraft is responsible for many more worldwide deaths than airplane crashes.

Although the air transport industry is growing at a fast pace, technology innovations are slow to take hold because of the long life span of aircraft, often in the range of 30 to 35 years. Furthermore, there are currently no alternatives to jet fuel, in contrast with the automobile industry, where hybrids and electric vehicles have helped reduce air pollution. However, some innovations, like lighter aircraft bodies and more efficient engines, have significantly cut emissions from newer aircraft.

Aaron Dorman

See Also: Ambient Air Quality; Asthma; Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Environmental Protection Agency; Formaldehyde; Greenhouse Effect and Global Warming; Hazardous Air Pollutants; Lead Poisoning Prevention; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Respiratory Disease and Air Pollution; Sewage Treatment and Disposal; Stormwater Runoff; Volatile Organic Compound Pollution; Water Pollution

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BHOPAL INCIDENT

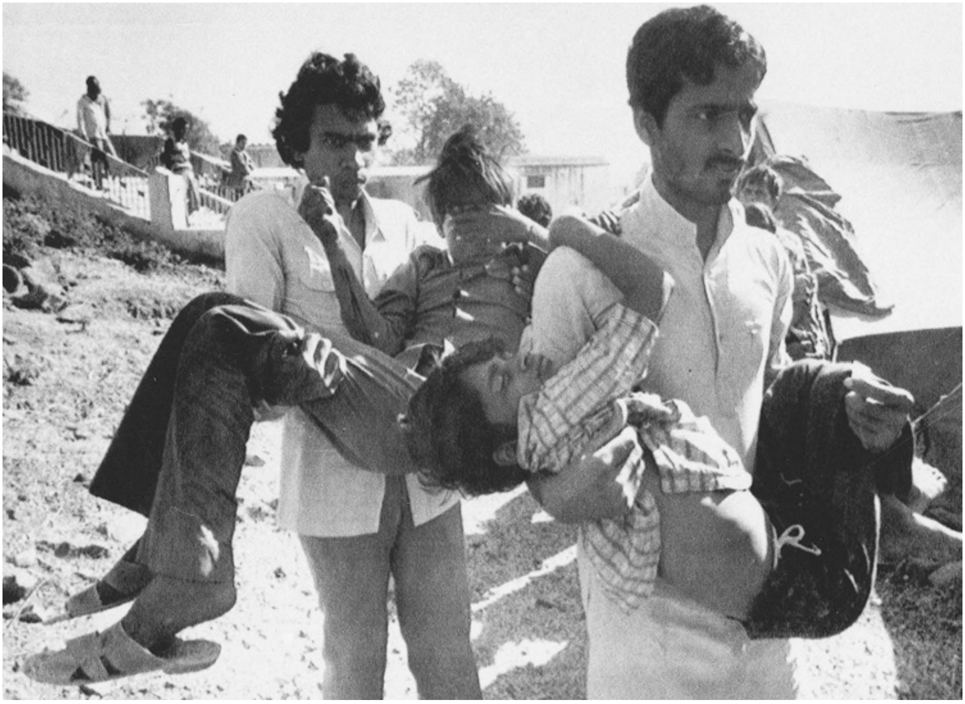
Just after midnight on December 3, 1984, a pesticide plant in Bhopal, India, released approximately 40 tons (36 metric tons) of methyl isocyanate, a highly toxic gas, into the atmosphere. It quickly spread to the surrounding communities, killing 8,000 in the following days and leading to over 20,000 mortalities—a death toll that may still be rising. The more than half-million survivors who were exposed to the gas suffered serious side effects, including respiratory problems, blindness, skin burns, anxiety, and depression.

The plant was owned by Union Carbide Indian Limited (UCIL), an Indian subsidiary of the American Union Carbide Corporation (UCC). Through later investigations, most accounts point to corporate-wide negligence as the culprit. Because of a low demand for pesticides in the years leading up to the disaster, the plant was operating at a much lower production capacity than it was capable. UCIL was looking to sell it in July 1984 but was ultimately unable. Subsequently, local managers were instructed to shut down various aspects of production, including safety mechanisms, to save costs.

The night of the leakage, a faulty valve allowed for water and methyl isocyanate to mix and build pressure in a tank. Several safety mechanisms were out for repair, turned off, or being used elsewhere in the plant. Within hours, the toxic gas had escaped and spread to nearby villages (many existing in extreme poverty), quickly killing an estimated 3,800 residents. The coming days, years, and decades brought that number to the tens of thousands, by some accounts.

The response to the disaster by both the Indian government and UCC has been highly criticized. In the immediate aftermath, the Indian government was accused of downplaying the death toll and number of injuries to protect UCIL. Some survivors have recounted memories of government officials disposing of bodies before recording their deaths. In addition, many workers did not have proper identification, indicative of their extreme poverty and oppression. In 1985, the Indian government sued UCC on behalf of the victims to obtain indemnity funds from the corporation. They settled on $470 million for the more than 500,000 injured and the families of those who died.

In 2001, Michigan-based Dow Chemical Company bought UCC. In 2004, the Indian Supreme Court ruled that the Indian government must supply drinking water to the residents of Bhopal as a result of years of birth defects and illnesses due to groundwater contamination. The same chemicals in the contaminated groundwater



Children seriously injured by a chemical pesticide leak at the Union Carbide plant in Bhopal, India, in 1984. The leak may have caused tens of thousands of injuries and deaths. (AP Photo/ Sondeep Shankar)

have been detected in the breast milk of women living near the plant, and high rates of deformities in newborns still exist in the area.

In 2010, eight former executives of UCC's Indian subsidiary were convicted of negligence, sentenced to two years in prison, and fined. Because of UCC's reluctance to cooperate, it is still unclear exactly how the disaster unfolded. UCC's chairman when the accident occurred, Warren Anderson, was briefly detained in India in the days following the incident, but he was quickly released on bail and never faced further criminal charges. Anderson died in 2014.

Mallory L. Daily

See Also: Disaster Preparedness and Response; Groundwater Pollution and Depletion; Hazardous Air Pollutants; Pesticides and Herbicides; Toxics Release Inventory

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BILL AND MELINDA GATES FOUNDATION

The Bill and Melinda Gates Foundation is the largest private charitable grant-making foundation in the world, with an endowment of over $42 billion. The foundation was formed in 2000 and is headquartered in Seattle, Washington. It supports grantees in the United States and over 100 countries worldwide, and its grant-making areas include global health, global development, global policy and advocacy, and various projects in the United States.

The global health division focuses on using science and technology to develop and provide vaccines, drugs, diagnostics, and interventions in developing countries. The global development division addresses solutions to help people suffering from poverty, hunger, and other social welfare and environmental problems. The global policy and advocacy division promotes public policies and builds strategic alliances and philanthropic partnerships. The foundation's work in the United States concentrates on ensuring all students graduate from high school prepared for college. Within its home state of Washington, the foundation is focused on solving widespread poverty and social inequality.

The foundation was formed when the William H. Gates Foundation merged with the Gates Learning Foundation. Prior to forming the Bill and Melinda Gates Foundation, Microsoft Corporation cofounder, Bill Gates, and his wife, Melinda French Gates, were involved with several charitable foundations, including efforts to provide free Internet access in public libraries throughout the United States, a scholarship program aimed at increasing the number of advanced degrees earned in the United States by minority students, and a children's vaccine program in their local Seattle, Washington, region. In 2006, billionaire Warren Buffett became a foundation trustee when he pledged a lifetime gift worth more than $30 billion, doubling the foundation's spending. Bill Gates left Microsoft to work full-time as cochair of the foundation in 2008.

The foundation is focused on reducing the vast disparity between rich and poor communities worldwide through sustainable environmental, public health, and educational efforts. In Asia and Africa, work is underway to reduce poverty and hunger by achieving food security through sustainable agricultural practices, including improving soil conditions, reducing environmental degradation, conserving biodiversity, and securing land rights. The foundation has contributed substantial support toward the eradication of polio, with the goal to eliminate the disease worldwide by 2018. Other public health initiatives include eradicating malaria, curbing the spread of diseases such as tuberculosis and HIV, and providing basic vaccines for preventable diseases. The foundation's educational focus includes partnerships to fund Internet access and training within public libraries in developing nations.

The foundation and Bill and Melinda Gates independently have received several prestigious awards and recognitions for their philanthropic work, including *Time* magazine's Persons of the Year in 2005 and India's Padma Bhushan award in 2015. Unlike most charitable foundations with perpetual life spans, the Bill and Melinda Gates Foundation plans to exhaust all assets within 20 years after the Gates are deceased. The motive for this decision is "to do as much as possible, as soon as possible."

Kelley Trahan

See Also: Biodiversity and Health; Children's Environmental Health; Infectious Diseases; Socioeconomic Status and Health; Sustainable Development and Health; Vulnerable Populations, Environmental Threats to; Waterborne Diseases

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BIOACCUMULATION OF ENVIRONMENTAL CONTAMINANTS

The terms "bioconcentration," "bioaccumulation," and "biomagnification" are frequently used interchangeably, but each has a distinct definition, as follows:

- Bioconcentration: refers to substances that are taken up strictly from water. Fish are said to bioconcentrate contaminants from their environment through uptake over the gills, and consequently, body concentrations of many contaminants can be much greater than they are in the environment.
- Bioaccumulation: similar to bioconcentration, except that it refers to uptake from all sources, including both food and water.
- Biomagnification: refers to the tendency of hydrophobic (water-repelling) substances to appear in increasingly greater concentrations in tissues of organisms that occupy increasingly higher levels in the food web. As substances become more hydrophobic, their tendency to accumulate also increases. On the other hand, substances with good water solubility tend not to concentrate in tissues because they are easily depurated (purged) via metabolic pathways and excretion in urine. (Many compounds can also be depurated over respiratory surfaces like lungs and gills if they have a high-enough vapor pressure.)

When discussing bioaccumulation and related phenomena, the concept of partitioning is important to understand because it relates to the fate of environmental contaminants in living tissue. In chemistry, partitioning describes how a solute is distributed between two immiscible or slightly immiscible solvents in contact with each other, according to the solutes solubility in each solvent. This relationship is characterized in terms of the log of the solute's partition coefficient, K_{ow}. The important point to understand is that contaminants with high partition coefficients tend to be less soluble in water, which means they are more likely to accumulate in the body. On the other hand, contaminants with low K_{ow} are more soluble and tend not to accumulate in tissues, making them less susceptible to bioconcentration, bioaccumulation, and biomagnification.

Some representative K_{ow} values from the Agency for Toxic Substances and Disease Registry are presented in Table 2. As you can see, DDT has a high K_{ow} and low water solubility, and consequently, it tends to accumulate in tissues. In contrast, trichloroethylene is much more water-soluble and tends to be depurated.

Environmental contaminants that bioconcentrate or bioaccumulate are of concern for many reasons. As body burden (i.e., the amount of a contaminant in the body) increases, the contaminant may cause toxic effects that threaten health. These kinds of toxic effects can generally be classified as either being acute, where exposure is short-term and relatively high doses are involved, or chronic, where exposure is long-term and relatively low doses are involved. Generally, body burdens that cause health issues in exposed organisms are not high enough to cause acute effects in the predators that consume them, although chronic effects are certainly possible. Chronic effects are a concern for humans, who consume organisms where bioconcentration or bioaccumulation may have resulted in high concentrations of toxicants, for example, the dangerously high mercury levels found in certain species of fish.

Biomagnification is a phenomenon that generally occurs in high K_{ow} compounds that cannot be detoxified or depurated easily. These compounds may accumulate, particularly in fatty tissues, and body burdens are observed to increase moving up the food web. A simple food web might, for example, begin with low concentrations of an environmental contaminant in soil that is taken up by vegetation. An herbivore, say, a rabbit, consuming that vegetation may have a body burden many times what is found in the vegetation because it consumes so much over a lifetime and does not depurate it. If such rabbits are then consumed by a carnivore, that carnivore may experience a body burden many times that is found in the rabbits for the same reason. Again, this may be a concern for humans at the top of the food web, where biomagnification may be greatest.

Table 2. Representative log K_{ow} values for compounds with widely different water solubilities.

Compound	Partition Coefficient (log K_{ow})	Water Solubility (mg/L)
p,p'-DDT	6.91	0.025
Benzene	2.13	1.88
Naphthalene	3.29	31.7
Atrazine	2.60	34.7
Trichloroethylene	2.61	1,280

Rachel Carson (1907–1964), in her seminal 1962 book, *Silent Spring*, warned that contaminants like DDT that biomagnify might one day lead to the demise of many species of birds because of DDT's tendency to cause eggshell thinning and reduced hatching success (hence, a springtime that lacks bird songs—a "silent spring"). This was one of the key publications that triggered the environmental movement, which began in the 1960s and 1970s. Since that time, many bioconcentrating, bioaccumulating, and biomagnifying substances have been banned in the United States, including notable groups of compounds like polychlorinated biphenyls (once used in electrical transformers as a cooling oil) and several pesticides, such as DDT, aldrin, dieldrin, endrin, and chlordane. This has inspired a movement toward chemical agents that are quickly decomposed in the environment, fairly freely water soluble, and do not tend to produce measurable body burdens in exposed organisms.

Philip A. Clifford

See Also: Carson, Rachel; DDT Exposure; Environmental Toxicology; Environmentalism; Persistent, Bioaccumulating, and Toxic Chemicals; Pesticides and Herbicides; Polychlorinated Biphenyls

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BIODEGRADABLE MATERIALS, HEALTH BENEFITS OF

Biodegradable materials are commonly thought to be better than other materials for use in products and packaging because they are easily broken down by living organisms (e.g., bacteria, fungi, and insects) and absorbed into the surrounding soil. In theory, nearly all materials are biodegradable to some degree because practically everything breaks down given enough time, but the term "biodegradable" is reserved for materials that break down over a short time frame, usually several months to years. Furthermore, biodegradable materials are assumed to have a beneficial, or at least neutral, impact when returned to the soil. (A material can biodegrade into something toxic, but this is a rare occurrence.)

The most direct way biodegradable materials can benefit human health is through composting (i.e., the biodegradation of organic matter into a rich soil amendment, adding nutrients to the soil and acting like a fertilizer), which reduces the need for chemical fertilizers and pesticides. Approximately 60 percent of waste in the United States (before recycling) is composed of biodegradable material, including wood, paper, food, and yard trimmings. Only about 40 percent of food waste and yard trimmings is recycled or composted, which means that over 50 million tons (45 million metric tons) per year of these materials are needlessly discarded in landfills.

Limiting pesticide use through composting has significant benefits to public health. The buildup of pesticides in our body tissues can lead to chronic health problems associated with endocrine disruption, infertility, and even cancer. Children are especially susceptible to harm because pesticides are linked to risk for autism and attention-deficit/hyperactivity disorder, in addition to other serious health effects. Not only does composting lead to healthier plants, the microorganisms derived from compost also serve as natural pest and disease deterrents.

If certain products can be converted to biodegradable forms, then the benefits to the environment could be substantial. Biodegradable plastic, for example, could offset the tremendous waste that accumulates in landfills and litters the oceans. And biodegradable plastic that is also compostable would have even greater benefits. Biobased plastics are made from plant material, but this does not mean they are necessarily biodegradable if they are designed to be structurally similar to petroleum-based plastics. On the other hand, biobased plastics, like traditional plastics, can be engineered to biodegrade and even be used as compost. The U.S. agriculture industry has shown strong interest in developing biodegradable plastics because they can be derived from corn starch or other common staple crops like potatoes, and they can be marketed as a carbon offset, similar to ethanol.

Aaron Dorman

See Also: Climate Change and Human Health; Land Disposal of Waste Materials; Municipal Solid Waste Management; Pesticides and Herbicides

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BIODIVERSITY AND HEALTH

Biodiversity, or biological diversity, is the assortment of forms of life on the earth, including species, ecosystems, and genetic variety. As such, biodiversity is essential to the health of the world's natural ecosystems, and it is the foundation of essential ecosystem benefits to humans, including clean air, plentiful fresh water, climate regulation, pest and disease control, and pollination. Biodiversity is important to human health and well-being by providing sources of food, medicine, energy, and livelihoods.

The contribution of biodiversity to ecosystems and human health occurs on several levels. Genetic diversity of individual species is important to reduce the risk of extinction due to disease or changes in environment (e.g., species with genetic differences may be able to survive in the face of disease that kills other individuals of that species). Species diversity is important because each species plays a different role in the ecosystem, interacting with many other species in particular ways (e.g., if one species is lost, this may adversely affect many other species and the roles they play in the ecosystem). Habitat or ecosystem diversity within a large landscape is important because each of these habitats or ecosystems plays a particular role in supporting species and ecosystem processes.

The most commonly used meaning of biodiversity is species diversity. Approximately 1.9 million species have been identified, but scientists believe there may be more than 15 million species on the earth, most yet to be discovered. However, some scientists also believe that over the last few centuries, species extinctions have occurred at rates at least 100 times greater than ever before. This loss of biodiversity around the globe is driven primarily by habitat destruction, which affects all terrestrial, freshwater, and marine ecosystems. Other causes include invasive species, overharvesting of species, environmental pollution, and climate change.

The loss of biodiversity profoundly affects the ability of ecosystems to function and provide benefits, including those important to human health. For example, the wealth of organisms that live in wetlands is in part responsible for the ability of wetlands to filter pathogens and other contaminants from water. Biodiversity may be most strongly linked to human health in the following areas: global food production, disease prevention, provision of medicines, and mental well-being.

Biodiversity is important for global food production because human health relies on nutritious wild and cultivated species to support crops, livestock, and fisheries. Within each food species, genetic diversity is necessary to provide a safety net for food production to adapt to future environmental changes, such as increasing temperatures or drought. In addition, the ecosystems that support the productivity of these food species, from agricultural soils to grasslands to fresh and marine waters, rely on the diversity of organisms. While less than 20 plant species provide around 75 percent of our global food supply, the health and productivity of these predominant food species depend on thousands or even hundreds of thousands of other species. These include the birds, insects, bats, rodents, and amphibians that pollinate flowers and eat pests and the many beneficial microbes that live in close association with plants and animals and inhabit the soil. These microbes prevent disease, decompose wastes, cycle nutrients important for plant growth, and assist plant roots in absorbing water and nutrients.

Human disease is influenced by biodiversity both positively and negatively. Increased biodiversity can mean increased pathogens, thereby potentially increasing human disease. On the other hand, biodiverse ecosystems may be able to better control the occurrence and spread of pathogens. In biodiverse ecosystems, more predators may be available to prey on species that carry disease. However, these ecosystems may contain more host species that disease vectors can infect. The "dilution" effect of more host species has been shown to occur with Lyme disease, West Nile virus, hantavirus, and schistosomiasis.

Even the diversity of life within the human body is important in maintaining health and combatting disease. Diverse microbial communities within our bodies keep us healthy by influencing nutrition and our immune response. This internal biological diversity is in turn influenced by human contact with microorganisms in the outside environment.

Most of the world's traditional and prescribed medicines are derived from the species in nature. Plant-based traditional medicines are used by more than half of the world's population. In the United States, most of the new drugs introduced in the past three decades were from natural products, and other industrialized countries around the world similarly rely on natural compounds for their prescribed medicines, especially for those that treat cancer and infection. The loss of biodiversity limits the number of species (some of which have not even been discovered) that will be available in the future to provide medicines to treat and cure diseases.

Some scientists believe that biodiversity is also important to human culture, spirituality, and mental health. For example, many humans around the globe have a variety of important relationships with natural areas. Some communities, especially indigenous and rural communities that represent most of the world's poor, have long histories of traditions and livelihoods that are integrated with nature, and nature may also directly supply many or all of their basic necessities of life, such food, water, shelter, and medicine. To these communities, biodiversity is essential to survival.

In addition, many people, including those living in urban areas, enjoy exercise, vacation, relaxation, arts, meditation, worship, and other activities in natural settings that support physical and mental health. Sometimes our experiences in nature are planned with specific plant- or wildlife-based objectives in mind, where biodiversity may improve our experience. These objectives might include wildlife safaris, bird watching, hunting, fishing, gathering of wild food and decorative plants, viewing spring blooms or autumn leaves, and even visits to zoos and botanical gardens. While little direct evidence exists to say why nature and its diversity are important to human culture, spirituality, and mental health, the many human activities in natural settings suggest that an important link may exist.

Melisa L. Holman

See Also: Biosphere, Environmental Threats to; Deforestation; Ecosystems, Importance of; Endangered Species and Human Health; Food Supply, Environmental Threats to; Genetic Engineering and GMOs; Invasive Species and Human Health; Wetlands and Healthy Waterways

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BIOFORTIFICATION

Biofortification is the process of deliberately improving the nutritional value of food through better agronomic practices, traditional plant breeding, or modern plant biotechnology. Biofortification is a very effective way to meet the world's nutritional requirements and eradicate malnutrition.

The "green revolution" of the 1960s increased crop yield and helped save the world from mass famine. But concerns about micronutrient deficiencies were left unanswered. In the developing world, many people consume enough calories but do not always get sufficient micronutrients. They depend on staple food like rice, wheat, and maize, and they cannot afford fruits and vegetables rich in vitamins and minerals. This has led to severe malnutrition symptoms in many regions, where people suffer from deficiencies in vitamin A, zinc, iron, and several other essential micronutrients. As a consequence, the growth of children can be stunted and cognitive development impaired. Even in developed countries, there is interest in biofortification. For example, researchers at the University of Warwick in the United Kingdom are investigating ways to boost the low selenium levels in British grains.

Biofortification can be achieved in various ways. Conventional breeding is the least expensive and controversial method, where plant breeders select germplasm rich in nutrient content and cross these varieties with high-yielding cultivars. This method enables crop improvement programs to achieve nutrient-rich, high-yielding varieties. These crops are developed in collaboration with nutritionists to determine if the consumer can absorb the extra nutrients and to assess the extent to which storage, processing, and cooking can affect the available nutrients. Recent achievements made by conventional breeding include beans rich in iron, sorghum rich in amino acids and proteins, bananas rich in beta-carotene, and pearl millet rich in beta-carotene, zinc, and iron.

Biofortification can also be achieved by genetic engineering, where foreign genes are incorporated into food crops by using biotechnology. Research of this type is being conducted on several food crops, the most advanced example being "golden rice," which has been genetically modified to contain beta-carotene, the source of vitamin A.

There are many challenges with the adoption of biofortified crops, including acceptance of changes in color, texture, or taste. For example, many Africans prefer eating white maize to yellow maize, where yellow maize is meant for feeding animals, but it could also supply vitamin A precursors to humans. The cost of biofortification research is also a challenge, and there are ongoing concerns among some people about the safety and environmental consequences of genetically modified crops.

Ranjita Thapa, Xingbo Wu, and Matthew W. Blair

See Also: Children's Environmental Health; Food Safety and Technology; Genetic Engineering and GMOs

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BIOMIMICRY SOLUTIONS IN MEDICINE, AGRICULTURE, AND ENERGY

Biomimicry, also known as biomimetics and bioinspiration, is a design philosophy that imitates nature to solve human problems. Biomimicry solutions promise to increase sustainability, efficiency, and productivity in industries as diverse as agriculture, medicine, and energy. As this field has evolved over the past decade, promising opportunities have emerged for preventing pollution and enhancing environmental health.

Biomimicry and the Shinkansen

A well-known example of biomimicry is the redesign of the Japanese Shinkansen 500-Series trains, which travel at speeds up to 200 miles (320 kilometers) per hour. When a train runs through a tunnel, air pressure builds until the train exits the tunnel, releasing a supersonic boom. To decrease air resistance, engineers designed the nose of the trains to resemble the beak of a kingfisher, a bird that snatches its prey from the water without making a splash. The new train design reduces air pressure by 30 percent, making it much quieter and cutting energy use. By using less energy, less air pollution is emitted from the power plants providing electricity to the trains.

The term "biomimicry" was coined by Janine Benyus (1958–), who cofounded the Montana-based Biomimicry Institute in 2006. Biomimicry is rooted in the idea that over 3.8 billion years of evolution, organisms, and processes in nature must have come to represent optimal design. The Biomimicry Institute maintains a database called AskNature.org, which lists various bacteria, plants, mammals, insects, and birds that offer inspiration for increasing efficiency and resource productivity. In particular, butterflies, ants, and honeybees have each inspired a wide range of design solutions.

Mimicking healthy ecosystems can help humans develop food systems that require fewer resources to sustain. Mass agriculture involves growing one type of plant per field, which depletes the soil of nutrients and requires the application of toxic herbicides. Meanwhile, prairies are diverse, self-regulating ecosystems that sequester carbon, recycle nutrients, and stabilize soil. Inspired by the resilience of prairie ecosystems, the Kansas-based Land Institute champions permaculture, which means growing perennial species instead of annual species. The institute is developing grains and legumes that will grow year after year, reducing soil erosion from repeated plowing as well as pest invasions that require herbicide treatment.

Beetles have inspired designs to collect moisture from the atmosphere in arid environments. For example, in the coastal Namib Desert in Africa where the annual rainfall is less than a half inch (1.3 centimeters), the Namib beetle (*Stenocara gracilipes*) keeps itself hydrated by collecting water on its wings, which are covered with bumps. Water vapor from ocean fog condenses in the depressions between the bumps, which then channel the water to the beetle's mouth. Inspired by the Namib beetle, designers have developed materials that can collect clean water from fog, a concept that holds promise for practicing agriculture in desert conditions.

Designs found in the animal world are also inspiring medical tools to assist surgery and reduce bacterial infections. For example, a biomimicry-inspired surface material inhibits the growth of disease-causing bacteria but not by killing the microorganisms. Instead, a design inspired by shark skin prevents the growth of bacteria by disrupting their ability to colonize. This works because the skin of sharks, unlike that of other fish, repels bacteria with microscopic bumps called denticles. Other uses for this surface material include a urinary catheter that resists bacteria and a bacteria-resistant countertop for use in hospitals, restaurant kitchens, childcare facilities, laboratories, and public bathrooms.

Another example of biomimicry solutions for medicine is the development of a unique surgical adhesive. Inspired by the adhesive power of gecko feet, researchers have devised a biodegradable bandage covered with an adhesive that can stick to tissues inside the body, like the bladder or lung. Related innovations include medical tape inspired by spider webs that is safe for the fragile skin of infants and elderly people, a glue for heart surgery inspired by underwater worms, and surgical staples inspired by porcupine quills.

Mimicking designs in nature can also help humans harness renewable energy, including wind and solar power. For example, inspired by whales, researchers have invented more efficient wind turbines, based on the tubercles on the leading edge of Humpback whale fins. In wind tunnel tests, models of wind turbine fins with tubercles improve lift and reduce drag compared with fins with smooth edges, which means that turbine fins made of this material can rotate with less wind resistance and greater efficiency. The design can also be used to improve the performance of airplane engine turbines and computer fans. Another energy application was inspired by the Asian hornet, which has a pigment on its abdomen that converts sunlight into energy. The nanostructure of the pigment is being studied for use with solar cells.

Some proponents of biomimicry believe that the concept should be put forth as an argument for conservation. For example, instead of framing habitat loss and species extinction as a crisis that threatens the earth's plants and animals, they contend that we should conserve nature because it offers biomimicry solutions that can help humanity survive and prosper.

Alisha K. Newton

See Also: Ecosystems, Importance of; Electric Power Generation, Health Implications of; Healthcare-Associated Infections; Intensive Farming Practices and Health; Renewable Energy, Health Implications of

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BIOMONITORING AND BIOMARKERS

Biomonitoring measures the amount of chemicals or their breakdown products in people. When humans breathe polluted air, drink contaminated water, or otherwise come into contact with environmental chemicals, those chemicals may get into the body. Once in the body, the chemicals may impact health. Depending on the chemical and dose, the impacts can vary widely, including effects on the nervous, respiratory, endocrine, and cardiovascular systems.

Real-World Biomonitoring

New York City was one of the first localities in the United States where biomonitoring was used to monitor exposure in an entire population. Before and after a ban on smoking in many indoor places, the department of health measured levels of cotinine (a marker of exposure to tobacco smoke) in saliva among nonsmokers, and the decline in cotinine levels demonstrated the effectiveness of the law. In fact, a study estimated that almost 4,000 hospital admissions for heart attacks were prevented in the first year after the law was enacted.

Biomonitoring provides information about which chemicals are getting into people's bodies and at what levels. This information can drive environmental health laws, regulations, and policies, and it can steer decisions about research needs and the cleanup of potentially toxic chemicals. In some cases, scientists measure the chemical directly, such as analyzing blood lead levels to check for lead poisoning. In other cases, the chemical can be changed (or metabolized) by the body, and when this happens, scientists measure a metabolite of the chemical. For example, cotinine is a metabolite of nicotine and helps to assess exposure to tobacco smoke. Sometimes scientists measure the impact the chemical has on the body; for example, cholinesterase is an enzyme that can be measured in the blood. Lower cholinesterase activity is a marker of damage to the nervous system and is linked to exposure to organophosphate pesticides (chemicals used to kill insects and other pests).

All three of these measures (the chemical itself, a metabolite of a chemical, and the effect of the chemical on the body) are called biomarkers. The first two are called biomarkers of exposure, while the last is called a biomarker of effect. Scientists typically measure biomarkers in blood or urine, but they can also make measurements elsewhere, for example, in feces, hair, nails, fat, breath, and saliva.

Depending on a chemical's toxicology (how it gets into the body and what it does once there), biomonitoring may provide a more direct estimate of exposure than environmental measurements and mathematical modeling. This is because biomonitoring integrates exposure from all sources. In other words, it does not matter how the chemical got into the body (breathing, eating, or touching) because biomonitoring simply measures how much is there.

Biomarkers may be used by physicians to diagnose or treat an illness, such as lead poisoning. Biomonitoring can also be used by public health professionals to monitor the health of a population. For example, the Centers for Disease Control and Prevention in the United States regularly monitors levels of more than 300 chemicals in people participating in a national health survey. Such monitoring is called surveillance, and its data can be used to identify trends in human exposure to environmental chemicals. An example is the rise in blood lead levels after Flint, Michigan, switched to a new water source in 2015.

Targeted biomonitoring studies provide insight into more limited questions. For example, in Minnesota, where perfluorinated chemicals were manufactured for many years, residents were concerned about levels of these chemicals in their drinking water. The state legislature commissioned a biomonitoring study that found exposure in the affected community exceeding that in the general U.S. population. And a follow-up study demonstrated a decline in urine levels of these chemicals following public health interventions that reduced exposure.

Epidemiologists, toxicologists, and other researchers use biomarkers to study relationships between environmental exposures and health effects. Citizens concerned about levels of pollution in their environment may be interested in these types of biomonitoring studies to determine if they have been exposed to a certain chemical, if their exposure differs from other populations, and whether the exposure may be linked to health effects.

Megan W. Latshaw

See Also: Centers for Disease Control and Prevention; Environmental Epidemiology; Environmental Toxicology

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BIOREMEDIATION FOR WASTE TREATMENT

Environmental contamination from human activities is recognized as a major problem that threatens affluent as well as developing societies worldwide. Since the chemical revolution, large quantities of increasingly complex synthetic chemicals have continued to find their way into every corner of the biosphere, where they can threaten human health and sensitive ecosystems. Ironically, these chemicals were, and continue to be, developed and used to enhance human standards of living through advancements in agriculture, medicine, manufacturing, defense, and recreation. But often the overuse or misuse of synthetic chemicals has had the opposite effect.

Practices collectively known as bioremediation emerged in the 1980s from attempts to mitigate the adverse health and environmental impacts of increasing intrusions of synthetic chemicals and other forms of waste into the earth's vulnerable ecosystems. Bioremediation strategies capitalize on the ability of microbial systems to be manipulated or managed in such a way as to enhance naturally occurring contaminant destruction and neutralization processes. Thus, bioremediation can be described as the science and practice of (1) identifying impediments to the ability of microbial systems to clean up a contaminant and (2) providing corrective strategies that accelerate such cleanup with simultaneous elimination of threats posed to human and ecosystem health.

Bioremediation has become a widely accepted concept because under appropriate conditions, it can be implemented to (1) neutralize wastes containing a wide range of organic compounds, including pesticides, pharmaceuticals, petroleum and other manufacturing chemicals, and defense industry wastes; (2) mitigate wastes containing certain metals and metalloids, making use of the ability of microbes to derive energy from oxidation-reduction reactions involving such contaminants, with their concomitant transformation into forms that can be more readily removed; and (3) remediate contaminated soils, sediments, water, and air. Significantly, bioremediation can be used to accomplish all of these functions at considerably lower costs compared with traditional waste disposal approaches involving excavation and transportation of contaminants to landfills or incinerators. These traditional approaches usually only transfer wastes from one phase to another, without guaranteeing their permanent destruction.

Is bioremediation the cure-all that it was initially touted to be at its emergence? In general, bioremediation strategies are ineffective alone for cleaning up persistent organic pollutants (toxic chemicals that persist for long periods in the environment and that can accumulate and pass from one species to the next through the food chain), mixed or aged wastes, and other substances that are naturally resistant toward microbial degradation or transformation. Nevertheless, bioremediation can be incorporated with other treatments for the cleanup of such wastes. Bioremediation is strongly influenced by climate, particularly cold climates, where microbial processes may slow down or cease to be effective. However, bioremediation techniques for cold regions have been developed to address the frequent spills and leaks occurring during oil and gas production in colder climates.

Bioremediation strategies are derived from two fundamental processes: (1) biostimulation of microbial populations to cause waste destruction in a contaminated material and (2) bioaugmentation involving the direct addition of naturally selected, genetically modified organisms or their products to promote contaminant removal. Depending on types and levels of wastes and contaminated material characteristics, these processes can be used alone or in various combinations for bioremediation.

Biostimulation can be accomplished by (1) nutrient-, substrate-, or growth factor-mediated stimulation of general purpose microbial populations, resulting in coincidental removal of contaminants; (2) inducible substrate-mediated stimulation of microbial populations to remove specific wastes (a process often referred to as rhizostimulation or rhizodegradation because it involves plant roots); (3) landfarming or land application, which is the controlled spreading of wastes over uncontaminated lands or land-vegetation systems to effectively dilute or remove toxicity, thereby making the job of bioremediation easier; and (4) bioventing and biosparging, which involve physicochemical alteration of waste material conditions (e.g., increased aeration) to stimulate the activity of aerobic microbes for destruction or removal of contaminants in the unsaturated zone or below the water table of soils. Combinations of biostimulation and bioaugmentation have found application in biopiles/composts and bioreactors, where nutrients, heat, oxygen, and pH are managed for waste destruction in soils and sediments.

Bioremediation is currently accepted as one of the most effective approaches for cleaning up environmental contamination for a broad range of wastes. Certainly, it is not an ideal technology for every situation, but increasing uses of molecular biology techniques to better understand microbial communities, and applications of nanotechnology to waste cleanup, are expected to further enhance bioremediation strategies.

Finally, a discussion about bioremediation would be incomplete without mentioning a related concept, phytoremediation, which involves using living plants to remove, degrade, or contain contaminants in soils, sediments, surface water, groundwater, and air. In practice, combinations of bioremediation and phytoremediation (sometimes called bio/phytoremediation) are often the most effective strategies for mitigating the adverse impacts of wastes on human and ecosystem health.

E. Kudjo Dzantor

See Also: Hazardous Waste Disposal; Heavy Metal Pollution; Persistent, Bioaccumulating, and Toxic Chemicals; Pesticides and Herbicides; Pharmaceuticals in the Environment; Soil Contamination and Remediation

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BIOSPHERE, ENVIRONMENTAL THREATS TO

The biosphere is the surface layer of the earth's atmosphere that includes all living organisms, such as plants, animals and bacteria, and their surrounding environments. It provides the land, air, water, and energy necessary to sustain life. For example, the biosphere provides the food we eat and the air we breathe. The biosphere is a life-supporting global ecosystem, and without it, the earth would be a lifeless planet.

Although essential to life on the earth, the biosphere is very fragile, and it is threatened by many of today's global environmental problems. These problems include deforestation, desertification, loss of species and reduction in biodiversity, air and water pollution, and depletion of energy resources. Each of these threats is described next.

Deforestation is the clearing of the earth's forests on a massive scale, often resulting in permanent destruction of forests and damage to the quality of the land. Due to deforestation, global forest coverage has declined in recent years from 6.2 million square miles (16 million square kilometers) to only 2.4 million square miles (6.2 million square kilometers), and between 5,020 and 27,800 square miles (13,000 and 72,000 square kilometers) of forest are lost each year. The major causes of deforestation are timber harvesting and agriculture. Trees are cut down to create commercial items, such as paper, furniture, and home-building materials, and to provide land for growing crops. Deforestation has caused many species to disappear due to habitat loss. Additionally, because the cut trees can no longer remove carbon dioxide from the atmosphere, deforestation contributes to climate change. (Carbon dioxide is the most significant climate change air pollutant.)

How Space Travel Benefits Humans on the Earth

Without the space program's need for miniaturized technologies, development of a laptop-size ultrasound unit may have been delayed for many years.

An Interview with Dr. Craig Kundrot

Life Science Lead, National Aeronautics and Space Administration

Dr. Kundrot is responsible for coordinating the National Aeronautics and Space Administration's life sciences research in the areas of astrobiology, crew health and performance, planetary protection, and space biology. Additionally, his office assesses the capabilities needed for current and future space missions.

When most people think about the National Aeronautics and Space Administration (NASA), they think about space travel. But NASA is actually much more than that. Can you comment on how NASA has contributed to the field of environmental protection and human health?

The National Aeronautics and Space Administration has been responsible for major advances in our understanding of human health and the environment. For example, recent studies have measured the extent of forested areas on the earth, studied vegetation in cities, and examined the health of coral reefs around the world. These areas all have implications for climate change, heat waves in cities, and ocean food supply.

Major contributions have also originated with the International Space Station (ISS) program. One example is development of a miniaturized ultrasound unit, about the size of a laptop computer, that provides a wide range of new applications, such as examining collapsed lungs, broken bones, eye and head injuries, and infections in teeth and sinus cavities. Back on the earth, this innovation can be used in remote locations and less developed countries where traditional MRI (magnetic resonance imaging) and CAT (computerized axial tomography) scan techniques often cannot be used. Without the space program's need for miniaturized technologies, development of a laptop-size ultrasound unit may have been delayed for many years.

Good health in the environment of a space vehicle must be extremely challenging for astronauts who live there for any length of time. For example, maintaining strong, healthy bones must be a problem when physical exercise is so limited. Are there any lessons from space travel that are relevant to preventing bone density loss on earth?

Research conducted in support of the ISS contributed to the new dietary recommendations for vitamin D in the United States. On the earth, we make vitamin D when our skin is exposed to sunlight. But astronauts do not get exposure to sunlight on the ISS. Thus, NASA researchers had to learn a lot about maintaining a healthy level of vitamin D in their bodies. These studies were used by the Institute of Medicine to make recommendations on the amount of Vitamin D people should have in their diets.

Other ISS research has revealed that astronauts who eat more fish experience less bone loss, and this has been confirmed in ground-based studies. Omega-3 fatty acids, the fatty acid found in fish, are thought to be responsible. This finding has broad implications for all Americans, especially in light of osteoporosis and other bone diseases that affect millions of people. NASA researchers have learned that short, high intensity exercise combined with bisphosphonates (a type of drug used to prevent osteoporosis) can also prevent bone loss, and this same approach can be used back on the earth.

These are just a few examples of how the national space program continues improving human health and the environment on the earth as it protects our astronauts in space.

What is a good career path for a recent college or university graduate who is interested in the work of NASA and wants to contribute to solving the world's environmental health issues?

There are multiple career paths within NASA and other federal agencies that lead to careers involving environmental health issues. You will probably want to graduate with a degree in the health or environmental sciences or in engineering, and it is always good to get some experience while in college, for example, with a research project or summer internship. Because many federal jobs are in high demand and you will continue to refine your interests as you gain experience, don't be too selective about your first job—just get started. To find federal jobs, set up a search on https://www.usajobs.gov. Once you gain a little on-the-job experience, you will have a better understanding of where your interests lie, and you will be able to move around in your agency to improve the match between your interests and the agency's needs.

Desertification is a land degradation process, often occurring in arid, semiarid, and dry subhumid regions, by which dryland ecosystems become deserts. The total area affected by desertification is between 0.8 and 2.3 million square miles (2.0 and 6.0 million square kilometers). Severe droughts in many parts of the United States, from the Pacific Northwest to the Southeast, are causing desertification. Desertification can also be caused by deforestation and improper agricultural practices (e.g., overgrazing, excessive tillage, and overdrafting of groundwater). This process reduces the capability of land to support life, threatens wild species and domestic animals, and reduces plant productivity and crop yields.

Species extinction and loss of biodiversity have major impacts on the earth. The current species extinction rate is estimated at 1,000 times the natural replacement rate associated with evolution (i.e., the background rate) and may continue to increase. Experts predict that 30 to 50 percent of all species will become extinct in the 21st century if present trends continue. Biodiversity refers to the variability among living organisms in terms of genes, species, functions, and ecosystems. A leading cause for the loss of biodiversity is habitat loss due to deforestation, desertification, intensive agriculture, and urbanization. Excessive hunting and overfishing also reduce species diversity. The ongoing loss of biodiversity significantly reduces food sources and alters the health and services provided by our ecosystems.

Pollution is another major threat to the biosphere. Air pollution not only damages the environment but also causes human disease. The World Health Organization estimates that about 7 million people died prematurely in 2012—about one-eighth of total global deaths—due to exposure to air pollutants. Water pollution is commonly caused by industrial discharges, sewage waste, application of fertilizers, and agrichemicals used for pest control. Groundwater, aquifers, lakes, rivers, and oceans are becoming more polluted, affecting the plants and organisms living in them. Because of water pollution, more than a billion people do not have access to safe water.

Depletion of energy resources also poses a great threat to the biosphere. The increasing global population and growing number of middle-class consumers is causing greater consumption of meat and consumer goods and increasing energy use to levels unheard of in human history. Fossil fuel reserves are being depleted as the use of fossil fuels for energy generation contributes to climate change and environmental deterioration. To sustain the growing population, finding alternative energy sources (e.g., renewable energy) has become urgent. Otherwise, the earth's carrying capacity for the human population will suffer.

The biosphere is facing serious environmental threats. To maintain a sustainable and healthy biosphere, we need to make changes that acknowledge the biosphere as an interactive system. The actions needed include growing more trees to increase forest cover, slowing the loss of species and reduction of biodiversity, controlling all forms of pollution, increasing use of alternative and renewable energy resources, and advocating for energy efficiency. A cooperative effort is urgently needed to protect the biosphere that we depend on for life.

Dafeng Hui

See Also: Air Pollution; Biodiversity and Health; Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Crops and Vegetation, Air Pollution Damage to; Deforestation; Drought and Desertification, Health Consequences of; Ecosystems, Importance of; Electric Power Generation, Health Implications of; Endangered Species and Human Health; Population Trends, Health Implications of; Renewable Energy, Health Implications of; Sustainable Development and Health; Water Pollution; Wetlands and Healthy Waterways; World Health Organization

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BIOTERRORISM

Bioterrorism is the intentional release of deadly biological agents, like bacteria, viruses, and toxins, for the purpose of damaging the health of a group of people. Counterterrorist experts say these agents can be difficult to detect and contain due to slow incubation periods and differing rates of secondary transmission (contagiousness). The most potent agents include anthrax (*Bacillus anthracis*), botulism (*Clostridium botulinum*), plague (*Yersinia pestis*), smallpox (*Variola major*), tularemia (*Francisella tularensis*), and viral hemorrhagic fevers, such as Ebola and dengue. Biological agents can spread through air and water and in food and may not cause symptoms of illness for several hours up to several days.

Japan's Subway Sarin Attack

A major bioterrorism event took place in Japan on March 20, 1995, when the cult leader Shoko Asahara convinced several disciples to release deadly sarin gas in the subway system during the morning rush hour. The attack killed 13 people, and over 6,000 were sickened, many requiring hospitalization. Asahara, whose real name is Chizuo Matsumoto, reportedly believed this action would elevate doomed souls to a higher spiritual world. Sarin is one of the most toxic and rapidly acting nerve agents used in chemical warfare.

Shortly after the terrorist attacks on September 11, 2001, letters laced with anthrax were sent to five media outlets and two U.S. Senators. As a result, 22 people were infected and 5 people died. Though the letters raised public alarm, no subsequent biological attacks followed. Various U.S. government programs have been established since this anthrax scare to develop vaccines and treatments to counter biological agents. Project BioShield was one such program authorized through the Biomedical Advanced Research and Development Authority, a branch of the U.S. Department of Health and Human Services (DHHS). In addition, the National Biodefence Science Board (later renamed National Preparedness and Response Science Board) was created in 2006 to provide nonpartisan oversight of DHHS strategies.

The threat of bioterrorism—and its cultivation as a wartime technology—started long before the 21st century. In medieval times, soldiers used bodies of dead animals and corpses infected with the plague as ammunition. Early American settlers decimated Native American populations through the spread of smallpox, sometimes intentionally. During the Cold War, the U.S. Army developed a tularemia-based agent that could kill within a few hours.

Bioterrorism is not just a perceived threat from abroad. In September 1984, a cult in Oregon called Rajneeshee contaminated various restaurant salad bars with salmonella (*Salmonella typhimurium*). They were attempting to take over the local government and aimed to keep their opponents out of the voting centers. More than 700 people became sick, and 45 individuals were hospitalized. The Rajneeshee then sought to transport homeless people from surrounding communities to the voting booths. This quickly caught the attention of local and federal officials, and the Rajneeshee withdrew their politicians from running for election.

Mallory L. Daily

See Also: Bubonic Plague; Ebola Virus; Environmental Toxicology; Neurotoxicants; September 11 World Trade Center Attack

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BISPHENOL A (BPA)

Bisphenol A (BPA) is a chemical compound that has been used since the 1950s in the production of hard plastics, including baby bottles and food storage containers. BPA is also used in thermal paper, dental sealants, and lacquer coatings for the insides of metal cans. In 2004, the United States produced approximately 2.3 billion pounds (1.0 billion kilograms) of BPA, with 6 billion pounds (2.7 billion kilograms) produced worldwide in 2007. Since the 1990s, the safety of BPA for humans has been widely disputed.

The U.S. Centers for Disease Control and Prevention has found BPA in the urine of 93 percent of a representative sample of people six years of age and older. People are most often exposed to BPA by eating food from plastic containers made with BPA or metal cans lined with BPA. When heated in dishwashers and microwaves, the plastic breaks down, allowing BPA to leach into food.

Laboratory tests in the 1990s first indicated the potential adverse effects of BPA exposure in humans. In animal studies, BPA has been shown to cause mammary and prostate cancer, genital malformations in male rodents, early onset of puberty in female rodents, obesity, and behavior problems such as attention-deficit/hyperactivity disorder. Based on these studies, it is possible that BPA exposure may be associated with similar effects in humans, such as prostate and breast cancer, obesity, and type 2 diabetes. As an endocrine disruptor, BPA would have the strongest effects during the early stages of biological development (i.e., in the womb and during early childhood).

A 2006 U.S. government report stated the safety of BPA. However, the report had been created by a contractor with ties to the chemical industry, and the contractor was subsequently fired over conflict of interest concerns. A year later, the National Toxicity Program (NTP) raised concerns about BPA, including effects on brain development, behavior, and prostate glands in fetuses, infants, and children. Soon after the NTP report, Canada's Ministry of Environment and Climate Change added BPA to its list of regulated toxic substances, and a number of U.S. retailers began to phase out BPA from certain products, including baby bottles.

By the end of 2010, eight states had placed bans on BPA in baby bottles. In 2011, the European Union also banned the use of BPA in baby bottles and cups, as did the U.S. Food and Drug Administration in 2012. In 2010, the U.S. Environmental Protection Agency (EPA) announced it would begin collecting information about BPA in surface water and groundwater, and the EPA is also investigating the effects on aquatic organisms.

In response to regulation, many manufacturers have started using bisphenol S (BPS) and bisphenol F (BPF) as "safe" alternatives to BPA. While their products may be advertised as "BPA-free," recent studies show that the replacement chemicals may also disrupt the endocrine system. For instance, a 2015 Canadian study on the effects of BPS on zebrafish brain development showed rapid neuronal growth, leading to hyperactive behavior in the fish. Most Americans now have detectable levels of BPS and BPF in their urine.

The EPA recommends that people who are concerned about the adverse effects of BPA avoid microwaving polycarbonate plastic food containers, instead using glass, porcelain, or stainless steel containers.

Alisha K. Newton

See Also: Centers for Disease Control and Prevention; Endocrine Disruptors; Environmental Protection Agency; National Toxicology Program; Reproductive Health and Environmental Exposures

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BLACK LUNG DISEASE

Black lung disease, the common name for coal workers' pneumoconiosis, is caused by inhaling small amounts of coal dust over a long period and is a major occupational hazard in the coal mining industry. This disease can significantly disable workers by damaging the lungs and causing a severe cough, chest tightness, and shortness of breath, and in the worse cases, it can lead to premature death. Its common name is derived from human lungs that are black due to the inhaled coal dust compared to healthy, pink lungs. This disease typically impacts miners and other coal workers over age 50, but recent cases of black lung disease are affecting a younger generation of miners.

Prior to major laws designed to protect the health of mine workers, it was very common for miners to get black lung disease. This led to the passage of several laws to protect miners, with the Federal Coal Mine Health and Safety Act, passed in 1969, being the most comprehensive and stringent law to regulate the safety and health of miners. The law included safety and health standards for miners, mine dust limits, increased federal inspections, fines and criminal penalties for violating standards, and mandatory training. The law also established benefits in the form of medical care and financial payments for miners disabled by black lung disease. In 1977, the Federal Mine Safety and Health Act placed authority for mine safety under the U.S. Department of Labor and created the Mine Safety and Health Administration. Passage of these laws and subsequent enforcement of health and safety standards caused black lung disease cases and deaths in the United States to decrease significantly.

Black lung disease manifests after years of exposure from inhaling coal dust. Fine coal particles that enter the body cannot be removed or destroyed and build up in the lungs. The body's white blood cells, called macrophages, engulf the coal particles, leading to inflammation, fibrosis (scarring), and nodular lesions on the lungs. Over time, significant scarring and thickening of the lung tissue occurs, reducing the lungs' ability to supply oxygen to the blood. This leads to shortness of breath, labored breathing, and decreased oxygenated blood flow to the body's organs. The initial form of black lung disease is often asymptomatic. However, continued exposure to coal dust results in more serious forms of the disease, called (1) simple coal workers' pneumoconiosis and (2) complicated coal workers' pneumoconiosis, better known as progressive massive fibrosis (PMF). PMF is the most serious form of the disease, leading to significant damage in the lungs. Other complications may include emphysema, bronchitis, chronic obstructive pulmonary disorder, and cor pulmonale—an enlargement and strain of the right side of the heart due to hypertension in the lungs that could lead to heart failure.

Black lung disease is diagnosed by evaluating a patient's history of exposure to coal dust and taking a chest x-ray or computerized tomography (CT) scan to check for spots in the lungs caused by dust exposure. In addition, the exclusion of other respiratory diseases similar to black lung is considered when diagnosing the disease. A pulmonary function test may also be performed to aid in diagnosis. Diagnosis and confirmation of the disease is critical to the patient successfully filing and receiving medical and financial black lung benefits.

Once diagnosed, there is no specific cure for black lung disease. Treatment includes prevention of new exposures to limit future lung damage and treating symptoms to improve the patient's quality of life. The prognosis of someone with black lung disease depends on the seriousness of the disease and how much lung damage has occurred. In many cases, people diagnosed with simple coal workers' pneumoconiosis can live a normal life, provided they take care of their lungs and ensure they stay in good health. However, those with PMF have poor quality of life outcomes and a higher risk of premature death due to the extensive lung damage.

While the overall numbers and deaths of black lung disease have decreased since passage of the Federal Coal Mine Health and Safety Act, an alarming number of new PMF cases has been observed. This could be from new or modified mining techniques that allow miners to access deeper coal or from thinner coal seams requiring cutting through more rock, thus generating significant dust. This dust may be mixed with silica, another environmental respiratory hazard that can complicate black lung disease. The only way to prevent black lung disease is to reduce long-term exposure to coal dust. Prevention requires federal enforcement of mine safety laws requiring dust control plans, mine ventilation, training and education, medical monitoring, and respiratory protective equipment.

R. Christopher Rustin

See Also: National Institute for Occupational Safety and Health; Occupational Safety and Health; Occupational Safety and Health Administration; Respiratory Disease and Air Pollution; Silica

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BREAST CANCER AND ENVIRONMENTAL EXPOSURE

Breast cancer is a severe disease in which the breast tissues grow uncontrollably, which can eventually lead to death. More women than in men are diagnosed with breast cancer in the United States, with a male-female predisposition of 1 to 100. About 80 percent of women with breast cancer are over 40 years of age, and it is the most commonly diagnosed form of cancer among American women. About

15 percent of women diagnosed with breast cancer have a family history of the disease (which doubles a woman's predisposition to the disease). However, 85 percent of women diagnosed have no family history, indicating that environment plays a significant role in the etiology of the disease.

Cancer occurs when the cell's DNA (the molecule that harbors information regarding the chemical basis of heredity in humans) becomes damaged, destabilizing the cell's growth cycle and resulting in uncontrollable growth. Exposure of a cell to certain stressors can lead to mutations (changes) in the cell's DNA, which can then progress to cancer. Carcinogenic (cancer-causing) environmental agents or stressors can be physical, biological, or chemical.

Environmental and behavioral causes of breast cancer include occupation, combined hormone replacement therapy in postmenopausal women, and exposure to radiation. A sedentary lifestyle, excess body fat, improper diet, smoking, excess alcohol consumption, and environmental chemicals are correlated with higher rates of breast cancer. For environmental chemicals to mutate a person's DNA and cause cancer, certain genetic factors have to be present to facilitate the process. Genomics research has strengthened our basic understanding of how genetic and environmental stressors interact to result in cancer.

Carcinogenic environmental chemicals may be present in the air or soil in the form of water, food, or dust or as a component of other consumer products. Research is still ongoing to ascertain the relationship between pesticides and breast cancer. Additionally, there are different estrogen-like substances, otherwise known as endocrine disruption substances, occurring exogenously (outside the body), which can cause breast cancer. Examples include dichlorodiphenyltrichloroethane, bisphenol A, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, dioxin, and heavy metals such as mercury, lead, and arsenic.

Current research indicates that these chemicals have the capacity to both alter the endogenous hormonal equilibrium in the body and contribute to the genesis of different types of cancer, including breast cancer. Humans can be exposed to these chemicals through contaminated foods, air inhalation, or absorption through the skin. Similarly, fetuses (unborn children) can be exposed to these chemicals from their mothers through the placenta (the source through which fetuses obtain dietary nutrients and eliminate waste products while in the womb). These chemicals, upon entry into the body, can alter the hormonal function of the body and have been associated with both cancer and fertility problems in humans.

Ifeanyi Abuachi

See Also: Cancer Risk from Environmental Exposure; Endocrine Disruptors; Pesticides and Herbicides; Radiation, Ionizing and Nonionizing

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BROWER, DAVID

David Brower (1912–2000) earned a widespread reputation as a passionate and influential environmentalist, with a lifelong focus on preserving the wilderness. His career was not without controversy, but his impact on the preservation of wild spaces throughout the nation, including in national parks, is undeniable. He is widely recognized as being a leader in establishing the contemporary environmental movement.

Brower's dedication to the environment began at an early age when he went camping with his family and later when he became a guide for his blind mother as they trekked around the hills in their Berkeley, California, neighborhood. He also worked in several roles at Yosemite National Park and became an enthusiastic and highly skilled mountain climber. Brower eventually was recognized for making 70 first ascents of U.S. peaks, including the first ascent of Shiprock, the eroded remnant of a volcano with nearly vertical walls, in New Mexico. All this time spent in the wilderness ignited his passion for preserving it.

During World War II, Brower was a mountaineering guide for troops in the Italian Alps, where he led daring assaults through treacherous terrain to overcome enemy positions, earning a Bronze Star for this actions in Italy. After the war, Brower and his wife, Anne, built their home on Grizzly Peak in Berkeley, the same area where he and his mother had hiked.

During Brower's tenure as executive director of the Sierra Club from 1952 to 1968, the club's membership grew from 2,000 to 77,000. With Ansel Adams, Brower oversaw publication of the club's first book, *This Is the American Earth*, and he spearheaded the signing in 1964 of the U.S. Wilderness Act. But despite his successes, he was fired from the Sierra Club in 1968 because of disorganized management of funds and his frequently opinionated and militant stances.

Although Brower was disappointed that his efforts to prevent construction of the Glen Canyon Dam across the Colorado River in 1963 were unsuccessful, he spent large amounts of Sierra Club funds to successfully prevent dam construction in the Grand Canyon and Dinosaur National Monument. Throughout his career, he continued to work on the prevention of dam construction in wilderness sites. He also supported the formation of national parks throughout the country, including Redwoods National Park, Kings Canyon National Park, and Point Reyes National Seashore.

After leaving the Sierra Club, Brower founded Friends of the Earth, an environmental advocacy organization that has had a far-reaching impact around the world, and its associated group, the League of Conversation Voters. In 1982, he founded another influential environmental organization, the Earth Island Institute, which focuses on creating a healthier and just world. Brower was also an eloquent and perceptive writer and editor, developing large-format books expressing the beauty of the wild with Ansel Adams and other leading nature photographers.

Despite the controversies that swirled around him, Brower was nominated for the Nobel Peace Prize three times, in 1978, 1979, and 1998. In 1998, he received the Blue Planet Prize for his lifetime achievements in protecting the environment. He was also the subject of John McPhee's best-selling book, *Encounters with the Archdruid*.

Susan J. Montgomery

See Also: Environmental Justice; Environmentalism

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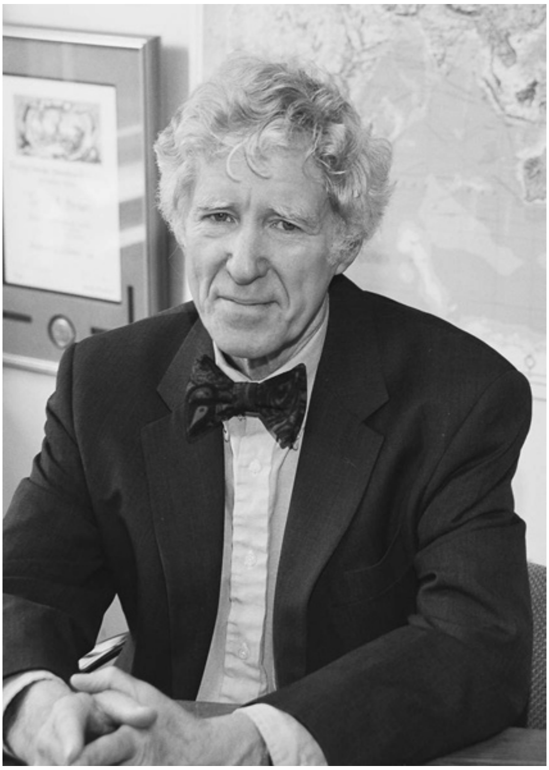
BROWN, LESTER

Lester Russell Brown (1934–) is widely recognized as a major leader and thinker in the environmental movement, particularly as it relates to global warming and how food, energy, and water shortages affect world populations. The *Washington Post* has described Brown as "one of the world's most influential thinkers." Throughout his career, he has been outspoken on the geopolitics of food, pointing out the serious threat food shortages in poor countries have on global stability.

Brown grew up in southern New Jersey on a farm without electricity or running water, but he was a prolific reader at an early age. Brown's passion for protecting the environment was ignited while he worked on his family's farm, where he and his brother raised chickens and grew tomatoes as a way to make money during high school and college. After earning a degree in agricultural science from Rutgers University in 1955, Brown moved to rural India for several months as part of the International Farm Youth Exchange Program, where he was exposed to the huge problem of world hunger. This experience changed his life and defined the direction of his career. Brown then became an international analyst with the U.S. Department of Agriculture's Foreign Service. After earning master's degrees in agricultural economics from the University of Maryland and public administration from Harvard, Brown was appointed advisor to secretary of agriculture, Orville Freeman, in 1964, a position where he advised on the topic of foreign agricultural policy.

In 1974, Brown founded the World Watch Institute, which focused on global environmental concerns. In the late 1970s, in his book, *The Twenty-Ninth Day: Accommodating Human Needs and Numbers to the Earth's Resources*, he warned about the serious perils of abusing nature, pointing out the dangers of overfishing



Lester Brown, an environmental movement leader described as one of the world's most influential thinkers. Brown founded influential environmental organizations, authored many books, and received countless awards, including the United Nation's Environment Prize. (Earth Policy Institute)

oceans and striping forests. In 1986, Brown's personal papers were requested by the Library of Congress because of his great influence on the issue of resource shortage in light of a growing population. In 2001, Brown founded and became president of the Earth Policy Institute, a nonprofit organization focused on environmental research with the goal of making plans to create an environmentally stable economy. He closed the institute in 2015.

Brown has authored or coauthored more than 50 books on a variety of environmental issues, and his books have been translated into more than 40 languages. In 2013, he published his biography, *Breaking New Ground: A Personal History*. Among his other most influential books are (1) *Man, Land, and Food*; (2) *Full Planet, Empty Plates: The New Geopolitics of Food Scarcity*; and (3) *Eco Economy: Building an Economy for the Earth* (described as an "instant classic" by E. O. Wilson, Harvard professor and one of the world's most distinguished scientists). Brown's most recent book is *The Great Transition: Shifting from Fossil Fuels to Solar and Wind Energy*.

Brown has received countless awards and recognitions, including more than 25 honorary degrees and a MacArthur Fellowship. In 1987, he received the United Nation's Environment Prize, and he was awarded the prestigious World Wide Fund for Nature Gold Medal in 1989. In 2012, Brown was inducted into the Earth Hall of Fame in Kyoto. He was recently honored with the Presidential Medal of Italy, and he is an honorary professor at the Chinese Academy of Sciences.

Susan J. Montgomery

See Also: Climate Change and Human Health; Deforestation; Environmentalism; Food Supply, Environmental Threats to; Population Trends, Health Implications of; Renewable Energy, Health Implications of

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BROWNFIELDS

Brownfields are abandoned or little-used industrial or commercial sites, usually in urban areas, that are contaminated or potentially contaminated with toxic chemicals or other substances dangerous to human health and environment. Prior to redevelopment of such sites for new commercial purposes, government regulations require that they be scientifically assessed and cleaned up. Exposure to the contaminants and pollutants present in brownfields generally pose the greatest risks to human health if the exposure occurs over a long-term period.

There are more than 450,000 brownfields in the United States, according to the U.S. Environmental Protection Agency (EPA). That number refers only to sites that have received environmental assessments by scientists, but many potential brownfield sites have never been properly assessed for their pollutants. Thus, the actual number of sites that would classify as brownfields is likely much greater than the

Cumberland Park

Most visitors to Cumberland Park, along the riverfront in Nashville, Tennessee, probably cannot tell that this beautiful and fun family place, with unique play structures and water attractions, used to be a brownfield. But it was formerly the site of a sawmill and a bridge-and-barge manufacturing facility, which was contaminated with lead, arsenic, and other toxic chemical compounds. The U.S. Environmental Protection Agency, Tennessee Department of Environment and Conservation, and Nashville Parks and Recreation Department collaborated on the site assessment, cleanup, and redevelopment. The new recreational development, covering 6.5 acres (2.6 hectares) and 900 feet (274 meters) along the riverfront, opened in April 2012.

EPA figure. In some cases, the location of a brownfield may be obvious, such as a shutdown manufacturing facility or a waste dump with leaking storage drums. In other cases, a site may provide no obvious visual clues to its potential classification as a brownfield, such as a paved-over parking lot or a secondary-growth forest. That is why most locations slated for commercial development in the United States require a careful scientific evaluation for possible pollutants.

The pollutants in particular brownfields depend on the type of business that formerly occupied the site. Such businesses may include factories, warehouses, gas stations and refineries, dry cleaning facilities, waste dumps, salvage yards, mines, and many other types of enterprises where harmful materials were produced or present. Common contaminants found in brownfields include oil and other petroleum products, heavy metals (e.g., arsenic, lead, and mercury), asbestos, dioxins and polychlorinated biphenyls, and uranium and other radioactive substances.

People living in the vicinity of brownfields may become ill by being exposed to the pollutants via direct contact at the site or via indirect contact, such as through drinking water that originated in tainted groundwater. Illnesses associated with brownfield substances include cancers of various kinds, respiratory inflammation, other organ damage, a weakened immune system, and conditions associated with poisoning.

Cleanup of a brownfield site in Oregon contaminated with volatile organic compounds. Brownfields are abandoned or little-used industrial or commercial sites contaminated with toxic chemicals or other hazardous substances. (Environmental Protection Agency)

After environmental scientists conduct an environmental site assessment to evaluate the level of environmental and health risks at a site—such as by analyzing the air, soil, and groundwater—cleanup can begin. This cleanup may involve such remedial actions as removing contaminated soils from land, dredging polluted sediments from stream beds, and installing special engineered caps, or barriers, over contaminated areas to isolate the contaminants from the surrounding land and water. Such caps may be made of compacted clay, asphalt, concrete, or other materials. After these remedial actions are undertaken, long-term monitoring of the soil, groundwater, and other elements of the site is necessary to ensure continued environmental and public safety.

As contaminated and polluted brownfields in blighted urban neighborhoods or other economically depressed areas are converted into clean and safe environments that are conducive to good health, the formerly abandoned and neglected sites become attractive again to investors, residents, and visitors. New developments on former brownfields might include such building projects as housing complexes, stores, restaurants, other businesses, and recreational parks. The cleanup and sustainable redevelopment of brownfields have resulted in the economic revitalization of many communities throughout the United States, including substantial increases in property values and tax bases and the creation of tens of thousands of new jobs.

Brownfields became a high priority among U.S. environmental officials during the 1990s, though previous government efforts to prioritize the cleanup of dangerous sites date to the 1970s. In 1995, the EPA established its Brownfields Program, under which the agency provides grants and technical expertise to cities, states, Native American governments, nonprofit organizations, and other entities for brownfield assessment, cleanup, and conversion into new productive uses. Many of the EPA's practices, policies, and guidelines concerning brownfields were codified in 2002 in the Small Business Liability Relief and Brownfields Revitalization Act (otherwise known as the Brownfields Law). In 1980, the Comprehensive Environmental Response, Compensation, and Liability Act (commonly known as the Superfund Act) made the purchaser of a property liable for any contaminants on the property, necessitating the assessment and cleanup of that site before development could proceed. Most municipal and state governments have their own brownfield programs, which they implement in coordination with the EPA.

A. J. Smuskiewicz

See Also: Asbestos; Dioxin Pollution; Environmental Protection Agency; Hazardous Waste Disposal; Heavy Metal Pollution; Land Disposal of Waste Materials; Polychlorinated Biphenyls; Superfund Act

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BUBONIC PLAGUE

Bubonic plague is a serious infectious disease that is caused by the rod-shaped coccobacillus bacterium, *Yersinia pestis*. It can be transmitted to humans and to other mammals by bites of infected animals, usually fleas (but also ticks or lice) from an infected host, most typically a rat, or it can be transmitted from one infected individual to another. Touching the bodies of infected host animals, or inhaling droplets from the cough of an infected animal (most commonly a cat) or person, can also transmit the infection.

Bubonic plague is named after the characteristic painful swollen lymph nodes, referred to as buboes, which typically occur in infected humans in the armpits, on the neck, in the groin, and elsewhere on the body. In addition to the formation of buboes, the disease is characterized by chills, diarrhea, extreme fatigue, fever, headache, muscle cramps, and vomiting. Within two to seven days after exposure to *Yersinia pestis*, flu-like symptoms and enlarged lymph nodes commonly appear. If not treated early, the bacterium *Yersinia pestis* can spread to other parts of the body, causing septicemic plague when it multiplies in the bloodstream or pneumonic plague when it infects the lungs.

In the Middle Ages, the bubonic plague was commonly known as the Black Death, a description thought to be derived from the deeply darkened skin that victims often present with. The Black Death was responsible for the death of nearly 200 million people at the time, and it is estimated to have caused the death of approximately 60 percent of the population of Europe from the eighth to the fourteenth centuries. The bubonic plague had appeared even earlier during the Byzantine era of the fifth and sixth centuries, when it spread from the Middle East to other Mediterranean lands and is thought to have killed about half of the population in the affected areas. Another major pandemic originated in 1855 in southwestern China and progressively spread around the world, reaching Hong Kong in 1894, India in 1896, Vietnam in 1898, Japan in 1899, and the United States and Europe by 1900. In 1894, Alexandre Yersin (1863–1943), a Swiss-born and naturalized French physician and bacteriologist working in China, isolated the bacterium *Yersinia pestis* that was subsequently named for him, and he also developed an effective antiserum treatment. Bubonic plague can now generally be successfully treated with antibiotics, but an infected individual must be promptly treated to avoid serious complications, including death. The recent discovery of antibiotic-resistant strains of *Yersinia pestis* is alarming to many in the medical profession.

Yersinia pestis continues to live on in millions of animals and in the billions of fleas that live on them around the world. Bubonic plague has persisted despite long disease-free periods because it can survive in reservoirs of wild rodent populations. From time to time, small outbreaks naturally erupt. For example, a large number of bubonic plague cases occurred in the 1980s in Tanzania. An average of about seven cases of bubonic plague are reported each year in the United States, mainly in the Southwest and West (particularly in Arizona, California, Colorado, and New Mexico), where mice, prairie dogs, rabbits, and squirrels, in particular, are believed to be vulnerable to infection. Domesticated animals, such as cats, can also become infected and serve as vectors to infect their owners. Around the globe, the World Health Organization receives reports of 1,000 to 2,000 cases of bubonic plague annually. The prime means of controlling the disease consist of rodent control, insecticide application, and avoiding contact with rodents and other infected animals and their fleas.

Victor B. Stolberg

See Also: Infectious Diseases; World Health Organization; Zoonotic Diseases

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CANCER CLUSTERS

According to the U.S. National Cancer Institute, a cancer cluster is "the occurrence of a greater than expected number of cancer cases among a group of people in a defined geographic area over a specific time period." Suspected clusters are usually brought to the attention of a local, regional, or state health department from community members, or health departments may look for clusters using existing regional surveillance data. Public health professionals rely on many tools from the fields of environmental exposure assessment, environmental epidemiology, occupational epidemiology, and statistics to determine when and how to investigate suspected cancer clusters. Though suspected cancer clusters are often not confirmed as true clusters of cancer once investigated by health departments, studying them remains an important and growing topic in environmental health.

There are many challenges to identifying cancer clusters. First, determining what constitutes an elevated number of cancer cases is difficult because often only a few cases comprise the clusters under study. Second, because different cancers have different etiologies, and because cancer is so prevalent, there will be areas with higher incidences of particular cancers simply by chance, and these would not be considered cancer clusters. Third, most cancers have a long latency period (i.e., they take years or decades to develop after human exposure to a causative agent). Furthermore, during their lives, people migrate, and even if they have the same residence for many years, they may be highly mobile, making it difficult to determine if and where any specific historical environmental exposure may have contributed to eventual cancer development. Fourth, cancer is multifactorial, meaning that many factors contribute to its development. Moreover, important time windows of exposure related to cancer development in both children and adults remain unknown, with the result that pinpointing specific exposures that may have occurred in the past or even in utero is challenging. Finally, defining the geographic area of interest can introduce bias, depending on how the geographic boundaries are drawn. For example, whether the area of interest is a neighborhood, zip code, or city will influence whether a statistical association can be determined. Despite these challenges, the study of cancer clusters has been facilitated by statistical methods to analyze clusters and by geographic information systems to manage spatially referenced environmental, demographic, and health information.

A notable suspected geographic cancer cluster relevant to environmental health was made famous by the book and film *A Civil Action*, which is about a childhood leukemia cancer cluster in Woburn, Massachusetts, in the 1970s and 1980s. Some studies suggested a statistical association between leukemia and proximity to wells contaminated with the carcinogenic solvent trichloroethylene (TCE), but this association was uncertain. Recently, TCE, perchloroethylene, and other chemicals were implicated as drinking water contaminants contributing to cancer development among former Marines and families stationed at Camp Lejeune, North Carolina, from 1953 to 1985. The most notable environmental cancer cluster was of mesothelioma cases among World War II shipbuilders due to asbestos exposure.

Beth J. Feingold

See Also: Asbestos; Cancer Risk from Environmental Exposure; Drinking Water Quality and Regulation; Environmental Epidemiology; Geographical Information System Mapping; Human Exposure Assessment; Leukemia and Environmental Exposure

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CANCER RISK FROM ENVIRONMENTAL EXPOSURE

Cancer risk from environmental exposure refers to the chances that cancer will develop in a person from exposure to certain chemical substances in the environment. Such exposure can result in cancer when the chemicals cause changes in the DNA of cells in the body, altering the growth rate or function of the cells in pathological ways. Two of the best-known environmental causes of cancer are tobacco smoke (a cause of lung cancer) and excessive ultraviolet radiation from the sun (a cause of skin cancer). Other examples of environmental carcinogens include numerous types of pollutants in air and water, some ingredients in food, certain

Cancer-Causing Infections

Scientists have identified a number of infectious microbes—viruses, bacteria, and tiny parasitic worms—that can cause cancer. Viruses can cause cancer by inserting their genetic material into the cells of a person's body, causing those cells to grow out of control. Certain other infectious agents cause chronic inflammation that leads to genetic changes in body cells. Still other infections suppress the immune system, reducing its defenses against cancer development.

drugs, and various household and workplace materials. Some infectious microbes also cause cancer. Overall, environmental exposures are associated with a relatively small proportion of cancer cases, estimated to range, according to different researchers, from about 4 to 20 percent.

Scientific knowledge of the cancer risks of environmental substances is imprecise and incomplete. The risk level of many substances is open to debate and the subject of continuing research. In the United States, the National Cancer Institute, under the National Institutes of Health (NIH), is the main government agency responsible for research regarding cancer and its causes, treatment, and prevention. Worldwide, the International Agency for Research on Cancer (IARC), part the World Health Organization, works to identify and quantify causes of cancer.

Arriving at definitive conclusions about the carcinogenic risk of any substance typically requires many years of laboratory research involving cell cultures and laboratory animals that are exposed to suspected carcinogens at various levels of potency. Although the bodies of humans and animals process some environmental chemicals in different ways, virtually all known human carcinogens also cause cancer in laboratory animals. Data on carcinogenic risks are also derived from epidemiologic studies, in which different human populations are examined to identify clues between cancer rates and substances in the environment.

Further complicating possible links between cancer and chemical substances is the fact that different people can have vastly different levels of risk to the same chemical. This difference results from variations in genetic characteristics. Some substances prompt the development of cancer only if the individual has a particular form of a certain gene. Yet another complicating factor is that some substances may cause cancer with only a single brief, potent exposure, but others require long-term exposure over many years to cause cellular damage.

Based on an evaluation of all relevant available scientific data, federal authorities determine if a substance should be labeled as a carcinogen or a probable carcinogen—or if evidence is insufficient to make either designation. In the United States, the National Toxicology Program (NTP)—consisting of parts of the NIH, Food and Drug Administration, Centers for Disease Control and Prevention, and other agencies—produces a *Report on Carcinogens* (RoC) every few years describing "known" and "reasonably anticipated to be" human carcinogens. The RoC currently describes approximately 250 such substances. The U.S. Environmental Protection Agency also maintains a database, called the Integrated Risk Information System, that describes five levels of carcinogenic risk for many environmental substances, ranging from "carcinogenic to humans" to "not likely to be carcinogenic to humans." The IARC uses a similar five-level system, which includes more than 100 substances classified as carcinogenic to humans.

The NTP's 14th RoC, released in November 2016, included six substances that were newly classified as known human carcinogens. Five were viruses—human immunodeficiency virus type 1, human T-cell lymphotropic virus type 1, Epstein-Barr virus, Kaposi sarcoma-associated herpesvirus, and Merkel cell polyomavirus. The sixth substance was an industrial solvent called trichloroethylene. In addition, cobalt and some cobalt-containing compounds were newly listed as reasonably anticipated to be human carcinogens.

Among the more than 60 other substances classified by the NTP as known human carcinogens are the following widely used or commonly encountered substances:

- Alcoholic beverage consumption
- Analgesic mixtures containing phenacetin
- Coal tars
- Estrogens, steroidal
- Formaldehyde
- Mineral oils (untreated and mildly treated)
- Oral tobacco products
- Solar radiation
- Soot
- Sunlamps or sunbeds
- Tobacco—smoking, environmental smoke, smokeless
- Wood dust
- X-radiation and gamma radiation

However, it is important to remember that these and other designated carcinogens are likely to cause cellular damage only at certain levels of exposure, which are described in detail in the RoC reports.

Risks of cancer from environmental substances can be minimized by adhering to certain behavioral practices. The American Cancer Society recommends several such practices, including (1) avoiding tobacco products; (2) minimizing skin exposure to the sun's ultraviolet rays; (3) eating a healthy and nutritious diet and staying physically active (because both practices fight cancer by building a healthy immune system and keeping weight down); and (4) following recommended cancer-screening guidelines to detect any cancer at an early stage, when it is most treatable. For some viruses linked to cancer, such as the human papilloma viruses that cause cervical cancer, preventive vaccines are recommended.

A. J. Smuskiewicz

See Also: Breast Cancer and Environmental Exposure; Cancer Clusters; Centers for Disease Control and Prevention; DDT Exposure; Dioxin Pollution; Dose-Response Assessment;

Environmental Protection Agency; Environmental Risk, Communication of; Exposure Pathways; Hazardous Air Pollutants; Human Exposure Assessment; Integrated Risk Information System; Leukemia and Environmental Exposure; National Air Toxics Assessment; National Toxicology Program

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CARBON CAPTURE AND SEQUESTRATION

Carbon capture and sequestration (CCS) is a category of technologies used to capture and store carbon dioxide emissions, mainly from electricity generation using fossil fuels. If CCS proves to be technologically and economically practicable, it could play a significant role in reducing the widespread adverse public health consequences of climate change. However, CCS would not reduce, and would actually increase, the threat to public health from air pollution (other than carbon dioxide) due to this technology's high energy requirements. Despite decades of efforts and billions of dollars in subsidies, CCS has not yet proven to be commercially viable at full scale in the United States.

The steps involved in CCS are (1) capturing the carbon dioxide gases at the facility before they are emitted into the atmosphere; (2) transporting the captured and compressed carbon dioxide to the storage site, usually by pipeline; and (3) injecting the carbon dioxide into deep underground geological rock formations. Potential storage sites include depleted oil and gas fields, coal seams, and saline formations. Layers of solid, impermeable rock above the underground storage areas prevent the carbon dioxide from migrating upward and escaping into the environment.

One example of a CCS project is the American Electric Power (AEP) Mountaineer coal-burning power plant in New Haven, West Virginia, where AEP, with partial funding from the U.S. Department of Energy, has captured carbon dioxide from about 2 percent of the exhaust stream (equivalent to about 30 megawatts of power production). To capture the carbon dioxide, AEP used a postcombustion chilled ammonia process developed by the Alstom company. AEP considered scaling up the project to 235 megawatts but eventually abandoned this idea.

Another example is Mississippi Power's Kemper County power plant in De Kalb, Mississippi. This plant uses integrated gasification combined cycle technology to convert coal into synthetic natural gas. When fully operational, carbon dioxide will be removed from the gas stream prior to combustion, with a goal of capturing approximately 65 percent. The captured carbon dioxide will then be transported by pipeline 98 kilometers (61 miles) to a facility that will use the carbon dioxide in an enhanced oil recovery process for extracting oil that was previously unreachable. Thus, although carbon dioxide is initially captured, it is used to extract more underground oil, which releases more carbon dioxide when burned. Without this technology, the previously unreachable oil would remain underground, and the additional carbon dioxide emissions would be prevented.

The Kemper plant turned out to be a financial disaster. Its nearly $6.5 billion price tag was dramatically greater than initial estimates of about $2.4 billion. Regulators eventually shielded Mississippi electricity customers from some of these costs, placing the burden on the shareholders of Southern Company (Mississippi Power's parent company), causing the company to nearly go bankrupt. Kemper is the most expensive utility-scale power plant ever built, and no similar power plants have been developed or proposed since.

Several other CCS projects never began construction despite substantial subsidizes and political support. For example, FutureGen and FutureGen 2.0 were ambitious coal-burning power plants to be located in Illinois, but construction was unable to commence after losing federal subsidies.

The only currently operating full-scale carbon capture facility is at SaskPower's Boundary Dam coal-burning power plant near Estevan, Saskatchewan, Canada. This relatively small, 115-megawatt unit that uses a postcombustion carbon dioxide capture system began operating in 2014. Because the plant uses its captured carbon dioxide to increase the extraction of oil, carbon dioxide emissions will actually increase when the newly extracted oil is subsequently burned. Thus, claims about overall carbon dioxide capture need to be carefully weight against the increased emissions that will occur later.

All CCS systems suffer from an energy penalty, called a parasitic effect. For example, at the Kemper County plant, approximately a quarter of the electricity it generates will be used to operate the equipment to capture and process the carbon dioxide. Thus, the plant will require 25 percent more coal to be mined and burned in the plant, with concomitant increases in air, water, soil, and solid waste pollution. This means that the life cycle pollution impacts of a facility with CCS are considerably higher than a facility without CCS on a net unit of useful electricity basis.

The ability to store carbon dioxide underground in the long term is not well understood. The major issue is that there are not enough studies confirming that the stored carbon dioxide will not slowly leak and be released into the atmosphere during the long time frame during which the carbon dioxide would need to be stored.

Numerous other potential dangers have been identified. For example, one study found that carbon dioxide storage could cause dangerous levels of uranium and barium to bubble up into underground drinking water sources. Another analysis compared carbon dioxide storage to the storage of natural gas, which is known to have leaked into the environment. One recent example is the serious natural gas storage leak detected at Southern California Gas Company's Aliso Canyon natural gas storage facility, located 30 miles northwest of Los Angeles. (If natural gas could leak from an underground storage facility, the reasoning goes, so could carbon dioxide.) There is also some concern that underground storage of carbon dioxide could cause earthquakes.

The greatest challenge for CCS technology remains its economic viability, particularly as clean, renewable energy sources are becoming more economically attractive. Wind and solar power are the lowest cost energy options in many parts of the United States, outcompeting coal and even natural gas power plants, even when the cost of CCS is not considered. Thus, many experts argue it will be difficult to justify CCS at any cost, even when full-scale CCS operations are successfully demonstrated.

Robert Ukeiley

See Also: Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Electric Power Generation, Health Implications of; Renewable Energy, Health Implications of

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CARBON DIOXIDE AND THE CARBON CYCLE

Carbon is a basic building block of life on the earth. It is found in almost everything—animals, plants, soil, the oceans, and the atmosphere. Carbon in the atmosphere is mostly in the form of carbon dioxide (CO_2). Because this CO_2 plays a major role in regulating the earth's temperature—keeping it from getting too hot or too cold—humans could not survive without it. A world without CO_2 in the atmosphere would be icy and devoid of life as we know it.

Carbon cycles naturally between animals, plants, soil, the oceans, and the atmosphere. This process is called the carbon cycle, and it has been around for millions of years, helping to regulate the earth's temperature. Beginning with the industrial revolution, the distribution of carbon in the biosphere began to shift, as the amount of CO_2 in the atmosphere increased due to human activities such as the burning of fossil fuels (e.g., coal and oil) to run factories and generate electricity. Because natural CO_2 sinks (i.e., biosphere components that absorb CO_2, like plants and the oceans) have been unable to keep up with the increasing CO_2, the concentration of this gas in the atmosphere has been steadily rising. Currently, the atmospheric CO_2 concentration is higher than at any time in the past 400,000 years or longer.

CO_2 is a greenhouse gas, which means it is good at absorbing heat and holding it close to the earth's surface, resulting in higher average temperatures near the surface of the earth. Temperatures naturally fluctuate diurnally, seasonally, and from year to year. However, the trend in global warming is clear. The average surface temperature of our planet has risen by about 2.0°F (1.1°C) since the late 19th century, and some of the warmest months and years since modern recordkeeping began in 1880 have occurred recently. Scientists attribute most of this warming to increased CO_2 concentrations in the atmosphere, mainly due to human activities. Other greenhouse gases, such as methane, also contribute to the warming.

In the United States, the main source of CO_2 and other greenhouse gases from human activities is the combustion of fossil fuels to generate electricity and power motor vehicles. The industrial, commercial, residential, and agricultural sectors of the U.S. economy also contribute significant amounts of greenhouse emissions. On the other hand, these emissions are offset somewhat by managed forests and other land-use changes, which, since 1990, have absorbed more CO_2 from the atmosphere than they emit, making them net sinks for CO2 gases. However, this trend is not necessarily true for other regions of the world, where lands cleared of forests for agricultural purposes or settlements can be a net source of CO_2.

Concentrations of CO_2 in the atmosphere have increased by about 35 percent since the beginning of the industrial revolution, and these increases have been occurring at an increasingly faster rate. At the Mona Loa observatory in Hawaii (site of the longest continuous measurements of atmospheric CO_2), CO_2 concentrations have been rising at a record pace, reaching an all-time high of over 405 parts per million (ppm). This contrasts with the average concentration of 280 ppm at the beginning of the industrial revolution and going back about 10,000 years before that. According to Pieter Tans, a lead scientist at the National Oceanic and Atmospheric Administration, the current rate of CO_2 increase in the atmosphere is 100 to 200 times faster than that experienced during the transition from the last Ice Age, representing "a real shock to the atmosphere."

Higher earth surface temperatures are not the only effects of increasing CO_2 concentrations. When ocean water absorbs additional CO_2 from the atmosphere, it becomes more acidic as the CO_2 reacts to form carbonic acid. New research shows that acidification in the Arctic Ocean is spreading rapidly, a phenomenon that may harm sea life, disrupt the food chain for many aquatic species, and affect human coastal communities that depend on food from the sea. Similar acidification trends have been observed in other oceans, and research shows that the oceans have absorbed as much as about 28 percent of the CO_2 produced by fossil fuel combustion over the past 250 years.

There are several actions the nation can take to reduce CO_2 emissions. These include (1) improving the energy efficiency of buildings, appliances, and motor vehicles so that less energy is required; (2) relying more on renewable energy sources such as solar and wind power; (3) applying CO_2 capture and sequestration technologies at electric power plant and other industrial operations that burn fossil fuels and emit large quantities of CO_2; and (4) supporting international treaties that engage the global community in reducing global greenhouse gas emission and promoting renewable energy sources. Additionally, individuals can help by turning off lights, computers, TVs, and appliances when not in use and by cutting back on heating and air conditioning when away from home.

Richard Crume

See Also: Carbon Capture and Sequestration; Climate Change and Human Health; Electric Power Generation, Health Implications of; Greenhouse Effect and Global Warming; Intergovernmental Panel on Climate Change; International Environmental Law and Policy; Mauna Loa Observatory, Carbon Measurements at; National Oceanic and Atmospheric Administration; Ocean Acidification; Renewable Energy, Health Implications of; United Nations Framework Convention on Climate Change

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CARSON, RACHEL

Rachel Carson (1907–1964) was both a scientist and a writer. She is best known as the author of *Silent Spring* (1962), a book written for the public that aims to bring awareness to the dangers of pesticide use. This book is often credited with spurring the environmental movement and with establishing the U.S. Environmental Protection Agency (EPA) in 1970.

Carson was born on May 27, 1907, in Springdale, Pennsylvania. She attended the Pennsylvania College for Women, initially majoring in English. Eventually, she switched to biology, but both literature and writing remained strong passions throughout her life, alongside her interests in science. She also completed a graduate degree in zoology at Johns Hopkins University.

Carson's love of the sea and wildlife were important influences on her professional career and writing. She worked for the U.S. Fish and Wildlife Service from 1936 to 1952. Her books on the ocean include *Under the Sea Wind* (1941), *The Sea around Us* (1951), and *The Edge of the Sea* (1955). *The Sea around Us* was a *New York Times* best seller and winner of the National Book Award.

Carson's most lasting contribution to environmental health was her book *Silent Spring*. Initially hesitant to take on the subject of pesticides, she dedicated four

Rachel Carson, noted scientist and author, testifies before Congress about the hazards of indiscriminate pesticide use. Her best-selling book *Silent Spring*, published in 1962, helped galvanize public support for the environment. (Library of Congress)

years of her life to completing the text. On June 16, 1962, the *New Yorker* magazine published the first of three condensed portions of *Silent Spring*. This serialization introduced the public to Carson's argument and brought widespread awareness to the effects of indiscriminate pesticide use. The text's title refers to the silence that has ensued in areas where birds, including the harbinger of spring, the robin, are now absent due to chemical spraying.

While the book alludes to silence, its argument brought noisy outrage from many parties. Carson's book was often discredited due to her gender and lack of doctoral education. Yet, it was also praised for its courage and notably singled out by President John F. Kennedy as the reason for starting government initiatives to research the harms of pesticides more fully. Today, Carson's text is popularly known for changing attitudes about dichloro-diphenyl-trichloroethane (DDT). DDT use was nationally banned in 1972 by the EPA, though it is still used globally—notably to fight malaria. While Carson promoted a "zero tolerance" policy, *Silent Spring* primarily argues for a more informed use of pesticides that carefully weighs the risks against the benefits they cause. Carson notes that the toxicants we spray to eliminate pests that endanger crops also have disadvantageous effects on human life. DDT exposure is linked to an increased risk of cancer, and traces of the chemical have been found in human breast milk.

Carson herself died from breast cancer in 1964, just two years after publication of *Silent Spring*. Rather than use her illness to support her claims against pesticides or gain public sympathy, Carson hid her failing health from the public. Her writing and research have left their mark by spurring both environmental activism and governmental reforms.

Meredith Hale

See Also: Breast Cancer and Environmental Exposure; DDT Exposure; Environmental Protection Agency; Environmentalism; Pesticides and Herbicides

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CARTER CENTER

The Carter Center is a nongovernmental, charitable organization focused on addressing vital global concerns, such as resolving conflict, supporting freedom and democracy, and improving health. Much of its work involves the eradication and elimination of diseases, including those transmitted by contaminated water and poor sanitation.

The Carter Center was founded by former U.S. president Jimmy Carter and former first lady Rosalynn Carter. Today, it is run by a chief executive officer and advised by a board of trustees and board of councilors. The center, which partners with Emory University, is headquartered in Atlanta, Georgia, and has field offices located internationally. The center's international presence also includes the Carter Centre United Kingdom, an independently registered charity that supports the Carter Center by raising awareness and securing funds in the United Kingdom and Europe. The center's Atlanta headquarters hosts 175 employees and a library and museum, which are open to the public.

The global initiatives of the Carter Center are organized into two categories: peace programs and health programs. Through its peace programs, the center promotes its belief that permanent peace is dependent on a culture of human rights and on alleviating human suffering, and it focuses its efforts on enhancing freedom and democracy, improving health, and resolving conflicts. The center monitors 100 national elections throughout the world to ensure the rights of people are respected, and when democracy does not succeed, the center offers conflict resolution programs. The center has been conducting multiple initiatives as part of its peace programs, for example: (1) monitoring elections in Tunisia, Guyana, Mozambique, Madagascar, and Nepal; (2) advancing citizen oversight of government by enabling access-to-information laws in Latin America, Asia, and Africa; (3) facilitating an initiative to improve the treatment of women and girls worldwide,

President Jimmy Carter on Environmental Protection and the Economy

I believe environmental protection is consistent with a sound economy. Previous pollution control laws have generated many more jobs than they have cost. And other environmental measures whose time has come—measures like energy conservation, reclamation of strip-mined lands, and rehabilitation of our cities—will produce still more new jobs, often where they are needed most. In any event, if we ignore the care of our environment, the day will eventually come when our economy suffers for that neglect.

—Jimmy Carter, "The Environment Message to the Congress," May 23, 1977. Online by Gerhard Peters and John T. Woolley, *The American Presidency Project*.

and (4) working with the United Nations to implement electronic voting observation methodologies and standards.

The center's health programs are primarily focused on eradicating six preventable diseases: Guinea worm, river blindness, trachoma, schistosomiasis, lymphatic filariasis, and malaria. The center's methods are low-cost, such as health education and access to health care, and often in partnership with other international organizations. The center also runs numerous initiatives to raise awareness about mental illness, which is a key passion for Rosalynn Carter. Through these initiatives, the center aims to ensure that mental health care is addressed by major healthcare systems and providers and to reduce discrimination against those with mental illnesses. One of the center's more significant accomplishments was to work with a coalition of organizations to reduce the presence of Guinea worm disease from 3.5 million cases in 1986 to just 22 cases in 2015. The Carter Center's work has impacted the lives of people in more than 80 countries.

Hana Elliott

See Also: Communicable Diseases; Drinking Water Quality and Regulation; Infectious Diseases; Insect-Borne Diseases; Schistosomiasis; Water Pollution; Waterborne Diseases

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CELL PHONE RADIATION

Cell phones are portable telephones that connect through wireless cellular networks made up of towers distributed throughout the United States (and most other countries) in a grid-like pattern. Also known as mobile, wireless, and cellular phones, cell phones work by transmitting radiofrequency waves that are received by the cellular network towers. Because cell phones are generally held in close proximity to the head, questions have arisen about whether the radiofrequency waves might increase the risk of tumors in the head and neck areas or cause other adverse health effects.

About 90 percent of Americans own a cell phone, and almost two-thirds of Americans have a type of cell phone known as a smartphone, which allows connection with the Internet. In addition to making phone calls, smartphones can be used to conduct a variety of activities, including sending e-mail and text messages, getting GPS-assisted driving directions, listening to music, and even conducting online banking. Among the world's population of about 7.3 billion, there are an estimated 6.9 billion cell phone subscriptions.

Lowering Radiofrequency Exposure

How can I lower my exposure to radiofrequency waves from cell phones?

- Use the built-in speaker or hands-free devices, which keep the phone farther from your head.
- Try text messaging (texting) instead of talking, but NEVER while driving!
- Make fewer calls and have shorter conversations.
- Use the phone in areas of good reception, which allow the phone to transmit at reduced power.
- Buy a cell phone with a lower specific absorption rate (SAR).

The radiofrequency waves emitted by cell phones are a type of nonionizing electromagnetic radiation, similar to radio waves, microwaves, visible light, and heat. These waves are different from ionizing radiation, such as x-rays, gamma rays, and ultraviolet light, which are more powerful and can cause cancer by damaging the DNA inside human cells. Although high levels of radiofrequency waves can heat up body tissues, the low level of radiation given off by cell phones is not nearly high enough to raise body temperatures.

The amount of radiofrequency energy absorbed by the body is known as the specific absorption rate (SAR). The highest allowed SAR in the United States is 1.6 watts per kilogram of body weight, as averaged over one gram of tissue. SAR values differ among phones, and the amount of energy someone is actually exposed to depends on several factors, including how long the person talks on the phone, whether the speaker mode or a hands-free device is used, the distance to the nearest cell phone tower (cell phones transmit less powerful signals when towers are closer), and the amount of cell phone use by other people in the area (with many users, more powerful signals are required to establish a good connection with the tower).

Why is there concern about exposure to radiofrequency waves from cell phones? Many scientists believe that because cell phone radiation does not damage DNA and does not raise body temperature, cell phone use cannot cause cancer, and most studies support this theory. However, other scientists contend that the radiofrequency waves from cell phones may affect human cells in other ways, for example, promoting tumor growth by carcinogens present in the cells. (A carcinogen is a substance capable of causing cancer.) Because cell phones are typically held very close to or against the head, much of the research has focused on whether cell phone radiation causes or contributes to tumor growth. Some studies have also investigated whether there is a relationship between short-term radiofrequency exposure and brain electrical activity, cognitive function, sleep, heart rate, and blood pressure.

Almost all of the studies performed so far have not found a link between cell phone use and tumors or other health issues. However, these studies have all had limitations. For example, the studies have not followed people for a long period of time. This is important because most cancers have a long latency period before they begin to grow. Thus, it is possible that the studies have not followed people long enough for the cancers to begin to appear. Another limitation is that most studies have focused on adults rather than children. Because children's bodies are smaller and still growing, it is possible that children might be more susceptible to cell phone radiation. Also, children will be exposed to the radiofrequency waves over a longer period than adults because they began using cell phones at an earlier age. Another concern is that many studies have relied on people's memories about previous cell phone use, and these memories are not always accurate.

Because of these and other limitations, questions remain about the safety of cell phone use, and the following guidance from the World Health Organization (WHO) is worth noting: "While an increased risk of brain tumors is not established, the increasing use of mobile phones and the lack of data for mobile phone use over time periods longer than 15 years warrant further research of mobile phone use and brain cancer risk. In particular, with the recent popularity of mobile phone use among younger people, and therefore a potentially longer lifetime of exposure, WHO has promoted further research on this group. Several studies investigating potential health effects in children and adolescents are underway."

The International Agency for Research on Cancer (the specialized cancer agency of the World Health Organization) classifies radiofrequency electromagnetic fields, such as those emitted by wireless communication devices, as "possibly carcinogenic to humans," placing it in Group 2B. Group 2B is used "for agents for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals. It may also be used when there is inadequate evidence of carcinogenicity in humans but there is sufficient evidence of carcinogenicity in experimental animals."

Richard Crume

See Also: Cancer Risk from Environmental Exposure; Radiation, Ionizing and Nonionizing; Ultraviolet Radiation and the UV Index; World Health Organization

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CENTERS FOR DISEASE CONTROL AND PREVENTION

The Centers for Disease Control and Prevention, commonly referred to as the CDC, is the leading public health agency in the United States. Headquartered in Atlanta, Georgia, the CDC has over 14,000 employees in Atlanta and 10 other offices nationwide. The CDC has broad responsibilities in the public health field, including detecting and controlling disease outbreaks, delivering lifesaving medicines from the strategic national stockpile, developing vaccines, providing information and expertise, promoting healthy and safe behaviors, and responding to emergencies. Today, about two-thirds of the CDC's federal funding is used to support state and local health departments throughout the United States.

Who Was Anne Miller?

Penicillin, an antibiotic used to treat a range of bacterial infections, has saved million lives worldwide and is considered by many a miracle drug. The first American saved by penicillin was a 33-year-old woman named Anne Miller, who was hospitalized in New Haven, Connecticut, in 1942 with a deadly streptococcal infection after miscarrying and developing an infection leading to blood poisoning. Anne Miller ran a life-threatening temperature of nearly 107°F (41.7°C), and the standard treatments of the day (sulfa drugs, blood transfusions, and surgery) were ineffective in controlling the infection and bringing down her temperature. As a last resort, she was treated with penicillin, an experimental drug at the time. Overnight, Anne Miller experienced a sharp drop in temperature and was no longer delirious the following day. She survived and went on to live a full life, dying in 1999 at 90 years of age.

The CDC was formed in 1946 (then called the Communicable Disease Center) to halt the spread of malaria by killing mosquitoes with the pesticide DDT. Later, the agency's mission was expanded to include all communicable diseases and to provide assistance to state and local health agencies. Over the years, the CDC has successfully addressed a variety of health emergencies. These include the Ebola virus, influenza, Legionnaires' disease, measles, polio, and toxic shock syndrome. Additionally, the CDC played a key role in the global effort to eradicate smallpox.

Dramatic Decline in Infectious Diseases

Thanks to the dedicated work of a nationwide network of health professionals, including those at the CDC, deaths from infectious diseases have dramatically declined in the United States. Much of the decline in the 20th century contributed to a striking reduction in infant and child mortality and increase in life expectancy. For example, in 1900, over 30 percent of deaths were among children less than 5 years old, whereas by the turn of the century, this figure had dropped to around 1 percent. Over this period, life expectancy increased by almost 30 years, and the leading causes of death—pneumonia, tuberculosis, and diarrhea and enteritis—were replaced by heart disease and cancer. The dramatic reduction in infectious diseases is attributed to improved sanitation and hygiene, the discovery of antibiotics, and universal childhood vaccinations.

The CDC is a complex organization with numerous roles aimed at protecting public health. To help the public better understand these roles, the agency has defined the following six key responsibilities:

1. Detecting and responding to new and emerging health threats
2. Tackling the biggest health problems causing death and disability for Americans
3. Putting science and advanced technology into action to prevent disease
4. Promoting healthy and safe behaviors, communities, and environment
5. Developing leaders and training the public health workforce, including disease detectives
6. Taking the health pulse of our nation

In planning for the challenges of the 21st century, the CDC has committed to several guiding principles. One is to be on the cutting edge of health security, which involves applying advanced computing and laboratory analyses to quickly find solutions to health threats. Other principles include putting science into action by tracking diseases and finding ways to prevent them, helping to improve medical care by bringing new knowledge to individual and community health care, fighting diseases before they reach our boarders, and nurturing public health by contributing to strong, well-resourced public health leaders and capabilities. In carrying out its mission and responsibilities, the CDC has made this pledge to the American people:

- Be a diligent steward of the funds entrusted to our agency.
- Provide an environment for intellectual and personal growth and integrity.
- Base all public health decisions on the highest quality scientific data that are derived openly and objectively.
- Place the benefits to society above the benefits to our institution.
- Treat all persons with dignity, honesty, and respect.

Several national health centers fall under the CDC. These are the National Center for Chronic Disease Prevention and Health Promotion; the National Center for

Emerging and Zoonotic Infectious Diseases; the National Center for Environmental Health; the National Center for Health Statistics; the National Center for HIV/AIDS, Viral Hepatitis, STD, and TB Prevention; the National Center for Immunization and Respiratory Diseases; the National Center for Injury Prevention and Control; and the National Center on Birth Defects and Developmental Disabilities. Additionally, the CDC is home to the Agency for Toxic Substances and Disease Registry and the National Institute for Occupational Safety and Health. A related institute under the National Institutes of Health is the National Institute of Environmental Health Sciences.

Richard Crume

See Also: Communicable Diseases; DDT Exposure; Healthcare-Associated Infections; Infectious Diseases; Insect-Borne Diseases; National Center for Environmental Assessment; National Institute for Occupational Safety and Health; National Institute of Environmental Health Sciences; Toxic Substances and Disease Registry, Agency for; Zoonotic Diseases

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CHADWICK, ALAN

Alan Chadwick (1909–1980) was an English master gardener who pioneered sustainable organic gardening in North America. In the late 1960s, Chadwick established and taught at the Student Garden Project at the University of California in Santa Cruz (UCSC). The Alan Chadwick Garden is now operated by UCSC's Center for Agroecology and Sustainable Food Systems, a research, education, and public service program emphasizing environmentally sound, sustainable, and socially responsible food and agricultural systems. Chadwick's contributions to agroecology (an ecological approach to designing and building sustainable food systems) include (1) popularizing raised beds and mixed gardens of vegetables, herbs, flowers, and fruits; (2) emphasizing hand labor and hand tools; (3) developing an apprenticeship program at UCSC; and (4) bringing attention to sustainable agriculture, which his apprentices have since carried on worldwide. He even influenced California cuisine, a movement that emphasizes using local, fresh ingredients.

Chadwick was born on July 27, 1909, in St. Leonard's-on-Sea in southern England. Raised as a vegetarian and pacifist, he excelled in a remarkable range of pursuits. Chadwick was a Shakespearean actor, an opera singer, an athlete, a painter, and a violinist. When World War II broke out, he was first a conscientious objector and later a naval officer. After the war ended, his passions led him to South Africa's National Theater Organization and then on to a position as head gardener at the Admiralty Gardens in Simon's Town, South Africa. Several gardening positions in other countries followed that eventually led him to UCSC.

Chadwick had become interested in gardening as a child by observing the gardeners who worked in the formal gardens on his aristocrat family's country estate and by visiting gardens across Britain and the European continent. As a teen, he worked on a German farm based on Rudolf Steiner's biodynamic agriculture (an early holistic organic agricultural movement), studied fruit-tree pruning in France, and apprenticed at productive English market gardens. Chadwick synthesized what he learned into the biodynamic French intensive gardening system of horticulture.

A charismatic teacher whose passion and love for his topic were contagious, Chadwick brought a talent for storytelling and theatrical flair with him to UCSC, where he delivered soliloquies while working in the gardens. Students joined him for meals, where he taught them about good food and fresh vegetables.

In the early 1970s, Chadwick left UCSC amid controversy and started a series of projects: a garden at Green Gulch (the San Francisco Zen Center), the Saratoga Community Garden Project, and a garden school in Covelo, California. His search for new projects, even amid his failing health and a diagnosis of prostate cancer, then led Chadwick to establish a short-lived garden for a religious community that had purchased property in New Market, a town located in Virginia's Shenandoah Valley.

Chadwick's cancer had progressed by that time. He was in pain and needed nursing care. After considering various options, Chadwick returned to Green Gulch, where he continued giving weekly garden study lectures from his bed. He died on May 25, 1980, having prepared his room with fresh flowers and with depictions of a Raphael's *Pietà* and Shakespeare's sonnet "When I consider everything that grows . . ." on his bedside wall. Numerous friends gathered for a final visit with Chadwick before his death, and hundreds came to a service held at Green Gulch following his death to remember his life and legacy of giving nature more than is taken.

Kathy Stolley

See Also: Community Gardening; Food Supply, Environmental Threats to; Organic Agriculture

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CHEMICAL WEAPONS ELIMINATION

During World War II and the Cold War, the U.S. military created over 30,000 tons (27,220 metric tons) of chemical weapons. These chemical weapons include mustard agents and nerve agents. The United States has never used chemical weapons on enemy soldiers during combat. However, even if never used in war, these weapons could represent a threat to environmental health if they were accidently released during storage or destruction.

Mustard agent is a blister agent, which is an oily substance that acts when inhaled or when it comes in contact with skin. Blister agents affect the eyes, respiratory tract, and skin, first as an irritant and then as a cell poison. As the name suggests, blister agents cause large and often life-threatening skin blisters, which resemble severe burns. Mustard agent has a delayed effect, and while death from mustard agent is rare, exposure often results in blindness and permanent damage to the respiratory system.

Nerve agents have been the dominant chemical weapon since World War II. Chemically, they are organophosphorus compounds, and they affect the transmission of nerve impulses. (Many pesticides are also organophosphorus compounds.) Nerve agents are chemically stable, easily dispersed, and highly toxic, and they have a rapid effect when inhaled or absorbed through the skin. The U.S. stockpile of nerve agents consists primarily of sarin (also known as GB) and VX, which is approximately 10 times more toxic than sarin. VX is one of the most toxic substances ever created.

The effects of nerve agents depend on the route of exposure. Effects associated with inhalation generally happen sooner than with other routes of exposure because the lungs contain numerous blood vessels that cause the nerve agent to reach the target organ quickly. The respiratory system is among the most critical organs for nerve agent exposure. Inhalation exposure to high concentrations of nerve agent can result in death in a few minutes, whereas exposure through the skin can take 20 to 30 minutes before a person starts feeling the effects. The toxic effects of nerve agents result from the nerve agent binding to the enzyme acetylcholinesterase. This binding inhibits the enzyme's normal biological activity in the nervous system.

LD_{50} is a measure of the dose at which half—that is, "50" percent—of the exposed population will die. Sarin's LD_{50} for exposure on the skin is 1,700 mg per individual, whereas VX's is only 10 mg per individual. Inhalation exposure is measured as LCt_{50}, which considers the amount of exposure as well as the time of exposure, measured in mg-minutes per cubic meter (mg·min/m^3). Sarin's LCt_{50} is 35 mg·min/m^3, while VX's is just 15 mg·min/m^3.

Symptoms of exposure to low doses of nerve agent include increased saliva, runny nose, headaches, and a feeling of pressure on the chest. The pupil of the eye contracts, which impairs night vision, and short-range vision also decreases, causing the victim to feel pain when focusing on a nearby object. Higher doses cause difficulty in breathing and coughing. Additionally, discomfort in the gastrointestinal tract can turn into cramping and vomiting, and involuntary discharge of urine and defecation may also occur. With moderate exposures, muscular weakness, local tremors, and convulsions may be present. For higher doses, people can lose consciousness and suffer muscular paralysis. Death can occur via paralysis of the respiratory muscles and effects on the respiratory center of the central nervous system. Thus, death from nerve agent is a kind of death by suffocation.

Chemical weapons are stored at eight sites in the continental United States and one site on an island in the Pacific. In 1985, Congress directed the army to destroy the nation's stockpile of chemical weapons. In 1993, the United States and numerous other countries drafted the Chemical Weapons Convention, which prohibits the development, production, stockpiling, and use of chemical weapons. The United States ratified the Chemical Weapons Convention in 1997, and currently 175 counties are party to the convention. The Organization for the Prohibition of Chemical Weapons, which administers the convention, won the Nobel Peace Prize in 2013.

In 1988, the U.S. Army decided to burn its chemical weapons stockpile in incinerators built at each of the nine chemical weapons storage sites. The first incinerator was built at the Johnston Atoll chemical weapons storage facility in the Pacific. It began operation in 1990 and completed burning the chemical weapons stored at the site in 1993. The National Research Council found that the incinerator at Johnston Atoll suffered from operational problems. Specifically, nerve agent leaked into nonagent areas of the facility and escaped into the environment.

In 1996, when the army began burning chemical weapons at its incinerator in Tooele, Utah, nerve agent escaped into nonairtight vestibules and an observation corridor. Workers were in the vestibules when the nerve agent was present, but the army did not discover the nerve agent until the day after the leak. The workers had removed their projective suits when nerve agent was present, exposing them to the hazard. A former general manager of the Tooele incinerator compared its management to that of Three Mile Island before the nuclear accident and to the space shuttle Challenger disaster. An emergency medical technician employed at the Tooele Health Clinic testified in court that the electrocardiograms he administered to incinerator workers indicated symptoms of nerve agent exposure. He also testified that his medical supervisors, army personnel, and Utah state regulators ignored his concerns about these signs of nerve agent exposure.

In addition to unburned chemical weapons, smoke stack emissions from the chemical weapon incinerators include 2,3,7,8-tetrachlorodibenzo-p-dioxin (often simply referred to as dioxin). Dioxin, a persistent organic pollutant, causes cancer, reproductive and developmental problems, and damage to the immune system, and it can interfere with hormones. Dioxin accumulates in the fatty tissues and mother's milk, and those especially at risk from these emissions include breast-feeding infants and subsistent farmers.

The army proceeded with its plans to burn the chemical weapons in incinerators located at the storage facilities in Anniston, Alabama; Pine Bluff, Arkansas; Tooele, Utah; and Umatilla, Oregon. However, at four other storage facilities (Richmond, Kentucky; Pueblo, Colorado; Newport, Indiana; and Edgewood, Maryland), the army switched to nonincineration neutralization technology after intense and sustained citizen action led by the Chemical Weapons Working Group. The neutralization technology is closed loop, meaning it does not have a smokestack. Therefore, the output of the process can be tested for chemical weapons and other toxic substances before it is released into the environment.

Robert Ukeiley

See Also: Cancer Risk from Environmental Exposure; Dioxin Pollution; Industrial Hygiene; Persistent, Bioaccumulating, and Toxic Chemicals; Respiratory Disease and Air Pollution; Three Mile Island Incident; Waste Incineration

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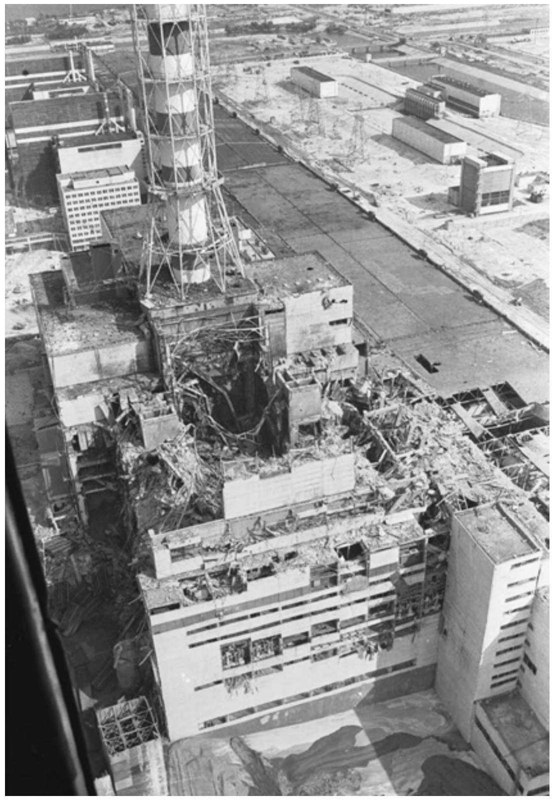
CHERNOBYL INCIDENT

A reactor explosion on April 26, 1986, at a nuclear power plant in Chernobyl, part of then-Soviet Ukraine, led to a 10-day leakage of radioactive uranium dioxide that spread across northeastern Europe. Over 25 deaths were immediately reported, but an estimated 4,000 people later died from the radiation exposure.

The evacuation of surrounding towns began within 36 hours of the explosion. Many residents of Pripyat, a nearby town of 50,000, were told they would only be gone for three days, but ultimately, they were not allowed to return because of high radiation levels. (Looters later raided their homes and apartments.) At the time of the 30th anniversary of the incident in 2016, many Pripyat residents were temporarily allowed to visit their homes, now overgrown with vegetation and devoid of personal artifacts.

A 19-mile (30-kilometer) exclusion zone around the plant still exists today due to potentially dangerous levels of remaining radiation. Following the explosion, more than 100,000 locals were evacuated from the area, in addition to more than 200,000 people who resettled in the following years. Though the contamination spread across the northeastern part of the continent, the nations of Belarus, Russia, and Ukraine suffered the brunt of the radiation poisoning. In these areas, thyroid cancer became prevalent, especially in children, partially due to contamination of milk with radioactive iodine. Many accounts attribute the Chernobyl incident to the beginnings of worldwide skepticism toward nuclear energy alternatives.



An aerial view of the damaged Chernobyl, Ukraine, nuclear power plant following the 1986 explosion and fire. The incident, which released large amounts of radiation into the atmosphere, is considered the world's worst nuclear plant accident. (AP Photo)

A few months after the incident, the International Nuclear Safety Advisory Group (INSAG), created by the International Atomic Energy Agency (IAEA), published an investigation into the accident that held the power plant operators culpable. In 1991, however, a Commission of the USSR State Committee for the Supervision of Safety in Industry and Nuclear Power diverted responsibility from the operators to the reactor design. This led to a new INSAG report that found the operators did not violate proper procedure, though their decision to run the reactor at low power was not vetted by safety experts or personnel with more authority. Running the reactor at lower power caused the cooling system to malfunction, which led to a power surge, causing the explosion.

A giant steel enclosure is being constructed to fit over the plant and minimize any further radiation leakage. (Completion is scheduled for 2017.) Over 2,000 workers were employed for the construction of this arch-like structure roughly 350-feet (107 meters) high and 500-feet (152 meters) long and weighing 36,000 tons (32,700 metric tons). In the spring of 2016, the Ukrainian government designated the 19-mile exclusion zone a nature reserve, which is home to wild boars, elks, lynx, wolves, bears, bison, and deer as well as aquatic life in nearby lakes.

Mallory L. Daily

See Also: Fukushima Daiichi Incident; Nuclear Regulatory Commission; Nuclear Safety; Radiation, Ionizing and Nonionizing; Radiation Sickness; Three Mile Island Incident

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CHILDREN'S ENVIRONMENTAL HEALTH

Environmental health is an important issue as it relates to every member of society. However, children's environmental health is especially important because children are members of our society who have little control over their social and physical environments or the potentially detrimental behavior of those around them. Furthermore, for a variety of reasons, children are particularly susceptible to poor health outcomes when they are exposed to environmental toxins. These poor health outcomes do not just affect the children and their respective families, but they also impact the global economy.

One aspect of children's environmental health is that children are significantly more vulnerable to environmental toxins than the general population. Specifically, children have greater exposure to health effects and safety risks because of their

Managing Childhood Asthma

Americans spend about 90 percent of their time indoors. Asthma in children can be triggered by various indoor environmental factors, including molds, dust mites, cockroaches and other pests, pet dander and saliva, and secondhand smoke. Because triggers differ from one person to the next, it is important to consult your family doctor to develop a plan specific to your child. About 7 million American children suffer from asthma.

physical proximity to the hazards. For example, children tend to put their hands and objects in their mouths. Also, because infants and young children crawl and play close to the ground, they are at a greater risk for contacting potentially contaminated dirt and dust. Furthermore, children's natural defenses (e.g., their immune systems) are not yet fully developed, and thus, they do not have the same ability as adults to naturally fight off toxins.

Experts say the timing of exposure to certain toxins plays a major role in the effect of that exposure. While in utero and during early childhood, children are especially vulnerable to catastrophic and long-term health consequences due to their underdeveloped digestive, neurological, immunological, and other body systems. Because humans have different susceptibility to toxins based on their point in the life cycle, the same dose of a toxin could have gravely different effects depending on the point of exposure. As children get older, their greater propensity for risk taking may put them in contact with additional toxins, as with tobacco smoking or substance abuse, which their young bodies and minds are less able to deal with than adults. Lastly, because children breathe, eat, and drink three times more relative to their body mass than adults do, they have more opportunity to take in harmful toxins.

As vulnerable members of the population, children suffer a broad range of common environmentally related ailments at rates significantly higher than the adult population. More than 4.7 million children under age five die each year from environmentally related diseases. Children are exposed to environmental hazards in a variety of ways, including exposure to (1) outdoor air pollution; (2) various toxic heavy metals and chemicals through contract with contaminated substances; and (3) contamination that their parents may bring home on their shoes or clothing from the workplace. Common environmentally related conditions that impact children in vast numbers are asthma (and other chronic respiratory diseases), diarrheal conditions, childhood cancer, and exposure to lead. As many as 10 percent of children in the United States are thought to have asthma, which may result from approximately 66 percent of children living in areas with poor air quality. Although far less prevalent in the United States than in the developing world, diarrheal diseases commonly occur among American children. These conditions often result from contaminated drinking water and insufficient sanitation. In addition, while the causes of many childhood cancers are not fully clear, several studies indicate that certain environmental toxins, including radiation, secondhand smoke, pesticides, and chemical solvents, may have a role in the development of certain childhood cancers.

One notable example of a common toxin to which many children have been exposed is lead. Although lead in paint was identified as a hazard for children as far back as 1904, lead exposure among children continues at an alarming rate. While there has been a steep decline in lead exposure since the 1980s, as many as 4 million households have children who are exposed to high levels of lead. This lead exposure is generally the result of children ingesting contaminated dust, soil, and paint. Children are also exposed to lead from ceramics, drinking water pipes and plumbing fixtures, batteries, imported toys, and other consumer products. The health consequences of this exposure include decreased intelligence, learning disabilities, impaired hearing, reduced attention span, and hyperactivity.

While children suffer significantly higher incidences of environmental health effects than the general population, there are certain groups of children that are far more likely to suffer negative health effects from environmental exposure. In the United States, children of color and from lower income families are significantly more likely to have detrimental environmental exposure with worse health outcomes than white children or children from more affluent families. For example, asthma disproportionately impacts African American children, who tend to have far worse outcomes than other ethnic groups. In recent years, studies have shown that as many as 13 percent of African American children have asthma, as compared with 9 percent of Hispanic children and 8 percent of Caucasian children. Furthermore, African American children die from asthma-related complications at a 500 percent higher rate than Caucasian children.

Outside of the United States, we find that children in developing and nonindustrialized countries have significantly worse environmental exposures and health outcomes than in the United States or other developed countries. Experts report that on a per capita basis, children in developing countries lose up to eight times the number of healthy life years compared with children in developed countries due to environmentally caused diseases. Some adverse environmental conditions that may be more prevalent in developing countries include unsafe drinking water, lack of sanitation, and indoor air pollution from the use of solid fuel. Additionally, for children in developing countries, the often-unfavorable social and economic conditions (including conflict, poverty, and malnutrition) exacerbate the environmental health effects. Mounting evidence suggests that the effects of climate change can increase the environmental health disparities between children in industrial and developing countries. In particular, malaria, diarrhea, and malnutrition (common killers of children in developing countries) are thought to be very sensitive to climatic conditions.

In recognition of the vulnerability of children to the proven consequences of environmental exposure, there have been various legislative efforts and policy reform initiatives to try to address the problem since the late 20th century. Legislative efforts have included the implementation of laws established to reduce children's exposure to toxins in consumer products. In addition, the U.S. Environmental Protection Agency has worked to address environmental risks to children by forming its Office of Children's Health Protection and instituting policies that require the agency to explicitly and consistently take into account environmental health risks to children in conducting risk characterizations (often part of rulemaking proceedings) and developing public health standards. In addition, there has been an effort among concerned organizations and governmental agencies to ensure that healthcare providers have the necessary education to properly address children's environmental health issues. This is especially important because healthcare providers are uniquely positioned to best detect, treat, and even prevent environmentally related health conditions.

Maryam Hatcher

See Also: Air Pollution; Asthma; Cancer Risk from Environmental Exposure; Climate Change and Human Health; Cookstoves, Health Impacts of; Environmental Protection Agency; Indoor Environment; Lead Poisoning Prevention; Radiation, Ionizing and Nonionizing; Respiratory Disease and Air Pollution; Tobacco Smoke, Secondhand and Thirdhand; Waterborne Diseases

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CHLOROFLUOROCARBONS

Chlorofluorocarbons (CFCs) are a group of chemical compounds that have been used in a number of products, including as refrigerants and coolants, aerosol and fire extinguisher propellants, metal degreasers, and cleaning solvents. CFCs, which contain atoms of carbon, chlorine, and fluorine, are noncombustible but very volatile, meaning that they are easily released into the atmosphere through evaporation during their production and use. They can survive for 20 to 100 years in the atmosphere. CFCs bind poorly to soil and are mostly insoluble in water. Thus, they tend to leach easily into groundwater, where they degrade slowly and remain for long periods as contaminants.

Chlorine atoms released from CFCs are involved in chemical reactions that damage the upper atmosphere's protective ozone layer by turning ozone molecules into oxygen molecules. The ozone layer is important as a shield to protect life on the earth's surface from excessive exposure to the sun's ultraviolet rays. Weakening of the ozone layer can allow these rays to cause cancer, cataracts, and other health problems in humans and animals. In plants, strong ultraviolet radiation can alter growth, form, and nutrient distribution.

As CFCs break down the ozone layer, increasing amounts of ultraviolet radiation reach the planet's surface, raising the risk for these biological problems. That is the main reason that most new uses of CFCs have been banned by the U.S. government as well as by other governments around the world. However, many old products containing these chemical compounds, such as refrigerators and air conditioners, continue to be used, releasing more CFCs into the environment, where they continue causing damage. Nevertheless, the U.S. Environmental Protection Agency (EPA) has noted improvements in the upper atmosphere's ozone layer since the CFC bans began in the late 1980s, and the agency estimates that the layer should be fully recovered by 2065.

In addition to the health risks posed by the CFC-caused weakening of the ozone layer, CFCs in groundwater, in the air, and at other environmental locations can cause health problems through direct exposure. Such exposure may occur by inhalation, ingestion, or absorption through the skin. Once inside the body, CFCs tend to become stored in fatty tissue. Low concentrations of these absorbed compounds may be cleared from the body within 24 hours. However, high concentrations of inhaled CFCs affect the central nervous system, causing lack of coordination, light-headedness, and headaches. Tremors and convulsions may also occur. Extremely high concentrations of inhaled CFCs, which some people take intentionally to achieve a "high," may disrupt the heart's rhythm to the point of causing death.

The higher the concentration and longer the exposure, the more severe are the symptoms and the greater the risk of CFC exposure. Some animal studies suggest that liver damage may be caused by chronic exposure to CFCs, although other animal studies have not found such an association. Research also suggests that cancer is not a high risk of CFC exposure, nor are reproductive and developmental abnormalities.

CFCs were first synthesized in the late 1920s as refrigerant chemicals that were safer than the toxic ammonia, methyl chloride, and sulfur dioxide that were used for such purposes in the early 1900s. American chemist Thomas Midgley Jr. (1889–1944) of the General Motors Company developed the first CFC in 1928. Freon, the best-known CFC coolant, was first produced in large quantities in 1930 by a company formed jointly by General Motors and DuPont. After World War II, CFCs came to be widely used as propellants in aerosol insect sprays, paints, hair conditioners, and other consumer products. The commercial use of CFCs peaked during the 1960s.

In 1974, chemists F. Sherwood Rowland (1927–2012) and Mario Molina (1943–) of the University of California proposed that the chlorine in CFCs could break down ozone in the upper atmosphere during catalytic reactions, and the CFC-caused loss of ozone over Antarctica was confirmed and quantified in the early 1980s by British geophysicist Joe Farman (1930–2013). In 1987, representatives of 27 nations signed the Montreal Protocol, mandating restrictions on the production and use of CFCs. A 1990 amendment to this agreement called for the end of CFC production by 2000. Almost all nations eventually signed the Montreal Protocol. CFCs have been largely replaced in consumer products by safer chemical compounds, such as hydrochlorofluorocarbons and hydrofluorocarbons, although these replacements have been linked to their own environmental problems.

Standards for safe levels of CFC exposure are set in the United States by the EPA and the Occupational Safety and Health Administration (OSHA). The EPA has established standards for CFC levels in drinking water, while OSHA has established standards for CFC levels in workplace air. The EPA is also concerned with monitoring and reducing CFC levels in the upper atmosphere's ozone layer and in groundwater.

A. J. Smuskiewicz

See Also: Air Pollution; Environmental Protection Agency; International Environmental Law and Policy; Occupational Safety and Health Administration; Stratospheric Ozone Depletion; Ultraviolet Radiation and the UV Index

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CHOLERA

Cholera is an infectious disease recognized by the World Health Organization (WHO) as a deadly preventable disease that plagues Third World countries. An estimated 3 to 5 million cases of cholera occur every year, with over 100,000 deaths per year worldwide. The infection is often mild or without symptoms, but it can be quite severe. Symptoms can develop anywhere from five hours to five days after infection, with the majority of the symptoms occurring within two to three days. Approximately 1 in 10 infected persons will experience a severe form of the disease, which is characterized by profuse watery diarrhea, vomiting, and leg cramps. In these people, the rapid loss of body fluids leads to dehydration and shock, and, without treatment, death can occur within hours.

Cholera is caused by *Vibrio cholera*, a comma-shaped gram-negative bacillus with a flagellum (tail) that helps it stay motile. This bacterium is usually found in water or food sources contaminated by fecal matter from an individual that was already infected by cholera. *Vibrio cholera* is typically transmitted via ingestion, leading to an infection of the intestinal system termed "gastroenteritis." It is most abundant in places where inadequate water treatment practices or inadequate hygiene is performed. *Vibrio cholera* may also live in brackish rivers and coastal water environments, and shellfish in certain regions of the world have been identified as sources of cholera if they are eaten raw or undercooked.

Cholera is rare in the United States and many other regions of the world with good water and sewage systems. However, this disease tends to be endemic in parts of the world that do not have such systems in place. It can also arise in areas prone to natural disasters like hurricanes, typhoons, or earthquakes. For example, a devastating cholera epidemic erupted in Haiti in 2010, when a large portion of their water supplies became contaminated with *Vibrio cholera* immediately following a major earthquake. The Centers for Disease Control and Prevention responds to outbreaks in any country by deploying outbreak responders who work within the center's global water sanitation and hygiene program. During cholera outbreaks, this team aids in treating the illness and provides education and training regarding prevention and sanitation practices.

Awareness and prevention are fundamental to prevent acquiring and transmitting the illness when traveling to cholera-infected areas (e.g., underdeveloped areas of Africa, Southeast Asia, and some Latin American countries). When traveling to areas of the world where there is known cholera, individuals should avoid eating undercooked food, especially fish and shellfish. They should also wash and peel their own fruits and vegetables and avoid ingesting water that may be infected by consuming carbonated bottled water or soft drinks. Prior to departing for the affected area, travelers can also seek medical care and guidance through a travel clinic or primary care office, where they may receive a vaccine or an antibiotic (such as doxycycline or ciprofloxacin) to take when they begin to develop symptoms.

Cholera vaccines come in injections and oral suspension (a liquid in which insoluble drug particles are dispersed). When receiving the vaccines, a person should complete the entire vaccine series prior to travel. The vaccines are successful at protecting against the disease only 25 to 50 percent of the time. Therefore, it is still important to avoid infected persons and potentially infected food and water supplies.

Howard W. MacLennan Jr.

See Also: Centers for Disease Control and Prevention; Communicable Diseases; Drinking Water Quality and Regulation; Infectious Diseases; Snow, John; World Health Organization

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CLEAN AIR ACT

The Clean Air Act (CAA) is a federal law aimed at protecting air quality in the United States. It establishes a comprehensive framework for the control of air pollutants from both stationary and mobile sources. Under this framework, the federal government has the primary authority to establish regulatory standards and state governments are primarily responsible for implementing those standards. Since its enactment in 1970, the act has improved the health of millions of Americans by reducing emissions of harmful air pollutants. These emission reductions have also resulted in significant environmental and economic benefits.

There are several different regulatory programs contained within the CAA, all of which overlap with and complement one another. The centerpiece of the act is the National Ambient Air Quality Standards (NAAQS) program. The act directs the U.S. Environmental Protection Agency (EPA) to establish NAAQS for certain air pollutants at a level that is sufficient to protect human health and welfare. Thus far, the EPA has established NAAQS for six principal pollutants (known as criteria pollutants): ozone, carbon monoxide, sulfur dioxide, particulate matter, lead, and nitrogen dioxide. Once the EPA establishes a NAAQS, state regulators are then responsible for developing and implementing plans to attain the standard within their jurisdiction. The EPA oversees this process by reviewing and approving state implementation plans and periodically issuing calls for plan revision.

Another key component of the CAA is the enforcement of emissions standards for stationary sources and mobile sources. The EPA establishes these standards for specific source categories, such as certain types of power plants and industrial facilities, as well as various classes of motor vehicles. Under current guidelines, the EPA typically enacts more stringent standards for new and majorly modified sources than for existing sources. The EPA has recently begun to use this authority to regulate greenhouse gas emissions, which are not currently subject to any NAAQS.

The CAA was amended in 1990 with several additional programs, including (1) more stringent emission limitations for hazardous air pollutants; (2) a cap-and-trade program to better control the pollutants that contribute to interstate air pollution transport (nitrogen oxides and sulfur dioxide); and (3) a program providing for the phaseout of ozone-depleting substances such as chlorofluorocarbons and halons. These amendments also granted the EPA sweeping authority to regulate any substance, process, or activity that affects the stratospheric ozone in a manner that endangers public health or welfare.

This combination of ambient air quality standards and source-specific emission limitations has been quite effective at reducing air pollution in the United States. The EPA reports that, from 1970 to 2016, aggregate national emissions of the six criteria pollutants alone dropped an average of 73 percent. These emission reductions have resulted in dramatic improvements to national ambient air quality. Since 1980, we have seen a 99 percent decrease in the average concentration of lead, an 85 percent decrease in carbon monoxide, an 87 percent decrease in sulfur dioxide, a 62 percent decrease in nitrogen dioxide, and a 31 percent decrease in ozone. In addition, rules enacted in 1990 to control hazardous air pollutants are expected to reduce toxic emissions from industrial sources by 1.7 million tons (1.5 million metric tons) a year. This resulted in significant decreases in the ambient concentrations of pollutants such as the carcinogen (cancer-causing chemical) benzene, which decreased 55 percent between 1994 and 2007.

Public health and economic benefits of the CAA have far outweighed its costs. According to a 1997 EPA report submitted to Congress, the value of emission reductions achieved from 1970 to 1990 was $22.2 trillion, whereas the economic costs to achieve those reductions was only $523 billion. In other words, the EPA estimates that the overall economic benefits exceeded the costs by a factor of 42. Health benefits from the CAA in that period were substantial as well. The EPA conducted a study of benefits from 1990 to 2020 and concluded that the CAA continues to produce substantial public health and economic benefits. It concluded that programs aimed at reducing fine particles and ozone will prevent up to 237,100 premature deaths, 135,000 hospitalizations, 75,000 cases of chronic bronchitis, 17 million lost work days, and 5.4 million lost school days in 2020. The projected economic value of these reductions is estimated to reach almost $2 trillion in 2020. Notably, these projections do not include the benefits of reducing emissions of greenhouse gases, hazardous air pollutants, precursors to acid rain, and ozone-depleting substances.

Implementation of the CAA has also led to dramatic technological improvements in electric utilities, industrial facilities, and motor vehicles. Today's new cars, light trucks, and heavy-duty diesel engines are up to 95 percent cleaner than past models. Stationary sources are also far cleaner due to the development and improvement of new technologies since 1970, such as catalysts and scrubbers.

While the CAA has been highly successful at improving our nation's air quality, more remains to be done. There are many parts of the country (particularly urban areas) where ambient air concentrations of certain criteria pollutants still exceed the NAAQS for those pollutants. There are also certain pollutants, such as carbon dioxide and other greenhouse gas emissions, that are only partially regulated at this time—meaning that there are no NAAQS and many major sources are not subject to emission standards for the pollutants. The EPA is currently in the process of enacting standards to cover a wider array of source categories for such pollutants.

Jessica Wentz

See Also: Air Pollution; AirNow and the Air Quality Index; Ambient Air Quality; Automobile and Truck Emissions and Controls; Children's Environmental Health; Chlorofluorocarbons; Electric Power Generation, Health Implications of; Environmental Protection Agency; Greenhouse Effect and Global Warming; Hazardous Air Pollutants; Lead Poisoning Prevention; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Respiratory Disease and Air Pollution; Stratospheric Ozone Depletion

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CLEAN COAL TECHNOLOGY

Clean coal technology refers to technological solutions that make the burning of coal for energy and other purposes less polluting to the environment and less hazardous to human health. Coal, the most abundant and widespread fossil fuel, is used to generate some 40 percent of the electricity in countries throughout the world. In addition, 70 percent of the world's steel is produced using coal to fuel the manufacturing process. These coal applications are projected to increase at least into the 2020s.

Traditional methods of burning coal generate large amounts of pollutants, including the greenhouse gas carbon dioxide, which scientists blame for climate change. An average of 15 billion tons (14 billion metric tons) of carbon dioxide are pumped into the atmosphere every year by coal-powered energy generation. The burning of coal also generates acid rain, smog, and other toxic chemicals and is a cause of respiratory illness. Clean coal technology is designed to advance the important uses of this plentiful energy resource while minimizing its adverse effects on human health and the environment.

More than $1 billion was spent in clean coal research throughout the world from 2009 to 2013, the period when the level of this research peaked. Technological and economic challenges have since slowed momentum and investment, although the research continues, and there are several clean coal technologies that remain under investigation and commercial development. Among the most scientifically advanced and commercially promising methods are certain forms of gasification. For example, coal can be reacted with oxygen and steam to yield a gaseous mixture of carbon monoxide and hydrogen, which undergoes further reactions and cleansing to ultimately produce a mixture of carbon dioxide and hydrogen. The hydrogen product can be burned to generate relatively clean energy, such as in a solid oxide fuel cell or a gas turbine, or it can be used as a chemical feedstock.

The carbon dioxide produced in gasification techniques could be captured and buried in deep geological formations, such as saline aquifers, using a process known as carbon capture and sequestration (CCS). The captured carbon dioxide gas could also be put to practical commercial use, such as in enhanced oil recovery processes, where the carbon dioxide gas reduces the oil's viscosity, allowing it to flow to recovery wells more easily.

In another advanced technology, known as the ultra-clean coal (UCC) process, ash, sulfur, and other harmful contaminants are mostly removed from bituminous coal. The resulting product can be used to generate power as a substitute for natural gas in gas turbines and for fuel oil in diesel engines.

The term "clean coal" typically is used today to refer to CCS, UCC, gasification, and similarly advanced technologies that have mostly come to the forefront during the 21st century. However, the term may generally and loosely be applied to older methods that have long been used in the energy industry to reduce the pollution generated by coal burning. Such less advanced methods include washing coal to reduce ash and sulfur dioxide emissions, using fabric filters and electrostatic precipitators to remove fly ash from flue gases, using low-nitrogen oxide burners and reburning techniques to reduce nitrogen oxide emissions, and applying several enhanced combustion efficiency technologies.

Another aspect of clean coal technology involves recycling of the waste products generated in the burning of coal. For example, the coal fly ash waste can be added to cement to make certain building materials.

Although clean coal technologies are scientifically viable and environmentally attractive, their economic viability and competitiveness are less certain. The economic uncertainties of clean coal have limited its industrial and political attractiveness and slowed its technological advance and practical deployment in the United States as well as in most other nations. Reducing the costs and improving the economic viability of CCS and other clean coal technologies is a high priority of research and development efforts, including those of the U.S. Department of Energy, which funds much of the energy research in the United States. Considerable clean coal research is also being performed in Europe, Australia, and China.

A. J. Smuskiewicz

See Also: Air Pollution; Ambient Air Quality; Coal Ash Disposal; Electric Power Generation, Health Implications of; Hazardous Air Pollutants; Respiratory Disease and Air Pollution

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CLEAN WATER ACT

The Federal Water Pollution Control Act, otherwise known as the Clean Water Act (CWA), was originally enacted in 1948. However, it was substantially amended in 1972 to include the components that are largely credited today with cleaning up the nation's waters and protecting human health and the environment.

Discharging Pollution to U.S. Waters

The CWA prohibits discharging pollution to waters of the United States without a permit. The federal government writes the permits with the health of the water body, and what the water is used for, in mind. One important goal of the act is for all waters to be safe for humans to swim in and consume fish from. While more work needs to be done, implementation of the act has resulted in a significant improvement in the health of the nation's waters and protection of human health.

From 1948 to 1972, the federal government provided states with grants to establish sewage treatment plants and develop pollution prevention programs. However, the 1948 federal law (1) established no nationwide federal standards; (2) included no pollution discharge permitting program; (3) called for no reporting of discharge quality; and (4) enabled federal enforcement only where a harm to waters could be demonstrated and its cause could be traced back to a particular discharger (i.e., an individual or entity that discharges pollutants into surface waters, such as lakes, streams, or rivers). The 1948 CWA proved inadequate to protect the nation's surface waters. As a result, water pollution was not abated but instead became a major threat to public health and aquatic life. Bacteria levels in many rivers made swimming dangerous; large fish kills were reported across the nation, and the consumption of certain fish was dangerous. One of the most famous examples of the state of the nation's waters occurred in 1969, when the Cuyahoga River in Ohio was so polluted that it caught on fire.

The stated purpose of the CWA is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Three more specific and complementary goals of the act are to (1) entirely stop discharging pollutants into waters within the jurisdiction of the United States; (2) make all the nation's waters attain a quality that would support aquatic life and human recreation, including swimming (this is known as the "fishable/swimmable" standard); and (3) prohibit any discharge of pollutants in toxic amounts. These goals are generally designed to guide all decisions made under the CWA.

The 1972 CWA amendments are complex, but there are three primary programs designed to meet its stated goals: (1) nationally uniform standards that limit the amount and types of effluents (chemicals and other constituents) that can be discharged into the nations surface waters; (2) water quality standards that protect individual surface waters by establishing the maximum pollutant concentrations that those waters can carry and still be healthy; and (3) a permitting program that applies these standards to individual dischargers and provides the basis for enforcement if the standards are not met. Perhaps most fundamentally, the 1972 amendments make it illegal to discharge any "pollutant" into "waters of the United States," unless the discharge is done according to one of these permits. Discharging pollution without a permit (or in violation of the terms of a permit) can result in civil fines and even criminal prosecution in appropriate circumstances.

The permit program, known as the National Pollutant Discharge Elimination System (NPDES), authorizes the discharge of defined quantities of pollutants into surface water but only according to the specific requirements of the NPDES permit. These requirements include effluent limitations (i.e., limits on the amount, type, or rate of pollution that a facility can discharge into waters) that impose nationally uniform technology-based standards and stream-specific water quality standards.

Technology-based effluent limitations generally reflect the effluent quality achievable (i.e., the pollution reduction achievable) by use of so-called best available or best conventional technologies, depending on the type of pollutant. Technology-based effluent limitations can be based on nationwide rulemakings in which the U.S. Environmental Protection Agency (EPA) establishes "effluent limitation guidelines" that regulate specific industries, or, where the EPA has not developed a regulation for a particular industry, the limitations can be based on a case-by-case evaluation consistent with the language of the CWA.

The 1972 CWA amendments also require that permits impose terms that assure compliance with water quality standards. States are given the job of establishing water quality standards for all surface waters within their borders. These standards must protect the "designated uses" of each water body. For example, waters that are used by humans to swim in and consume fish from may need to be held to higher standards than water bodies used only as industrial water supplies or for irrigation. Each designated use is assigned a series of "water quality criteria," which are simply the maximum concentrations of individual pollutants that can exist in the water body without impacting the health of the water body for its designated use. These water quality criteria, in turn, are the basis for water quality-based effluent limitations that appear in the NPDES permits.

In addition to the effluent limitations imposed by permits, waters are periodically assessed by the states, and if a body of water is not meeting the minimum quality to support its designated uses, a pollution budget is established for that water body to return it to good health. This budget, called a total maximum daily load, tells permit writers by how much they need to tighten the effluent limitations in future discharge permits to protect the water body's designated uses.

While the CWA prohibits, among other things, the discharge of a pollutant from a point source into waters of the United States without a permit, in practice the application of the act turns on the definitions of its terms. Virtually every term in the CWA is defined, and multiple court cases have further interpreted and explained these definitions. For example, "discharge of a pollutant" means adding a "pollutant" to a "water of the United States" from a "point source." The term "pollutant" can not only mean chemical waste or garbage, but it also includes materials such as sand or dirt. A "point source" is a "discrete conveyance" such as a pipe or ditch, but this term has been interpreted by the courts very broadly and can include farm equipment, a coal pile, a stormwater ditch, or even an entire system of sumps, pumps, liners, and other equipment designed to forestall discharge if that system fails and a discharge results. Individual residential homes are generally exempt as long as they are discharging to a septic or city sewer system.

Perhaps the most controversial term in the CWA is "waters of the United States." The CWA only applies where "waters of the United States" are impacted, but the definition of those jurisdictional waters has been a topic of contention and litigation for over 20 years. A recent Supreme Court opinion purported to clarify the extent of jurisdictional waters, and the EPA and U.S. Army Corps of Engineers have issued regulations intended to implement that definition. Those regulations, however, remain under challenge by a group of states and private entities, and the final word on which waters are protected by the CWA remains unwritten.

The CWA is administered and enforced primarily not only by the EPA and state environmental agencies but also by other federal, state, and local agencies. It has been amended many times since 1972 to add specific programs and accelerate progress related to topics such as toxic pollutants and stormwater control. States must report to the EPA on water quality, and the EPA issues publicly available water quality assessment reports summarizing the state of the nation's waters.

Overall, the CWA has been viewed as a success in cleaning up the nation's waters and protecting public health and the environment. Release of untreated sewage and toxic pollutants to the nation's waters has been significantly reduced, and major targeted cleanup initiatives have improved the conditions of previously endangered water bodies (including the Great Lakes and the Chesapeake Bay). Fish in U.S. waters do not contain the levels of contaminants they once did (although consumption advisories are still issued), and drinking water sources are now far better protected from municipal and industrial discharges. Additionally, the loss of wetlands has declined since the passage of the act, and boaters and swimmers in major urban areas now enjoy rivers once too polluted for use.

Accounting for all the human health, environmental, and economic benefits of the CWA, and comparing these to the costs of compliance, can be very difficult. However, reports on the effectiveness of the CWA have generally been positive, finding that its benefits outweigh its costs. While more work is needed to integrate protections on a watershed scale and to address currently unregulated nonpoint source discharges, such as agricultural runoff, the CWA has resulted in substantial improvements in protecting public health and the environment from discharges related to human activity.

Leah A. Dundon and Richard S. Davis

See Also: Cuyahoga River Incidents; Drinking Water Quality and Regulation; Environmental Protection Agency; Fish Consumption Advisories; Fluoridation of Water; National Pollution Discharge Elimination System; Sewage Treatment and Disposal; Stormwater Runoff; Water Pollution; Waterborne Diseases; Watershed Management, Health Implications of; Wetlands and Healthy Waterways

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CLIMATE CHANGE AND HUMAN HEALTH

As anthropogenic contributions to climate change continue (e.g., generating power with carbon-based fuels and land-use changes), health and human well-being will continue to be at risk. The scope and severity of associated health risks depend on both the individual's degree of exposure as well as preexisting sensitivity to health threats. Exposure is influenced by one's environmental and institutional context, including access to basic support services and how well a community can respond to related health and safety concerns, such as severe heat waves. Furthermore, social or behavioral contexts, such as poverty, social isolation, recreational patterns, and medication use, may increase an individual's risk of exposure or exacerbate existing sensitivity to changes in environmental conditions. Although there are many examples of health-related impacts, climate change will continue to affect human health primarily through changes in temperature, precipitation, sea-level rise, and intensity and frequency of extreme weather events.

Getting a Handle on Climate Change Scenarios

Many complexities are involved with climate change projections due to the large number of variables, many of which depend directly on human decision making. Accounting for these variations and the range of potential climate impacts is a herculean task. To get a handle on potential changes to the earth's climate, the Intergovernmental Panel on Climate Change has created four plausible climate scenarios, called Representative Concentration Pathways, that project the variable rate and magnitude of future climate changes, based on a set of socioeconomic factors. Such scenarios act as storylines through which scientists make explicit assumptions about economic activity, energy consumption, and population growth for use in mathematically modeling of projected climate outcomes. Each scenario identifies starting condition values and estimates changes in atmospheric greenhouse gas concentrations through the year 2100. This approach helps decision makers understand uncertainties and evaluate the impact of different policy options under a range of possible futures.

Recent studies in communities across the United States have shown that extreme temperatures, particularly extreme heat coupled with high humidity, commonly lead to premature death. Extreme heat can impede the body's ability to regulate internal temperature and induce health complications. Under the Intergovernmental Panel on Climate Change's (IPCC) climate scenarios, the United States can expect an increase in the annual average temperature between 3°F and

Toward a Clean Energy Economy

To avoid the worst outcomes of climate change, we must cut global carbon emissions by implementing a price on carbon pollution and spurring investment in renewable energy technologies.

An Interview with Steve Kux

Climate Change and Energy Policy Analyst, David Suzuki Foundation

Steve Kux specializes in climate and clean energy policy in Canada for the David Suzuki Foundation. He has written extensively on climate and energy topics, including the implications of Canada's commitment to phase out coal as an energy source. The David Suzuki Foundation, headquartered in Vancouver, Canada, works to conserve the environment and promote sustainability through evidence-based research, education, and policy development. David Suzuki, an award-winning scientist, is renowned for his radio and television programs explaining the complexities of the natural sciences in a compelling and easily understood way.

David Suzuki has said that the longer we delay addressing environmental problems like climate change, the more difficult it will be to resolve them, and he laments the ongoing approval of fossil-fuel infrastructure by political representatives, "as if we had all the time in the world to slow global warming." In the time that remains before global warming wreaks havoc on the biosphere, what climate change mitigation steps do you believe are most urgent?

Climate change is already happening. We are seeing increasingly frequent extreme weather events, and plant and animal species, including humans, are already facing the consequences. To avoid the worst outcomes of climate change, we must cut global carbon emissions by implementing a price on carbon pollution and spurring investment in renewable energy technologies. We don't often hear about the economic risks associated with pinning the economy on fossil fuels even though we have recently seen what can happen when the price of oils falls. If we come together to support investment in renewable energy and development of clean technologies, we can diversify the economy; provide good, stable jobs; and support the global movement away from fossil fuels. We also need to encourage alternatives to gas-fueled automobiles, including public transit, walking, cycling, and electric vehicles.

In addition to the environmental challenges of climate change, there are certain to be severe economic and security issues that will affect everyone. Do we need to do more to ensure that threats to the global economy and national security are understood and taken seriously in the public discourse on climate change?

As climate changes, people will be forced to relocate from areas that are particularly hard hit into regions that are still livable, putting additional stress on some regions and exacerbating unfolding conflicts. Many climate and security experts believe the Syrian refugee crisis was fueled, in part, by climate change, with people moving from rural areas into Syria's cities as farmland turned to desert in the wake of extended drought. This will continue if we do not take steps to address climate change. (In 2015 at a climate change conference in Anchorage, Alaska, former U.S. Secretary of State John Kerry cautioned, "You think migration is a challenge to Europe today because of extremism, wait until you see what happens when there's an absence of water, an absence of food, or one tribe fighting against another for mere survival." Ed.)

The David Suzuki Foundation has been very active in addressing climate change issues, including supporting the Paris Agreement that entered into force in 2016. How do you see the Foundation's climate change priorities evolving in the future? For example, will the Foundation continue pressing for international treaties or take a different approach?

We have seen a lot of encouraging action on climate change at the international level, including recent commitments by the Canadian government to a national price on carbon pollution and an accelerated phaseout of coal-fired power. In the near future, the David Suzuki Foundation will help communities throughout Canada that have taken the lead on renewable energy solutions to share their stories and lessons learned. Our hope is that the successes can help speed the transition to a clean energy economy throughout the country.

What would be a good career path for a recent college or university graduate wanting to apply a science-based approach to tackling climate change and energy issues?

Natural resource management, public policy, political science, and even communications are just a few of the many career paths available to students hoping to work on climate change and energy issues. One of the ongoing challenges we face in reducing greenhouse gas emissions is getting people to understand what the solutions are and how they fit into their own lives. As more people learn about and get inspired by the solutions to climate change, it is easier to spur governments to take action. In that sense, communicating the science, conducting new research, and developing new climate models are all critical to building a low-carbon future.

10°F (1.7°C and 5.6°C) by the end of the century. Furthermore, many locales will experience new record temperatures, with the hottest day of the year increasing by between 4°F and 6°F (2.2°C and 3.3°C) by 2100. Hotter days and more frequent heat waves will lead to greater heat-related deaths due to increased episodes of heat stroke, heat exhaustion, and dehydration.

Extreme heat will also worsen cardiovascular, respiratory, and cerebrovascular diseases. City-dwellers are particularly at risk due to the urban heat island effect, where air temperatures can be as much as 22°F (12.2°C) warmer than the air in neighboring regions due to the prevalence of dense building and roadway materials like concrete, brick, steel, and asphalt that tend to absorb more sunlight and emit it as heat. While some preventative measures, including increased access to air conditioning, may reduce the risk of extreme heat for some populations, changing temperatures are projected to increase the number of premature heat-related deaths each year by the thousands to tens of thousands across the United States.

Air quality is also expected to worsen due to warming temperatures, changing weather patterns, and increased levels of atmospheric carbon dioxide. Outdoor air pollutants like ground-level ozone are dependent on air temperature, precipitation, humidity, wind trajectory, cloud cover, and vertical mixing in the atmosphere. Under climate change, these conditions are expected to favor greater ozone formation, increasing the risk of chest pain, asthma, coughing, throat irritation, reduced lung function, and other smog-related illnesses. The increased risk of wildfires is also expected to lead to adverse health effects, which may include lung cancer and cardiovascular disease due to higher concentrations of airborne particulate matter.

Under the Clean Air Act, the U.S. Environmental Protection Agency has established national ambient air quality standards to protect public health and the environment from harmful pollutants. Despite improvements in air quality since the 1970s, there are still many counties in the United States that have failed to meet these ambient standards. Climate change may make it even harder and costlier for these counties to comply with the standards, putting more Americans at risk. Higher temperatures and increased levels of atmospheric carbon dioxide are also expected to alter the growing season of plants and corresponding production of allergenic pollens. Associated spikes in aeroallergen concentrations have the potential to increase the number and severity of allergic illnesses.

Between 2004 and 2013, the United States experienced 58 weather and climate disasters, each having economic losses reaching more than $1 billion. By the end of the century, the United States is projected to experience an increase in the frequency and intensity of such extreme events due to climate change. Floods, droughts, wildfires, hurricanes, and winter storms can all directly increase the risk of negative health outcomes, particularly for the most vulnerable populations. In addition to the injury, illness, and death that occur during extreme events, post-impact effects can include contaminated food and drinking water, mental health issues, loss of essential infrastructure, and prolonged exposure to particulate matter. Because much of the country's infrastructure is interdependent, the loss of one component (e.g., electricity) due to damage during an extreme event can create cascading effects. The direct impact of these cascading failures on hospitals and emergency response teams can greatly reduce an individual's timely access to healthcare services in times of crisis.

Each year, the Centers for Disease Control and Prevention documents upward of 50,000 individual cases of vector-borne diseases in the United States. Vector-borne diseases are caused by pathogens that are transmitted through carrying agents, such as mosquitos, ticks, and fleas. Changes in precipitation patterns and temperature extremes can have an impact on the distribution, seasonality, and prevalence of vector-borne diseases in the United States and elsewhere. The most common vector-borne diseases reported in the United States are Lyme disease and West Nile virus.

Climate change can impact Lyme disease by increasing vector abundance, the prevalence of disease among vectors, and the frequency of contact between vectors and humans. Initial research shows that over the next century, climate change will likely lead to earlier annual onset of Lyme disease cases and potential northward range expansion of disease-carrying ticks.

Unlike Lyme disease, West Nile virus is passed to humans by mosquitos that have previously bitten infected birds. Warming temperatures could increase the fledgling survival of infected birds, and extreme events could create more favorable habitat for mosquitos. Affecting more than 300 species of birds, differences in climatic conditions and the preferred breeding habitats of West Nile vectors mean that climate change will impact human disease risk differently across the country. In general, predicting changes along the disease exposure pathway is difficult due to compounding factors, such as land-use change, population demographics, human behavior, and the adaptation of vectors to ecosystem changes.

Exposure to many waterborne diseases is expected to increase due to climate change. Temperature and precipitation changes, storm surge, and increased runoff all influence the growth, survival, spread, and virulence or toxicity of many bacteria, viruses, protozoa, and algae. Common sources of these pathogens include human and animal wastes and agricultural activities, including the use of fertilizers. Without climate-smart infrastructure designed to capture contaminants before they enter water bodies, rapid rainfall and flooding may overwhelm current infrastructure capacities, resulting in increased pathogen concentrations. (Between 12 and 19 million people are affected by acute gastrointestinal illness in the United States each year, with waterborne pathogens accounting for approximately 97 percent of all cases.) Warming seawater temperatures have also been linked to increased occurrences of ciguatera poisoning due to worsening algae blooms. (Ciguatera poisoning is caused by consumption of fish contaminated with ciguatoxin, which originates with certain types of algae.) Behaviors that put individuals at higher risk include recreational exposure to contaminated waters, such as through swimming, and eating undercooked or raw shellfish.

While the negative impacts of climate change on physical health are well understood, the psychological impacts can be just as damaging. The threat of impending climate change-related events, for example, extreme weather, has been linked to a range of mental health consequences, including stress, anxiety, depression, post-traumatic stress, and suicidal thoughts. At the individual level, these consequences can be exacerbated by existing mental health conditions, reoccurring disasters, and an unsupportive social structure. Increases in mental health impacts can also lead to decreased community health, as evidenced by higher levels of interpersonal aggression, increased violence and crime, social instability, and decreased community cohesion. On the other hand, individuals participating in adaptation or mitigation activities are often able to cultivate buffers against distress and experience overall improvement in health and well-being.

Due to the differential effect of climate change impacts, certain populations are more at risk, including children, the elderly, communities of color, occupational groups with high outdoor exposure, people with disabilities, pregnant women, and those suffering from chronic medical conditions. According to the IPCC and the National Research Council, exposure, sensitivity, and adaptive capacity jointly determine an individual's or community's vulnerability to climate change. Exposure to climate stressors depends on one's occupation, time spent in risk-prone locations, socioeconomic status, compromised mobility, and mental function, among other factors. Even if an entire population has a similar level of exposure, individuals will vary in their overall sensitivity to climate stressors due to preexisting biological traits or psychological conditions. For example, the immature immune systems of children and compromised immune systems of the elderly make these groups more sensitive to increases in airborne pollutants.

Adaptive capacity represents the ability to mitigate the adverse impacts of climate stressors. Social capital, access to high-functioning infrastructure and health care, and a range of institutional resources can increase the timeliness and effectiveness of adaptive capacity, resulting in fewer and less severe impacts on health and well-being.

Rachel L. Lamb

See Also: Air Pollution; Ambient Air Quality; Asthma; Carbon Dioxide and the Carbon Cycle; Centers for Disease Control and Prevention; Children's Environmental Health; Clean Air Act; Drinking Water Quality and Regulation; Electric Power Generation, Health Implications of; Environmental Protection Agency; Greenhouse Effect and Global Warming; Heat Island Effect in Urban Areas; Heat Waves; Infectious Diseases; Intergovernmental Panel on Climate Change; Lyme Disease; Occupational Safety and Health; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Respiratory Disease and Air Pollution; Socioeconomic Status and Health; Vulnerable Populations, Environmental Threats to; Water Pollution; Waterborne Diseases

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CLINTON FOUNDATION

The Clinton Foundation is a nonprofit organization founded by former president Bill Clinton in 2001. The foundation's purpose is to build lasting partnerships with organizations and individuals around the world to address issues related to health and wellness, economic development, climate change, and equal opportunity.

Alliance for a Healthier Generation

About one of every three young people (age 2 to 19) in the United States is overweight or obese, and this had led to a dramatic rise in type 2 diabetes and other health problems. The goal of the Alliance for a Healthier Generation, cofounded by the Clinton Foundation and the American Heart Association, is to reduce the prevalence of childhood obesity and to empower young people to develop lifelong healthy habits. In school, healthy children miss fewer classes, score higher on tests, and behave better in class. Recently the Alliance, in cooperation with the Coca-Cola Company, Dr. Pepper Snapple Group, and PepsiCo, announced an initiative to decrease the beverage calories consumed per person by 20 percent by 2025.

Although President Clinton is a Democrat, the foundation is bipartisan and involves Democrats, Republicans, and Independents in its work. Its priorities include improving global health, raising general awareness about health and wellness, fostering economic development, fighting climate change, and empowering girls and women. The foundation is run by a leadership team and advised by a board of directors.

The goal of the foundation's global health initiative is to reduce deaths associated with treatable diseases, such as malaria, tuberculosis, and AIDS, in regions of the world that lack access to medical resources. A large part of this program is managed by the Clinton Health Access Initiative (CHAI), which became a separate nonprofit organization in 2010. The CHAI's initial focus was on boosting access to HIV/AIDS treatments, but its work has grown to include malaria, diarrhea, and tuberculosis treatments. Accelerating access to new vaccines, recruiting and training healthcare workers, and improving healthcare systems are all part of the CHAI mission. The CHAI also plays an important role in providing health care to mothers, newborns, and children. One such program, Prevention of Mother-to-Child Transmission, expands access to HIV testing and treatment for children.

The CHAI is also active in helping the foundation achieve its goal to empower and create opportunities for girls and women. The foundation believes that as women lift themselves out of poverty, they help lift up their communities and that providing access to education and increasing economic opportunity are critical means of empowering women across the world.

The Clinton Foundation's health and wellness programs raise awareness about healthy lifestyles and the impact they have on our communities. Starting with individual lifestyle choices, the foundation advises on the incremental steps allowing individuals to take control of their personal health, preventing chronic disease and associated healthcare costs. The foundation also emphasizes children's health, believing that healthy children have higher attendance rates and test scores than unhealthy children and that their behavior in class is better than their classmates. Through the Healthy Schools Program, the foundation works to reverse the effects that obesity and diabetes have on children, assisting over 30,000 schools to provide healthier lunch options.

Over 400,000 people have benefited from market opportunities created in Latin America, the Caribbean, and South Asia through the Clinton Foundation's economic development initiative. Additionally, over 85,000 farmers in Malawi, Rwanda, and Tanzania have benefited from the agronomic training and increased market access provided by this initiative. The foundation believes that improved economic development starts with giving people access to education and employment, which helps them alleviate poverty and lift their communities with them.

The Clinton Foundation focuses on fighting climate change in ways that work for business, government, and the economy. One example is the foundation's investment in green energy in Haiti, helping boost Haiti's economic recovery by reducing energy costs and its reliance on fossil fuels. In the United States, work by the foundation has helped to reduce more than 33,500 tons of greenhouse gas emissions annually.

Hana Elliott

See Also: Children's Environmental Health; Climate Change and Human Health; Communicable Diseases; Renewable Energy, Health Implications of; Socioeconomic Status and Health

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COAL ASH DISPOSAL

Coal ash, also known as coal combustion residuals (CCR), is a byproduct of the coal combustion process that takes place at coal-powered electric plants. Coal ash makes up a significant portion of the industrial waste generated in the United States each year. It contains contaminants that, if not disposed of properly, pose serious risks to human health and the environment.

In 2012, there were 470 coal-powered electric utilities in the United States and Puerto Rico that burned over 800 million tons (726 million metric tons) of coal. As a result, more than 110 million tons (100 million metric tons) of CCR were generated. According to the U.S. Environmental Protection Agency (EPA), coal ash consists of any of four different types of materials (fly ash, bottom ash, boiler slag, and flue gas desulfurization material) that are created when coal is burned at these utilities. Fly ash is a powdery substance made mostly of silica that is produced through the burning of finely ground coal. Bottom ash is a larger particle that is formed at the bottom of a coal furnace and is too heavy to rise in a smokestack. Boiler slag is a type of bottom ash that turns into pellets after it is cooled with water. Finally, flue gas desulfurization material is a substance that can develop as a wet sludge or dry powder, usually containing a mixture of sulfates and sulfites.

These by-products of coal burning often contain substances, such as mercury, cadmium, and arsenic, that are known to be associated with cancer and other adverse health effects. As coal ash is disposed of in both wet and dry forms, protections are needed to ensure that chemicals do not leach into groundwater, thus contaminating sources of drinking water and endangering public health.

Depending on the form of coal ash, the ash can be drained of liquid or mixed with water for easier transport. Coal ash can then be beneficially used (e.g., in the manufacture of concrete or wallboard) or deposited in a landfill or surface impoundment. (Surface impoundments usually take the form of man-made ponds or lagoons.) Currently, coal ash in the United States is deposited into more than 300 on-site landfills and over 735 surface impoundments at coal-powered utilities.

The EPA has recently begun regulating coal ash disposal in the United States due to concerns that improperly built or managed landfills and surface impoundments could lead to contamination of water resources and the ambient air. These regulations are aimed at limiting the risks of ash components leaking into groundwater, contaminants blowing into the air as dust, and the catastrophic failure of surface impoundments. There are also requirements for recordkeeping and reporting and for making information available to the public.

In 2009, the EPA began conducting a comprehensive assessment of more than 500 surface impoundments nationwide under the Coal Ash Surface Impoundment Integrity Assessment Program. The assessment came on the heels of the discovery in 2008 of a massive spill of over 5 million cubic yards (3.8 million cubic meters) of coal ash from a storage pond at the Tennessee Valley Authority near Knoxville, Tennessee. As a result, the EPA proposed in 2010 its first-ever rule regarding the management of coal ash.

Duke Energy brought coal ash concerns back into the nation's environmental conscience in 2014, when a large storm pipe burst that was located beneath an ash basin at a closed coal plant in North Carolina, dumping approximately 39,000 tons (35,380 metric tons) of coal ash and 27 million gallons (102 million liters) of contaminated water into the state's Dan River. Later that year, the EPA finalized its regulatory requirements for disposal of coal ash at landfills and surface impoundments under Subtitle D of the agency's Resource Conservation and Recovery Act, the nation's preeminent law for regulating solid waste. The EPA announced the long-awaited rule on coal ash disposal after receiving 450,000 public comments on the proposed rule and conducting seven public hearings. The rule was finalized on April 17, 2015.

The rule included language to close surface impoundments and landfills that failed to meet engineering and structural standards, and it also restricted new construction of impoundments and landfills near sensitive areas, such as wetlands and earthquake zones. Fugitive dust controls, groundwater monitoring, and regular inspections of surface impoundments are some of the other notable requirements listed under the rule.

While coal ash can pose potential risks to both human health and the environment if improperly disposed of, beneficial uses can improve environmental conditions and provide economic advantages. The EPA encourages the beneficial use of coal ash as an alternative to disposal, and currently, about 50 percent of the CCR recycled in the United States is being used as a substitute for cement during the production of concrete and for gypsum in the manufacture of drywall.

Anthony C. Holderied

See Also: Air Pollution; Arsenic Pollution; Clean Coal Technology; Drinking Water Quality and Regulation; Electric Power Generation, Health Implications of; Environmental Protection Agency; Fugitive Dust; Groundwater Pollution and Depletion; Land Disposal of Waste Materials; Mercury Pollution; Recycling; Resource Conservation and Recovery Act

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COMBINED SEWER OVERFLOW

A combined sewer system collects both sewage (human and industrial waste) and stormwater (rainwater as runoff) in one pipe and typically transports this combined wastewater to a sewage treatment plant. Once at the treatment plant, the wastewater is cleaned and released into local waterways. A combined sewer overflow (CSO) occurs when increased precipitation overwhelms the capacity of the combined sewer system or the treatment plant, resulting in the release of untreated wastewater directly into nearby waterways. Untreated wastewater may contain many harmful pollutants that are a threat to public health and ecosystems.

The occurrence of a CSO poses a risk to humans who rely on waterways for clean water, food, and recreation. Untreated wastewater may contain a variety of biological, chemical, and physical pollutants, including bacteria, viruses, and pathogens that are significant health risks if ingested. The presence of biological pollutants, such as *E. coli*, sometimes prompts beach closures and boil-water notices. Sewage may contain toxic chemicals from industrial wastes, cleaning products, and fertilizers, and stormwater may contain sediments, trash, and other materials that degrade water quality. In addition to harming human health, CSO pollutants can affect aquatic organisms like fish that humans consume. It is not always known what pollutants may be in a particular wastewater discharge, making it difficult to predict the safety of a waterbody after a CSO.

CSO events are primarily a concern in urban areas because cities tend to have large amounts of impervious surfaces that prevent rainwater from infiltrating into the ground. To reduce water pooling and flooding during rain events in cities with combined sewer system, the stormwater is directed to the combined sewer, causing a large increase in water volume. This contrasts with rural areas, where grass and other vegetation allow more rainwater to infiltrate into the ground, thereby reducing the amount of stormwater runoff. According to the U.S. Environmental Protection Agency (EPA), there are approximately 772 cities in the United States that have combined sewer systems.

To reduce the number of CSO occurrences, the EPA published its Combined Sewer Overflow Control Policy in 1994 under the National Pollutant Discharge Elimination System program. This policy contains guidelines for reducing CSOs so that communities can ensure that waterways are safe from pollution. Communities implement a variety of solutions to prevent future CSOs, including building new treatment plants or expanding existing plants to increase the volume of water that can be treated and constructing storage facilities where wastewater can be stored until treated. Many urban areas are also developing green infrastructure projects, such as rain gardens, green roofs, and cisterns, to reduce stormwater runoff before it is captured by the combined sewer system.

Eventually, it is hoped that CSO events can be prevented and all water released into the environment meets the criteria set in the Clean Water Act. But for now, CSO events still occasionally occur. Many cities offer real-time maps and alerts of CSOs, like Philadelphia's CSOcast, so that the public can take appropriate precautions.

Elise C. Hunter

See Also: Clean Water Act; Drinking Water Quality and Regulation; Environmental Protection Agency; *Escherichia coli* (*E. coli*) Infection; Green Space in Urban Environments; National Pollution Discharge Elimination System; Safe Drinking Water Act; Sewage Treatment and Disposal; Stormwater Runoff; Water Pollution; Waterborne Diseases

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COMMUNICABLE DISEASES

By definition, communicable illnesses are illnesses and diseases that spread from one individual to another through either direct contact or a vector (disease carrier). Communicable diseases can be insect-borne, foodborne, and zoonotic illnesses that are viral, bacterial, fungal, or parasitic in origin. To identify public health threats and monitor prevention efforts, the Centers for Disease Control and Prevention tracks and requires reporting of many communicable diseases. Effective disease tracking is critical to the development of therapies and disease control programs as well as the identification of common-source outbreaks and epidemics.

Viral hemorrhagic fevers are a global cause of acute concern. One of these, the Ebola virus, is transmitted via fecal-oral contamination and causes a severe and often fatal hemorrhagic fever in both humans and animals. Recent epidemics have resulted in an increased scientific interest and drive toward developing an Ebola vaccine. Many of these hemorrhagic fevers utilize an animal vector. For example, the Crimean-Congo hemorrhagic fever, caused by the *Nairovirus* in the *Bunyaviridae* family, is transmitted by ticks in Africa and the Middle East. Also, the acute hemorrhagic fever called Lassa fever is caused by the Lassa virus, which is transmitted via rodent feces or urine. Finally, the African fruit bat is the natural reservoir for the Marburg virus, which causes Marburg fever—a highly infectious disease that is typically fatal.

Direct animal to human transmission of communicable diseases is not limited to viral hemorrhagic fevers. Rabies occurs when an infected animal bites a human or pet, transmitting the viral organism and leading to inflammation of the brain, confusion, fear of water, and convulsions. Exposure to the rabies virus is typically fatal. Vaccination of at-risk individuals is highly recommended, as the vaccine is more effective than the remedies available to treat rabies after exposure. Another example is tularemia, a disease that can lead to skin ulcerations, vision loss, lung disease, and death. This disease is caused by the microorganism *Francisella tularensis*, which is transmitted by fleas, ticks, and deer flies that feast on rodents.

Fungal illnesses, such as empty building syndrome, histoplasmosis, coccidioidomycosis, blastomycosis, and paracoccidioidomycosis, are also communicable illnesses. These diseases are endemic to certain American regions. *Histoplasma capsulatum* is a fungal species that causes a disease referred to spelunker's lung or caver's disease. This organism is found in soil where bat guano or bird droppings have decayed, usually within caves or in the Ohio River Valley. The *Coccidioides* family causes valley fever or desert rheumatism in persons living in Central America, Mexico, and the southwestern portion of the United States, where they inhale the airborne fungal spores mixed with sand and dust blowing in the air. Most exposures to these fungal species are minimally harmful. However, they can be life-threatening for immunosuppressed individuals.

Sexually transmitted infections (STIs) have been present for thousands of years, and the only guaranteed way to prevent these communicable illnesses is completely abstaining from sexual contact. However, as this is an impractical solution for many people, contraceptive barrier methods are often used for protection against STIs. STIs can be bacterial, viral, and parasitic. Bacterial STIs include syphilis, gonorrhea, chancroid, and chlamydia. Herpes, the human immunodeficiency virus (HIV), hepatitis B and C, and the human papilloma virus (HPV) are all caused by viruses. When it was discovered that HPV can cause cancer as well as genital warts, the German virologist Harold zur Haussen identified the cancer-causing HPV strains and created a vaccine against them. Pubic lice and *Trichomonas vaginalis* are both parasitic organisms that can infest a human's genital region via sexual contact, leading to an itching or burning sensation.

Some food poisonings are also reportable communicable illnesses. For example, ciguatera fish poisoning is an illness caused by ingesting fish that contain the toxins of the marine microalgae *Gambierdiscus toxicus*. Common ciguatera symptoms include nausea, vomiting, and neurological symptoms. Another type of food poisoning that is treated as a communicable illness is domoic acid. This is a neurotoxin found in shellfish, sardines, and anchovies that have consumed a particular type of algae. Human consumption of the contaminated organism can result in a disease referred to as either amnesic shellfish poisoning or domoic acid poisoning. This disease can cause short-term memory loss, brain damage, and death.

Some communicable diseases, such as measles, mumps, and rubella, can be prevented by following the national guidelines on universal vaccination protocols. Immunization regimes to prevent the spread of disease are often initiated during childhood. Many serious illnesses have been nearly eradicated due to the use of vaccines. However, outbreaks of these illnesses sometimes occur when communities experience vaccine shortages, or when individuals opt out of vaccinations.

Howard W. MacLennan Jr.

See Also: Bubonic Plague; Centers for Disease Control and Prevention; Cholera; Ebola Virus; Environmental Toxicology; Foodborne Diseases; Guinea Worm Disease; Infectious Diseases; Insect-Borne Diseases; Legionnaires' Disease; Lyme Disease; Neurotoxicants; Norovirus Infection; River Blindness; Rocky Mountain Spotted Fever; Tetanus Infection; Zika Virus; Zoonotic Diseases

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COMMUNITY GARDENING

A community garden is a piece of land used for gardening that is typically owned by a local government or a nonprofit organization and run by local citizens. Community gardens provide fresh produce while improving the neighborhood and

A local resident tends her vegetable plot in a community garden. Neighborhood gardens like this one provide fresh produce while helping to create a sense of community and concern for the environment. (Baronoskie/Dreamstime.com)

creating a sense of community and connection with the environment. Community gardens in the United States range from familiar "victory gardens," where people grow small plots of vegetables, to large "greening" projects that help to preserve natural areas. Community gardens can even be tiny beautification planters located on urban street corners.

Historically, community gardens have provided food during wartime or periods of economic depression. And at other times, many city governments and nonprofit organizations use community gardens to help low-income families, children's groups, and community organizations grow their own produce. Because of their small and manageable size, community gardens are often amenable to organic gardening methods.

Community gardens improve the physical and mental health of participants through exercise and increased fresh vegetable consumption, and they also help break down isolation among people by creating a social activity. Additionally, community gardens provide food security by allowing communities to be less dependent on retail grocery stores that may obtain their produce from many miles away, even from other countries. If only in a small way, community gardens help reduce air pollution and fight climate change by cutting back on the use of large-scale farm machinery and the shipping of produce by truck over long distances.

A growing tradition in many American urban areas is to clean up abandoned lots, turning them into productive gardens for the surrounding community. Alternatively, a community garden can be created as a health or recreational amenity in a public park or other public space. Community gardens may be open to everyone or require membership. Some gardens are grown collectively, with everyone working together, whereas others are split into individual plots, each managed by a different gardener, group of gardeners, or family.

Xingbo Wu and Matthew W. Blair

See Also: Food Safety and Technology; Food Supply, Environmental Threats to; Organic Agriculture

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COMPOSTING, HEALTH BENEFITS OF

Composting is a controlled process of breaking down organic matter. The process begins with raw materials called feedstock. Microorganisms chemically decompose this feedstock, producing nutrient-rich material that can be used to fertilize plants. Composting reduces landfill waste and prevents the release of environmental contaminants produced by more common waste-disposal methods. Human health is improved with composting because fewer contaminants are released into the environment.

Compost is widely used for agriculture. For instance, compost added to sandy soil improves the ability of the soil to store water, reducing the amount of water required for irrigation. Likewise, compost added to soil with high levels of clay allows more air to penetrate the soil. Improving the soil through composting helps reduce erosion, which currently threatens 28 percent of cropland in the United States. When added to soil, composting can suppress soil-borne pathogens, thereby reducing the need for synthetic fungicides.

Successful composting requires the right nutrient balance, particle size, moisture level, oxygen flow, and temperature. The compost needs a certain ratio of carbon-rich "brown" to nitrogen-rich "green" organic matter, and it also needs to be sufficiently moist and aerated. Finally, waste will simply rot (i.e., convert into nutrient-rich compost) if the core temperature is not hot enough (at least 140°F or 60°C) for a sustained period. When the right conditions are met, bacteria and fungi in the soil will slowly convert the organic matter into compost.

In 2013, 2.3 million households in the United States practiced composting. Households can compost a wide variety of waste, such as fruits and vegetables, crushed eggshells, coffee grounds, tea bags, nutshells, paper and cardboard, cotton rags, and grass trimmings. On the other hand, dairy products, grease, meat bones and scraps, and pet wastes should only be composted using well-aerated, large-scale facilities. (Otherwise, these materials will attract flies and create odors.) The waste to be composted is ordinarily placed in a pile and covered with a tarp, or placed "in-vessel," meaning in a covered drum or silo. The time required for composting can be increased by adding red worms in a method called "vermicomposting." One pound (0.45 kilograms) of worms can consume up to half a pound (0.23 kilograms) of organic material daily.

On an industrial scale, large compost facilities can accommodate waste from restaurants, landscaping companies, farms, institutions, and local communities. This includes special compostable food-service items like plates, cups, utensils, and take-out boxes. These facilities may be subject to zoning regulations, and the Environmental Protection Agency (EPA) recommends that industrial compost be periodically tested for harmful bacteria and heavy metals. In 2012, there were at least 4,914 composting facilities in the United States, although 71 percent of these composted only yard trimmings.

Composting reduces landfill waste. According to the EPA, 20 to 30 percent of the current waste stream in the United States could be composted. Several cities and states have banned commercial food waste, including San Francisco, New York City, Connecticut, Vermont, and Massachusetts. This forces businesses to reduce source production, donate food to people or animals, or compost. Using the same strategies, member states in the European Union are being required to cut their food waste in half, beginning 2015 through 2030. The EPA holds an annual Food Recovery Challenge for universities, schools, grocery stores, restaurants, and other businesses. In 2014, this program diverted nearly 606,000 tons (550,000 metric tons) of food waste from landfills.

Composting can improve human health by preventing the release of pollutants such as nitrogen, dioxins, and methane into the environment. First, mature compost can provide essential plant macronutrients, thereby reducing the need for synthetic fertilizers. In the absence of composting, nitrogen in synthetic fertilizer can leach into groundwater, posing health risks to local populations, and nitrogen runoff can also enter the ocean through rivers, creating hypoxic (oxygen-depleted) "dead zones." For example, the Mississippi River feeds a dead zone in the Gulf of Mexico that averages 5,500 square miles (14,000 square kilometers) in size. Second, composting reduces the air pollution caused by burning yard waste, such as leaves, branches, and grass clippings, an activity that creates dioxins (highly toxic air pollutants that persist in the environment). Finally, composting can play a role in reducing emissions of methane, a greenhouse gas produced from the decay of organic material. Rotting organic matter in landfills currently accounts for about 18 percent of methane emissions in the United States, according to the EPA. Diverting waste from landfills to composting can help reduce these emissions.

Another benefit of composting is the potential for educating people by teaching the concepts of environmental sustainability and resource stewardship. Especially in households and schools, composting activities can provide children with hands-on experience with reducing waste and recycling food back into the earth. Composting activities can also help build communities by supporting local food production and food security.

Alisha K. Newton

See Also: Biodegradable Materials, Health Benefits of; Community Gardening; Dioxin Pollution; Hypoxia, Gulf of Mexico; Land Disposal of Waste Materials; Landfill Gas Pollution; Open Burning of Waste; Organic Agriculture; Pollution Prevention; Waste Incineration

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CONCENTRATED ANIMAL FEEDING OPERATIONS, POLLUTION FROM

Concentrated Animal Feeding Operations (CAFOs) are factory farms on a scale that pose significant environmental challenges. A factory farm may hold tens of thousands of animals intended for either dairy use or slaughter, or both. The U.S. Environmental Protection Agency defines a CAFO as any animal feeding operation that has more than 1,000 "animal units" (i.e., 1,000 pounds of animal, which is roughly the size of beef cattle). Also, any animal feeding operation that discharges manure or liquid waste into a nearby watershed is defined as a CAFO.

The scalability issues of housing such a large number of animals leads to problems not seen in traditional farming methods, the most significant being waste management. For example, the hogs in North Carolina CAFOs alone produce more manure than the combined waste streams of New York, Los Angeles, and Chicago. In fact, the production of manure at CAFOs in the United States is so large that it exceeds the sewage output of the entire U.S. human population. As CAFOs do not have sewage treatment facilities, the manure sits in holding ponds or treatment lagoons, and some may eventually be sprayed onto farmlands as fertilizers.

These ponds and lagoons are dangerous to water, air, and soil. Although plastic-lined basins are usually employed, leaks are common, resulting in groundwater contamination, and storms can cause the pools to overflow. Toxic gases that leach from the manure include ammonia and hydrogen sulfide. (At low levels, hydrogen sulfide smells like rotten eggs, but at higher levels, where adverse health effects can occur, it may no longer be noticeable.) The manure itself can contain large quantities of chemicals that may not be present in significant amounts at smaller farming operations, including growth hormones, antibiotics, birthing fluids, and blood. Also, chemicals used for cleaning and maintenance of the CAFO sites may be included in the waste stream.

Even when used as manure, spraying CAFO wastes onto fields can lead to an excess of nitrates in the soil, which can also become a health problem for nearby communities if the nitrates get into the water supply. For example, infants drinking tainted water may be affected by blue baby syndrome, which is a condition where nitrates build up in the bloodstream and prevent the proper transfer of oxygen within the circulatory system. The CAFO wastes can also contaminate bodies of water and cause algae blooms, damaging local water habitats. This is a major problem in the Chesapeake Bay, where runoff waste from poultry CAFOs in Maryland has caused massive dead zones due to a lack of oxygen in the water.

Even when held in ponds or lagoons, the waste is not safe. Droplets of the manure can condense in the atmosphere, subjecting local residents to airborne pathogens (in addition to the smell). This also occurs when the manure is sprayed as fertilizer, resulting in some of the wastes contaminating the air as particulate pollution. Some of the more serious dangers from CAFO operations include exposure to fecal coliforms like *E. coli* and many other pathogens that grow in the waste. Additionally, the wastes CAFOs produce can become a haven for garbage-eating insects like houseflies and mosquitos. Rats and other vermin may take up residence near CAFOs as well. CAFO animals can also cause pollution by emitting large amounts of methane, a potent greenhouse gas, during their digestive process. Surprisingly, as much as 18 percent of greenhouses gasses worldwide are the by-products of livestock.

Workers at CAFOs who regularly come into contact with animals and their wastes are far more likely than the rest of the population to contract a variety of diseases, including salmonella, leptospirosis, and hepatitis E. A study of neighborhoods around North Carolina CAFOs found that the smell alone was enough to cause headaches and impaired eyesight. Additionally, there appears to be a noticeable impact on the mental health of local residents, although this is somewhat more subjective.

Although CAFOs are required to report emissions of pollutants, including ammonia, there are currently no federal regulations directly limiting air pollution from CAFOs. However, CAFOs are regulated through the federal Clean Water Act, and state laws must be at least equally restrictive in what can be dumped into watersheds. Enforcement authority is sometimes an issue. The U.S. Department of Agriculture has attempted to give CAFO a voluntary path to better environmental stewardship in the form of financial assistance for certain practices. At the local level, many towns near CAFOs have fought against new or expanded operations. However, local ordinances and other attempts to curb the impacts of nearby CAFOs often clash with state and federal regulations, such as right-to-farm laws.

Aaron Dorman

See Also: Air Pollution; Carbon Dioxide and the Carbon Cycle; Clean Water Act; Climate Change and Human Health; Drinking Water Quality and Regulation; Environmental Protection Agency; *Escherichia coli* (*E. coli*) Infection; Greenhouse Effect and Global Warming; Land Disposal of Waste Materials; Particulate Matter and Bioaerosols Pollution; Water Pollution

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CONSTRUCTION SITE RUNOFF

Construction site runoff can generate many types of pollutants that are harmful to humans and the environment. Recognizing the pollution potential, the Environmental Protection Agency and state environmental agencies have focused on the problem. Two primary ways that the agencies have tackled construction site runoff pollution are by issuing Municipal Separate Storm Sewer System (MS4) National Pollutant Discharge Elimination System (NPDES) permits and by requiring NPDES Construction General Permits (CGPs).

Most MS4 permits contain six minimum control measures for compliance, one of which is to address construction site runoff. Within the permits, which are issued primarily to governmental agencies such as cities and counties, the jurisdiction is generally required to prohibit the discharge of pollutants from a construction site, to educate the construction community about ways to identify and prevent stormwater pollution, to inspect construction sites periodically to identify potential and ongoing pollution issues, and to conduct enforcement actions to address sources of pollution.

CGPs are issued by the regulatory agencies to prevent pollution during construction. These permits require the preparation of a Storm Water Pollution Prevention Plan (SWPPP), which usually includes (1) an Erosion Prevention and Sediment Control (EPSC) Plan or an Erosion Control Plan (ECP); (2) identification of possibly affected water resources; (3) a description of the proposed site work; and (4) a series of Best Management Practices (BMPs) to prevent or minimize the discharge of pollutants from the construction site. The CGP will also require submission of a Notice of Intent, which identifies and provides contact information for the construction site developer and onsite contractors and acknowledges, by their signature, their commitment to prevent the discharge of pollutants. Individual NPDES permits with additional requirements may also be issued for construction sites based on the type or location of the construction site and the threat to water resources.

Sediment is one of the top two causes of stream and lake impairments for many states and is one of the top five causes of impairments for most states. Other top causes of impairments include pathogens and nutrients, which may be related to or exacerbated by the presence of the sediment. Sediment affects bodies of water in several ways. For example, it can physically fill the water body, causing plants and animals on the bottom (the benthic zone) to be covered, disrupting the food chain. Sediment deposition in streams can cause a stream to be more likely to overflow and to establish a new water course, leading to unstable banks and erosion of adjacent land, which may threaten people and structures along the stream. Sediment deposition in lakes can reduce the storage capacity of a lake or reservoir, causing lakeside and downstream flooding. Sediment can be suspended in the water, making the water so cloudy that plants and animals cannot survive and reproduce, affecting the human food supply.

Sediment can increase the effects of other pollutants from the construction site and pollutants already present within the body of water. Bacteria can use sediment particles as a substrate where they can reproduce and travel farther than they may have traveled just within the water column. Metals may form bonds with the sediment particles, which again may allow the metals to travel further in the water column and may make them bioavailable. Both bacteria and metals can affect human health.

For bodies of water used for a drinking water source, the presence of excessive turbidity in the water can lead to additional treatment, which increases the cost. There can be by-products of the surface water treatment process, such as the formation of trihalomethanes, which may be formed when water with organic matter is treated with chlorine. Some trihalomethanes may be carcinogenic.

While sediment is the primary source of pollution from most construction sites, other pollutants that can affect human health and the environment include concrete wash water (high pH), paints (metals and volatile organic compounds), oil, gasoline, diesel, portable toilet waste (bacteria and disinfectant), and trash. Measures to prevent the discharge of these pollutants are in the SWPPP.

Thomas B. Lawrence

See Also: Heavy Metal Pollution; Sewage Treatment and Disposal; Stormwater Runoff; Water Pollution

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CONSUMER PRODUCT SAFETY COMMISSION

The Consumer Product Safety Commission (CPSC) was created by Congress in 1972 with the Consumer Product Safety Act. The CPSC is an independent federal regulatory agency that is tasked with protecting "the public against unreasonable risks of injuries and deaths associated with consumer products" from fire, electrical, chemical, or mechanical hazards.

Reporting Your Product Safety Concerns

Are you concerned about the safety of a product you want to buy or recently bought? At the CPSC website (cpsc.gov), you can review product safety recalls and explore other research, and you can also report your concerns. To file a report, you will need to provide the following information: (1) a description of the consumer product or substance; (2) the name of the manufacturer, importer, or private labeler of the product; (3) a description of an illness, injury, or death, or the risk of illness, injury, or death, related to use of the product; and (4) the date or estimated date when the incident occurred or when you first became aware of the potential for the product to act in an unsafe manner. You will also need to provide information on who you are (e.g., consumer, healthcare professional, or government agency), contact information, permission to publish your report on saferproducts.gov (except that your name and address will not be published), and verification that the information you provided is true and accurate to the best of your knowledge.

Making Consumer Products Safe

It is always better to design safety into the product rather than relying upon the users of the product to modify their behavior.

An Interview with Marc Schoem

Executive Director, International Consumer Product Health and Safety Organization

Marc Schoem is executive director of the International Consumer Product Health and Safety Organization, a professional association made up of consumer product health and safety professionals from across the globe. The goal of the organization is to facilitate inclusive, nonpartisan dialogue on consumer product health and safety through training meetings and symposia. Schoem was previously with the U.S. Consumer Product Safety Commission, serving as the deputy director of compliance and field operations.

What are some of the challenges in the international marketplace for ensuring that products are safe? Are manufacturers in some countries held to stricter standards than in other countries?

With the advent of the internet, there is truly a global marketplace. Consumers from anywhere in the world can purchase products, whether intended for sale to them in their own country or not. Generally, products must meet the safety standards of the country where they are being sold. This applied for years to the sale of consumer products in traditional brick and mortar stores. With the internet and consumers' ability to purchase any product, it is more challenging to assure products meet standards enacted by different countries. Country safety standards may be different because of the priorities they place on the products they sell and on available data concerning those products. What may be of concern to one country may not be of concern to another because of different cultural variations in the use of products and for other reasons. At a minimum, products should meet whatever available safety standard exists for that product. Generally, if the most stringent product safety standard is met, then there is greater reliability that the product you are buying is safe. While product safety standards may differ from country to county, it is important for purchasers of the product, whether a consumer or retailer, to know what standards exist and what problems have been identified with similar products in the past, and to ensure adequate review and testing is conducted on the product before it is offered for sale anywhere in the world. With these basic steps taken by manufacturers, importers, retailers, and others in the distribution chain, consumers will have more confidence in the purchase they are making.

While manufacturers are responsible for producing safe products, consumers also have responsibilities, for example, carefully reading product use and safety labels. In our busy world when not everyone takes time to read labels, what is being done to make it easier for consumers to know how to use products safely?

Safety is a shared responsibility. However, it is incumbent upon manufacturers to design their product to be as safe as possible, and where the design of the product can eliminate or reduce the risk presented by consumer use, that should be a priority. It is always better to design safety into the product rather than relying upon the users of the product to modify their behavior. Where a product design still requires consumer awareness of a potential risk, the labeling should be clear and concise and meet all applicable safety standards for consumer warnings. Video instructions are now generally made available by manufacturers and retailers online for the safe assembly, installation, and use of products. Consumers should be aware of the existence of such information online, and companies should do all they can to encourage the viewing of these important safety messages through notifications and incentives to ensure consumers receive this critical safety information.

Despite premarket testing, sometimes problems do not appear until after the product is in the marketplace. If consumers are concerned about the safety of a particular product, what should they do?

Consumers can take several steps to make sure information about a potential product problem is brought to the attention of the responsible party:

- File a consumer complaint with the manufacturer, retailer, or other responsible party who distributed and sold the product so that they are aware of the issue with the product. Provide enough detailed information about what you believe is the nature of the risk and safety issue so the company can adequately respond.
- File a complaint on the U.S. Consumer Product Safety Commission's Saferproducts.gov website at: saferproducts.gov/CPSRMSPublic/Incidents/ReportIncident.aspx. Saferproducts.gov was set up by the Consumer Product Safety Commission so that consumers and businesses could file safety related complaints. By filing a complaint, the agency can readily determine if the complaint is part of a bigger issue and whether further investigation is required. Consumers in other countries should also check with their regulatory authorities to see if they have a similar way of filing complaints.

If the complaint involves nonconsumer products like cars or food items, other government agencies and not the Consumer Product Safety Commission would handle those complaints. Each government agency in the United States having authority over certain products may have similar complaint reporting on their websites.

The CPSC covers thousands of types of consumer products, including toys, cribs, power tools, cigarette lighters, coffee makers, and household chemicals. Additionally, many other product types are covered by other agencies. For example, the Food and Drug Administration covers food, drug, and cosmetic products, and the Department of Transportation covers cars, trucks, and motorcycles.

The CPSC develops and enforces standards for many industries, prohibits consumer products from the market if no standards exist to protect the public, arranges recalls and logistics supporting recalls when necessary, researches potential dangers associated with products, and provides education to consumers on products and their potential hazards. Consumers are welcome to contact the CPSC to report unsafe products.

Standards set by the CPSC can be voluntary or mandatory. Voluntary standards are created in collaboration with voluntary standards organizations (e.g., the American National Standards Institute, ASTM International, and UL) and serve as best practices for individual consumer products. Mandatory standards require compliance, and failure to comply may result in sanctions or penalties. An example of a mandatory standard is that high chairs must be 15 inches (38 centimeters) above the floor.

Hana Elliott

See Also: Hazardous Air Pollutants; Indoor Environment; Personal Care Products, Health Issues with

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CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

The Convention on Long-Range Transboundary Air Pollution is an international treaty that is intended to reduce and prevent air pollution crossing national boundaries. The treaty was first signed in 1979 and since extended by eight protocols that specify specific actions needed to address various air quality concerns. Currently, 51 member states of the UN Economic Commission for Europe are parties to the convention. Over the years, the convention has contributed to large reductions in air pollutants, resulting in improved public health and strengthened measures to protect the environment.

Why Environmental Treaties Matter

A treaty is an agreement negotiated between two or more sovereign states, formally signed by representatives of the states, and usually ratified by the states' lawmaking authorities. Treaties involving environmental matters have become increasingly necessary as pollution spreads beyond national boarders, becoming an international concern. Perhaps the best example of an international environmental concern is climate change. Carbon dioxide and other greenhouse gases that cause climate change originate in many countries and spread around the globe, potentially remaining in the atmosphere for hundreds or thousands of years. Furthermore, greenhouse gases associated with human activities have been increasing (up 35 percent from 1990 to 2010), despite the worldwide concern about climate change. One nation alone cannot solve the climate change problem, and cooperation among all nations is essential.

The convention defines “transboundary air pollution” as “air pollution whose physical origin is situated wholly or in part within the area under the national jurisdiction of one State and which has adverse effects in the area under the jurisdiction of another State at such a distance that it is not generally possible to distinguish the contribution of individual emission sources or groups of sources.” In other words, the convention targets pollutants originating from a variety of sources that travel long distances between nations. The convention was originally designed to reduce acidic rainfall (also called acid rain) by limiting emissions of sulfur dioxide and other sulfur-containing compounds. Later, the convention was expanded to address other air pollutants, including nitrogen oxides, volatile organic compounds, heavy metals, persistent organic pollutants, ammonia, and ground-level ozone.

Parties to the convention have agreed to actively cooperate to develop national air pollution policies and to coordinate pollution control efforts through information exchange, consultation, research, monitoring, and the development of air pollution models and emission inventories. Thousands of health and environmental scientists and government officials are engaged in research, monitoring, and data analysis under the convention. Actions to reduce pollution now extend from the European Union to eastern Europe, the Caucasus, Central Asia, and North America.

In the future, the convention will continue research into the effects and control of transboundary air pollutants while integrating greenhouse gases into its purview. Because air pollutants and greenhouse gases often have the same sources (e.g., electric power plants using fossil fuels), the convention is developing co-control strategies for these sources. The convention is also considering adding new pollutants, such as dissolved solvents, dust, and fine particulate matter, and it will continue facilitating international cooperation on transboundary pollution control efforts.

Richard Crume

See Also: Air Pollution; Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Electric Power Generation, Health Implications of; Greenhouse Effect and Global

Warming; Hazardous Air Pollutants; Heavy Metal Pollution; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Persistent, Bioaccumulating, and Toxic Chemicals; Volatile Organic Compound Pollution

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COOKSTOVES, HEALTH IMPACTS OF

Among the basic needs of human life, which include shelter and clothing, food is an essential requirement, without which humans cannot survive. In the process of preparing food and staying warm when the weather is cold, energy in the form of heat is required. One of the ways by which people create heat in households is by relying on cookstoves. It is estimated that about 3 billion people worldwide, mainly in developing countries, rely on cookstoves for domestic energy demands. Traditional cookstoves are simple cooking devices that are designed to function mostly on biomass fuels. Examples of the biomass fuels commonly used are charcoal, wood, animal dung, and crop residue (e.g., husks of coconuts or palm kernels). The use of cookstoves causes household air pollution, which has been associated with respiratory and heart-related diseases affecting a large proportion of the world's population. Thus, cookstoves are considered by many health professionals to be a major global health threat.

Toxic Emissions from Cookstoves

When fuel does not burn efficiently, ideal conditions exist for the creation of toxic compounds. The incomplete combustion of fuel is the major source of toxic household air pollution from cookstoves, which are generally primitive technologies where fuel often burns poorly and may smolder for hours. Ideally, during combustion, the carbon in the fuel should be transformed completely to carbon dioxide. Incomplete combustion occurs when the carbon does not get completely converted to carbon dioxide due to insufficient oxygen levels as well as inefficiencies inherent in the combustion process. The result is that some of the carbon goes toward the formation of toxic compounds that are harmful to human health and the environment.

Why We Should Care about Cookstoves

Other than smoking, nothing is as proximate as cooking—every house, every day, right when people are present.

An Interview with Dr. Kirk R. Smith

Professor of Global Environmental Health, University of California at Berkeley

Dr. Kirk R. Smith is professor of Global Environmental Health at the University of California at Berkeley, where he directs the master's program in Global Health and Environment. Dr. Smith previously managed the energy program at the East-West Center, and he is a renowned global expert on environmental health issues, including indoor air quality and the widespread use of cookstoves in developing countries. He has served on many scientific advisory committees, including the World Health Organization's air quality guidelines executive committee. In 2007, he shared the Nobel Peace Prize with other scientists who contributed to the Intergovernmental Panel on Climate Change's third and fourth assessments, and he is the convening lead author for climate and health for the fifth assessment. His many honors include election to the National Academy of Sciences, the Heinz Prize in Environment, and the Tyler Prize for Environmental Achievement.

Why is there such concern over cookstoves and the environmental health consequences of their use in many developing countries? After all, they are often part of local culture, and they are so small compared to, say, a big electric power plant.

Pollution sources near people are far worse per unit emissions than ones far away. Other than smoking, nothing is as proximate as cooking—every house, every day, right when people are present. Thus, cooking has a much bigger impact than power plants even if power plants produce more total pollution. In understanding human health, we have many traditional, accepted, and sometimes free activities that are also highly unhealthy. Burning sticks off the ground for heating and cooking is one, as is defecating in the open. We need to move people away from these practices to promote health, and the fact that 60 percent of the world uses clean fuels for cooking (gas and electricity) gives us hope that all could.

What are some of the obstacles to implementing cleaner cooking options, and what is being done to overcome these obstacles?

There has not been much success trying to implement cleaner biomass stoves over the decades, although there has been some progress, and it is well worthwhile continuing this work for the very poorest people. What has succeeded to a much greater extent is providing clean fuels to poorer segments of the population. India, for example, is now in the middle of providing clean fuel—liquefied petroleum gas—to some 350 million poor people through very innovative policy programs. India deems the needed government expenditures not as a "subsidy" but as a social investment, like vaccine and maternal care for the poor. If targeted to those in need and achieving a social benefit, governments should be willing to promote such programs.

What is a good career path for a recent college or university graduate who is interested in addressing global issues like cookstoves?

A good science degree or double major in science and then application of high-quality scientific methods to the problem.

For people in developing economies, especially in rural communities, biomass fuel for cookstoves is readily available in nearby agricultural lands and animal farms. Biomass fuel is a low-cost, reliable, and readily available source of energy for domestic energy needs compared with alternate fuels, including kerosene and liquefied petroleum gas.

Traditional cookstoves create large amounts of smoke that can result in high levels of indoor air pollution that may contain harmful gases and particles, including acrolein, benzene, black carbon, carbon dioxide, carbon monoxide, dioxins, formaldehyde, methane, nitrous oxides, particulate matter, and polycyclic aromatic hydrocarbons. Three of these constituents—benzene, dioxins, and polycyclic aromatic hydrocarbons—have the potential to cause cancer in humans. Additionally, black carbon, carbon dioxide, carbon monoxide, and methane contribute to climate change.

Breathing the harmful substances in biomass fuel smoke can affect the natural defense system that protects the human body from diseases. Air pollution from biomass fuel is estimated to cause about 4.3 million premature deaths yearly from respiratory diseases (e.g., pneumonia, chronic obstructive pulmonary disease, and lung cancer) and heart-related diseases (e.g., ischemic heart disease and stroke). According to the World Health Organization, in 2012, household air pollution was responsible for 21 percent of lower respiratory infection deaths, 35 percent of chronic obstructive pulmonary deaths, and 3 percent of lung cancer deaths worldwide. Lower income countries are particularly vulnerable to the health effects associated with traditional cookstoves. For example, household air pollution was responsible for 1.62 million deaths in the Western Pacific regions and 1.69 million deaths in Southeast Asia in 2012.

Most household cookstoves are used in poorly ventilated kitchens, where women and children are most vulnerable. (Older children in these households often help with cooking.) For pregnant women, exposure to biomass smoke during cooking poses significant health risks to themselves and their unborn babies. Fetuses have developing body systems that are prone to adverse health effects that can include low birth weight, prematurity, still birth, and early infant death. Cookstoves irritate the respiratory tract, putting children at risk for infection and aggravating underlying asthma and tuberculosis.

Considering the enormous global health challenges caused by the use of cookstoves, a comprehensive approach is urgently needed to minimize the impact.

Some immediate solutions that could minimize the health risks are cooking outdoors instead of in enclosed spaces and increasing ventilation in kitchens by having more windows or installing smokestacks. Households equipped with kitchen smokestacks have demonstrated significantly lower levels of household air pollution than those without. It is important to educate users of cookstoves on the possible health effects of cookstove smoke and options for reducing their risk.

The use of improved biofuels (e.g., biogas, charcoal, wooden pellets, and ethanol) and alternate energy sources (e.g., kerosene, liquefied petroleum gas, electricity, and solar energy) has been explored and is being implemented in many parts of the world. Improved cookstove designs using materials such as clay, cement, ceramics, metals, and solar panels has also been explored to improve their efficiency and enhance their heat-retaining capacities, and these designs have generally been proven to reduce household air pollution. Some improved cookstove designs made of brick with wood as biofuel have yielded a 70 percent reduction in average household air pollution and a 56 percent reduction in household fuel consumption, and they have demonstrated an improvement in children's health by reducing the duration of respiratory tract infections. Other improved cookstove designs consisting of ceramic materials and charcoal as biofuel have reduced average small particulate concentrations in the air by 52 percent and CO

Food prepared over a wood-fired cookstove in the city of Purulia in West Bengal, India. The smoke from cookstoves represents a major global health threat. (Samrat35/Dreamstime.com)

concentrations by 40 percent, and they have reduced the risk of children under five years of age dying from respiratory diseases by 25 percent. (However, these improvements have not been demonstrated by other studies.) Many other interventions have shown initial reductions, especially in small particles and gases, but these reductions were short-lived and still above the World Health Organization's recommended air quality levels.

Despite the reported reductions in household air pollution and improvements in health by the use of improved cookstoves, the sustainability of these devices and their health benefits continue to be major challenge. Factors that influence their acceptance and use in developing economies include the cost of improved cookstoves and their fuel (especially if relying on alternate fuel apart from biomass), ease and convenience of usage by members of the household, and appropriateness to the culture of the users. Other factors include the need for minimal maintenance and for preserving culturally relevant designs. To achieve acceptable household small particulate concentrations in the indoor air, the World Health Organization recommends the widespread use of "clean fuels," such as gas and electricity, in households. And until gas and electricity are widely available and affordable, households should depend on improved cookstoves and other measures to reduce indoor smoke.

There is ongoing research by many organizations on developing cleaner and affordable technologies to improve the design of cookstoves. These organizations include the U.S. Environmental Protection Agency, which conducts laboratory testing of cookstove designs and supports field studies, and the Global Alliance for Clean Cookstoves, which is working toward the goal of making improved cookstoves accessible to 100 million homes by the year 2020.

Emmanuel Kyeremateng-Amoah

See Also: Air Pollution; Asthma; Carbon Dioxide and the Carbon Cycle; Dioxin Pollution; Environmental Protection Agency; Formaldehyde; Hazardous Air Pollutants; Indoor Environment; Particulate Matter and Bioaerosols Pollution; Polycyclic Aromatic Hydrocarbons; Renewable Energy, Health Implications of; Respiratory Disease and Air Pollution; Woodstove Air Pollution; World Health Organization

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CORAL REEFS AND FOOD SUPPLY

Coral reefs are vital marine ecosystems, providing unique biodiversity, coastal protection, medicine, and ecotourism that supports local economies. Because of their unique ability to support life for many different organisms, coral reefs also provide a stable food source for both local communities as well as global markets. Coral reefs are very fragile as well, and the various threats to them can jeopardize this important food source. Without the food coral reefs supply, the potential to impact local and global communities is significant.

Why Healthy Coral Reefs Matter

When we compromise the nurseries of the oceans—including coral reefs—it's safe to say that we are reducing the resilience of global fisheries.

An Interview with Dr. Kim Cobb

Professor, Georgia Institute of Technology

Dr. Kim Cobb manages the Paleoclimate and Climate Change Laboratory at the Georgia Institute of Technology. Her research concerns the use of ocean corals and cave stalagmites to reconstruct ocean temperature and rainfall patterns over the past 1,000 years, and she has recently documented the precipitous decline in the world's coral reefs. The mission of Dr. Cobb's laboratory is to understand the mechanisms of climate change, to characterize natural climate variability in the tropical Pacific, and to identify climate change trends associated with anthropogenic factors. She has received many academic awards, including the National Science Foundation's Career Award, the Presidential Early Career Award for Scientists and Engineers, and the Sigma Chi Best Paper Award. Dr. Cobb is currently an editor for Geophysical Research Letters *and was recently named the Georgia Power chair and the ADVANCE professor at the Georgia Institute of Technology*.

You and other marine scientists have observed a mass bleaching of coral reefs that has never happened before in modern times, and over a third of the world's coral reefs are threatened. Why is this happening, and what can be done about it?

The past year's global coral bleaching and mortality event—the worst on record—was caused by exceptionally high ocean temperatures resulting from a lethal combination of human-caused global warming and a massive El Niño event. [El Niño refers to the periodic warming of surface temperatures across the central and east-central Equatorial Pacific Ocean.] While El Niño warm extremes are natural occurrences that we have no direct control over, we do have the capacity to reduce the rate of ocean warming over the next century by curbing greenhouse gas emissions from fossil fuel burning. Without aggressive, near-term efforts to reduce our dependence on fossil fuels, the coral mortality event of 2015–2016 will be dwarfed by more frequent, more severe global coral mortality events in the future.

The coral reefs support fish stocks that many people depend on for food, and it was recently discovered that half of the Great Barrier Reef near Australia has already died. If many of the reefs die out, what will happen to the supply of fish in the world's oceans?

Global fish stocks face a range of pressures, including overfishing, climate change, and habitat destruction. When we compromise the nurseries of the oceans—including coral reefs—it's safe to say that we are reducing the resilience of global fisheries to these pressures, such that fish stocks will be under increasing threat.

Can we say for sure that climate change is to blame for rising ocean temperatures and the resulting bleaching of the coral reefs, or are there other factors at play?

Yes, there is no doubt that human-caused climate change is the main culprit behind the recent ocean warming extreme. I have worked at a remote, sparsely-habited coral reef atoll named Kiritimati Island (aka Christmas Island) for the past 20 years. It lost 85 percent of its corals over the past year during a nine-month interval of extreme ocean temperatures. There is no reef that can escape the march of ocean warming—my remote research site was no exception.

What would be a good career path for a recent college or university graduate wanting to make a real difference in protecting sea life and the world's coral reefs?

There are so many ways to contribute in meaningful ways. We need to know more about the science of coral reef resilience, so there are great opportunities for students to work toward breakthroughs in our understanding of coral biology, ecology, and geochemistry. We also need people who can translate this understanding into solutions to help reefs through the coming temperature extremes—engineering the temperature-resistant reefs of tomorrow or devising strategies to speed reef recovery. And of course, none of this will matter if we do not have effective public policy focused on reducing the pervasive threats to the health of our global oceans, including climate change.

Despite their rock-like appearance, corals are organisms, members of the phylum Cnidaria and class Anthozoa. Related to sea anemones and jellyfish, corals are tiny polyps, which are small tubes with openings at the end containing tentacles to capture smaller organisms for food. Corals are categorized into two categories: hard and soft corals. Hard corals, known as Scleractinia, are corals that secrete from their bases a layer of calcium carbonate, the material also found in chalk and limestone. One type of Scleractinians, colonial corals, is responsible for the formation of coral reefs. On the other hand, soft corals, or Alcyonacea, such as sea fans and sea whips, do not produce stony structures and often resemble plants or trees.

Coral reefs exist in a symbiotic relationship with Zooxanthellae, which are microscopic algae. The coral reefs provide protection for the Zooxanthellae, and in turn, the Zooxanthellae provide food for the corals through photosynthesis. Coral reefs are found primarily in shallow, tropical, or semitropical waters where the temperatures are optimal for reef building, 73°F–84°F (23°C–29°C), and where light can penetrate clear water for photosynthesis.

Throughout the world, over 1 billion people rely on reef fish and other marine organisms that are dependent upon coral reefs for food supply. Of those 1 billion people, approximately 85 percent depend on fish as their principal source of protein. Coral reefs provide habitats for various species of fish that are targeted by the commercial fishing industry. For example, of the 30 million small-scale fishermen living in developing nations whose livelihoods depend on fishing, at least 25 percent of the fish they catch are from coral reefs.

Not only are coral reefs essential for subsistence fishing, they support a multibillion-dollar industry worldwide. Of the $29.8 billion globally derived from coral reefs, around 25 percent is specifically from fisheries. According to the National Marine Fisheries Services of the National Oceanic and Atmospheric Administration, reef-based recreational fisheries produce over $100 million annually in the United States alone.

There are a number of anthropogenic and natural threats to coral reefs that jeopardize them as essential food sources and economic providers. It is estimated that 60 percent of coral reefs are under immediate threat from anthropogenic activities, and a total of 75 percent of coral reefs are currently threatened when the harmful effects of climate change are also taken into consideration. On a global level, the effects of climate change, such as higher ocean temperatures and more acidic oceans, have already had measurable, negative impacts on the sustainability and future development of coral reefs. Coral reefs have very narrow temperature tolerances, and as oceans warm outside of those tolerances, corals become stressed, leading them to eject the Zooxanthellae. This process is known as coral bleaching, and while corals can survive a bleaching event, it makes them more susceptible to mortality. An ocean water temperature change of only 1.8°F–3.6°F (1°C–2°C) can have this effect. In addition, as more carbon dioxide is emitted into the atmosphere, more is absorbed in the oceans. This absorption of carbon dioxide acidifies the water (raises its pH), which decreases the carbonate concentration of the water. Without carbonate, corals cannot secrete the calcium carbonate needed to create the reefs.

On the local level, overfishing, pollution, unsustainable tourism, and development all have negatively impacted the viability of coral reefs. Overfishing not only leads to the collapse of fisheries due to depleting numbers of fish to the point of unsustainable populations, but the actual fishing practices themselves, such as the use of poisons, explosives, and bottom trawling (the practice of dragging a weighted net along the seafloor), are often very destructive as well.

As the world's population continues to increase, the demand for fish will continue to grow. Because coral reefs are inextricably linked to food supply, many efforts at the global, national, and local community levels are urgently needed to preserve those resources.

Anthony G. Papetti

See Also: Biodiversity and Health; Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Ecosystems, Importance of; Fishing Practices and Food Supply; Food Supply, Environmental Threats to; National Oceanic and Atmospheric Administration; Ocean Acidification; Population Trends, Health Implications of

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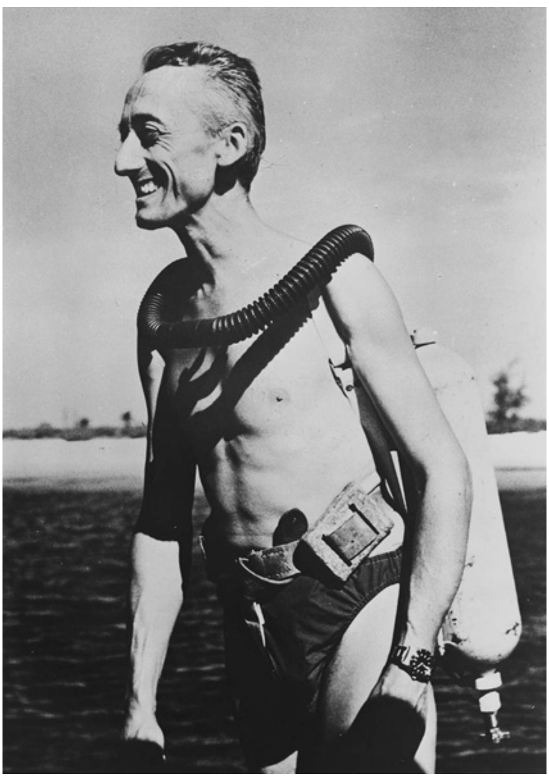
COUSTEAU, JACQUES-YVES

Jacques-Yves Cousteau (1910–1997) is known today for his contributions to exploration of the oceans, underwater scientific research, and environmental activism. He began his career as a gunnery officer in the French naval academy in 1930, but when a near-fatal automobile accident broke both arms and took away his hope of becoming a pilot, Cousteau decided to pursue his lifelong interest in sea exploration and research. By the end of his life, he was widely recognized as the most famous underwater explorer of the 20th century.

Captain Cousteau and the Medal of Freedom

For decades, Captain Jacques-Yves Cousteau has been a celebrated undersea explorer. His journeys aboard the Calypso have become known to millions through his books and films. His manned, undersea colonies yielded wealths of research and data and made important technical advances. His aqualung has made underwater diving available to all. Captain Cousteau perhaps has done more than any other individual to reveal the mysteries of the oceans that cover more than two-thirds of the surface of our planet. It is, therefore, likely that he will be remembered not only as a pioneer in his time but as a dominant figure in world history.

—Ronald Reagan: "Remarks at the Presentation Ceremony for the Presidential Medal of Freedom," May 23, 1985. Online by Gerhard Peters and John T. Woolley, *The American Presidency Project*. http://www.presidency.ucsb.edu/ws/?pid=38676.



Jacques-Yves Cousteau, a celebrated undersea explorer and environmental activist. His journeys aboard the research vessel *Calypso* led to important discoveries and technological innovations. (Library of Congress)

During World War II, Cousteau was a member of the French Resistance against the German occupation of France, and he was later awarded the Legion of Honour for his espionage. In 1950, after the war had ended, a former mine-sweeping ship named *Calypso* was turned into an oceanographic vessel, complete with dive and research equipment for Cousteau's crew. Later his team moved to a newer ship, called the *Alcyone*, which was powered by one of his inventions (along with engineer Bertrand Charrier and Professor Lucien Malavard), a wind-power system called the Turbosail. Cousteau also pioneered oceanographic base camps, including Conshelf I, II, and III, which were underwater laboratories able to house *oceanauts* for weeks at a time while they conducted research.

Another of Cousteau's important achievements was to develop (with engineer Emile Gagnan) the Self-Contained Underwater Breathing Apparatus (SCUBA), a portable underwater breathing device consisting of a mouthpiece, hoses, and one or two tanks of air that are strapped to the diver's back. SCUBA diving ultimately opened up the oceans to millions of divers around the world. The SCUBA, along with the Turbosail and Conshelf laboratories, are just three of Cousteau's many innovations that changed the face of sea exploration.

Not only was Cousteau an active inventor and explorer, but he was also an environmental activist. For example, he helped to restrict commercial whaling and ran a successful campaign to eliminate the underwater dumping of nuclear waste in France. In 1974, Cousteau founded the Cousteau Society, a nonprofit membership organization based in the United States, with more than 50,000 members worldwide. The Fondation Cousteau (later changing its name to Equipe Cousteau) was founded in France in 1982.

Over his career, Cousteau was responsible for more than 115 television shows and 50 books, sharing his learnings from the sea with the world. He was a member of the U.S. Academy of Sciences and served as director of the Oceanographic Museum of Monaco for 30 years. In 1977, the United Nations awarded Cousteau the International Environmental Prize, and in 1985, he received the U.S. Presidential Medal of Freedom. In 1988, he was listed on the UN Environment Programme's Global 500 Roll of Honor for Environmental Achievement, and he received the National Geographic Society's Centennial Award. Cousteau was elected to the Académie Française in 1989, France's highest recognition for lifetime cultural contributions.

Hana Elliott

See Also: Environmentalism; Radioactive Wastes; Renewable Energy, Health Implications of; United Nations Environmental Programme

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CROPS AND VEGETATION, AIR POLLUTION DAMAGE TO

Air pollution has been a serious environmental problem ever since the beginning of the Industrial Revolution. While the effects of air pollution on human health are the most important concern, air pollutants also pose great risks to the growth of plants and yield of crops. It is estimated that air pollution damage to crops, ornamentals, and forests in the United States amounts to over a billion dollars annually.

Air pollution may come from anthropogenic or natural sources. Power plants, manufacturing facilities, chemical industries, and motor vehicles are major contributors to air pollution in the United States. Major air pollutants affecting crops and vegetation include ozone, peroxy-acetyl nitrate (PAN), sulfur dioxide, fluorides, and chlorine. Air pollutants may cause deleterious effects on plant physiology and metabolism due to the oxidizing potential of air pollution, particularly during periods of elevated concentrations.

Responses to air pollution vary among different plant species and crop cultivars. Annual leafy vegetable crops, forage crops and grasses, ornamentals, and flowers are among the most seriously damaged plants. The signs of air pollutant damage on plants include mottled foliage, “burning” at the tips of leaves, dieback of twigs, early leaf drop, delayed maturity, growth and yield suppression, and reduced quality of fruit and produce. Among the major air pollutants, ozone causes up to 90 percent of the air pollution injury to vegetation in the United States, adversely affecting plant growth and development and decreasing yield.

Ozone is a widespread secondary photochemical air pollutant (i.e., it is created by chemical reactions involving oxides of nitrogen and volatile organic compounds in the presence of sunlight). Its damage to plants was first observed in 1944, and it is probably the most significant plant-toxic air pollutant in Europe, North and Central America, and Asia. Global yield reductions due to ozone exposure range from 8.5 to 14 percent for soybeans, 3.9 to 15 percent for wheat, and 2.2 to 5.5 percent for maize, with global crop production losses estimated at 87 to 133 million tons (79 to 121 million metric tons) and valued at $11 to $18 billion annually.

Ozone enters plants through stomata during the normal gas exchange process. Symptoms of ozone damage include chlorosis (a loss of color in the leaf), mottling, bronzing, reddening, stunted growth, premature senescence, and early maturity. Young plants generally are the most sensitive to ozone, while mature plants are relatively resistant. Ozone stimulates respiration, inhibits oxidative phosphorylation, and changes membrane permeability. The type and severity of injury is affected by multiple factors, including length and concentration of ozone exposure, climatic conditions, and plant genetics. In general, susceptible plants are injured by exposure of 0.04 to 1.0 parts per million (ppm) ozone for four hours.

Next to ozone, PAN is the most significant plant-toxic oxidant. It is formed by oxides of nitrogen reacting with unsaturated hydrocarbons in the presence of sunlight. Like ozone, PAN is produced when sunlight reacts with various exhaust gases from motor vehicles and industries. PAN usually causes a collapse of tissue on the lower leaf surface. It also inhibits photorespiration, carbon dioxide fixation, cellulose synthesis, and the enzymes associated with photosynthesis and respiration. The common visible symptoms are chlorosis and necrosis in leaves, and the typical leaf marking is a glazing, bronzing, or silvering that commonly develops in bands or blotches. PAN is most toxic to small plants and young leaves, while the very young and most mature leaves are highly resistant. PAN damage to plants requires light before, during, and after exposure, and susceptible plants are injured by PAN concentrations of 0.01 to 0.05 ppm for an hour or more.

Sulfur dioxide is produced in large quantities from operations involving the combustion of coal and other fossil fuels. Sulfur dioxide enters the leaves mainly through the stomata, and the resultant injury is classified as either acute or chronic. Acute injury is caused by absorption of high concentrations of sulfur dioxide over a relatively short period, resulting in swelling of thylakoids and interference with the electron transport chain. The common visible symptom of acute injury is the water-soaked appearance of leaves, which later becomes necrotic. The color of the necrotic area can change from light tan or near-white to orange-red or brown.

Chronic injury from sulfur dioxide is caused by long-term absorption at low concentrations. Sulfur dioxide, which is oxidized and used in protein synthesis in the plant, reduces stomatal openings, and plants show initial reduction of photosynthesis and increased respiration. The symptoms occur as a yellowing or chlorosis of the leaf and occasionally as a bronzing on the undersurface of the leaves. The extent of plant injury increases as the duration and concentration of sulfur dioxide exposure increase. Susceptible plants are injured by exposures of 0.5 ppm of sulfur dioxide for 4 hours or by 0.25 ppm for 8 to 24 hours.

Fluorides are discharged into the atmosphere from the processing of ores containing fluorine during industrial operations such as the production of brick, tile, enamel frit, ceramics, glass, hydrofluoric acid, and fertilizers. Fluorides are accumulated in the plant tissues over long periods. They are absorbed by leaves and translocated toward the margins of broad leaves and to the tips of monocotyledonous leaves. The symptoms of injury are produced only after a critical level of fluoride is attained. The injury starts as a gray or light-green water-soaked lesion, which turns tan to reddish-brown. With continued exposure, the necrotic areas increase in size, spreading inward to the midrib on broad leaves and downward on monocotyledonous leaves. Accumulated leaf-fluoride concentrations of 20 to 150 ppm often injure susceptible plants, although resistant species will tolerate leaf concentrations of 500 to 4,000 ppm or more without visible injury. The extent of tissue damage is related to the dosage and the quantity of fluoride accumulated.

Chlorine injury is somewhat similar to that caused by sulfur dioxide and fluorides in that it is marginal and interveinal. Three types of damage generally can occur: (1) for broad-leaved plants, marginal necrotic, bleached, or tan-to-brown areas; (2) for grasses, progressive streaking toward the main vein in the region between the tip and the point where the grass blade bends, usually occurring alongside the veins; and (3) for conifers, chlorosis, tip burn, and necrosis in needles. For very susceptible plants, symptoms occur when exposed for two hours or more at chlorine concentrations ranging from 0.1 to 4.67 ppm. Chlorides do not accumulate in plant tissues after exposure.

The U.S. Clean Air Act identifies two types of national ambient air quality standards: the primary standards, which protect human health, and the secondary standards, which protect human welfare (principally animals, crops, vegetation, and buildings). The act also establishes federal and state environmental protection agencies and pollution control boards to monitor air pollutant concentrations and enforce the air quality standards. As a result, aggregate emissions of the principal ambient pollutants have been significantly lowered since the act was signed into law in 1970. However, according to U.S. Environmental Protection Agency's National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data, about 80 million tons (73 metric tons) of air pollution are still emitted nationally as of 2014. Thus, to reduce crop loss, it is important for researchers to continue identifying tolerant cultivars of important crops.

Qi Deng and Dafeng Hui

See Also: Air Pollution; Ambient Air Quality; Automobile and Truck Emissions and Controls; Clean Air Act; Electric Power Generation, Health Implications of; Environmental Protection Agency; Ozone and Smog in the Urban Environment

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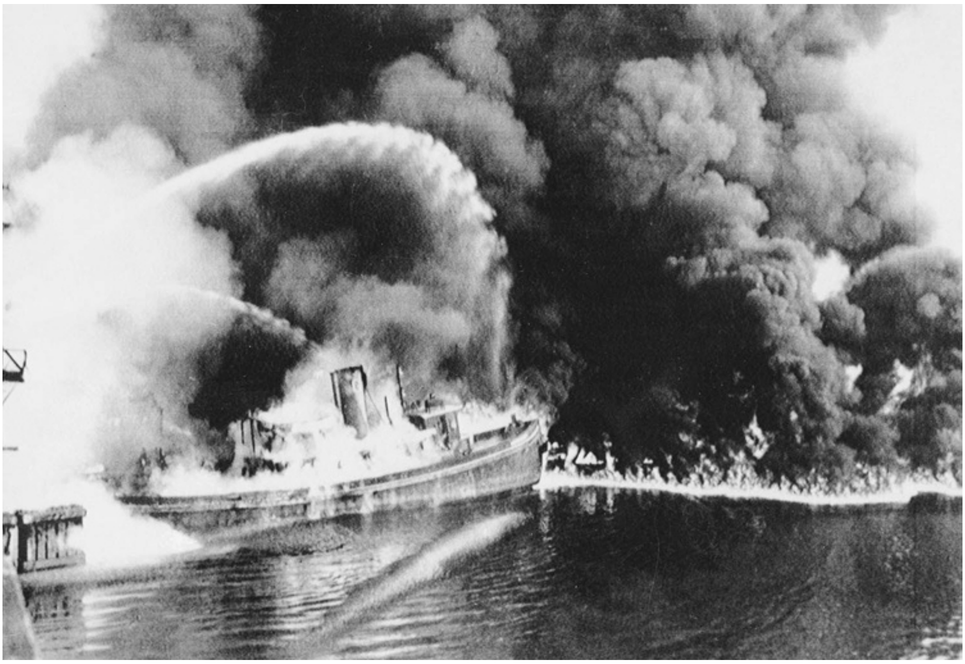
CUYAHOGA RIVER INCIDENTS

The Cuyahoga River has caught fire many times during the 20th century due to its contamination with industrial wastes. The river runs in northeastern Ohio through Akron and Cleveland, hubs of industrial development in the early to mid-1900s, and empties into Lake Erie. On June 22, 1969, a fire on the Cuyahoga River that burned for roughly 30 minutes sparked nationwide discourse on the need for environmental reform. Previous incidents of fire on the river typically only received local coverage, but a photograph of the burning river that was published in *Time* magazine that year led to the river being in the national spotlight.

The photograph of the Cuyahoga on fire is widely regarded as the image that set forth momentum to pass the Clean Water Act of 1972. Later reports noted, however, that the photograph was actually from a fire on the Cuyahoga 17 years earlier. The 20th century saw at least 13 fires on the Cuyahoga and countless river fires in many other industrialized cities. By the time the Clean Water Act passed, water reforms were already underway in a number of cities, and the 1969 Cuyahoga fire was one of the last of its kind.



Burning oil and other industrial wastes on the Cuyahoga River near downtown Cleveland, Ohio, in 1952. Concern about this and other fires on the river contributed to passage of the Clean Water Act. (AP Photo)

The Cuyahoga was polluted with waste oil and debris from nearby industrial operations, and these wastes caught fire below two railroad trestles that morning in June. The total damage from the incident was estimated at just around $50,000, small in comparison to a 1952 fire that caused an estimated $500,000 to $1.5 million in damages. The first reported Cuyahoga River fires were well over a century ago, and steamboats' captains remarked that if they shoveled the glowing coals overboard, the water would erupt in flames.

The pollution of the Cuyahoga had been building up for decades as Cleveland rose to an industrial powerhouse. It was common practice for refining operations to dump excess crude oil into the river, and untreated sewage also often made its way to the river as well. In 1963, well before the passage of the Clean Water Act, Cleveland leaders formed the Cuyahoga River Basin Water Quality Committee, and the city began funding efforts to remove debris from the river.

Although cleanup was underway, a federal report in 1968 designated the Cuyahoga as one of the most polluted rivers in the country. That same year, Cleveland residents voted to approve a $100 million bond issue for restoring the river. When the fire of 1969 occurred, the city was already on its way to prioritizing the river cleanup. More recently, the Cuyahoga was designated an area of concern by the U.S. Environmental Protection Agency's Great Lakes Water Quality Agreement, which has funded more than $13 million toward projects to restore the health of the Cuyahoga.

Mallory L. Daily

See Also: Clean Water Act; Environmental Protection Agency; Great Lakes Pollution; Industrial Effluents; Safe Drinking Water Act; Sewage Treatment and Disposal; Water Pollution

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CYANOBACTERIA TOXINS

Cyanobacteria toxins, or cyanotoxins, are poisonous substances produced by cyanobacteria. Cyanobacteria are a type of aquatic bacteria that obtain energy through photosynthesis, giving them a blue-green color that is associated with chlorophyll pigments. (Certain species may also appear red or brown due to the presence of phycobilin pigments.) Despite being photosynthetic and recognized by the common name blue-green algae, cyanobacteria are actually prokaryotic bacteria, not eukaryotic algae. (Prokaryotic cells do not have a nucleus and their DNA is located in the cytoplasm, whereas eukaryotic cells have a nucleus containing DNA.) Cyanobacteria are present in both coastal and inland water bodies and are typically found in lakes and estuaries. Cyanotoxins are commonly associated with hypereutrophic (nutrient abundant) conditions, often called harmful algal blooms.

Blooming cyanobacteria may produce cyanotoxins in amounts that are harmful or even deadly to humans and animals. Some specific types of cyanotoxins include cytotoxins (causing cell damage), dermatoxins (affecting the skin), hepatoxins (causing liver damage), and neurotoxins (damaging nerve tissue). Depending on the type of toxin and the amount of exposure, health effects in humans can be as mild as an upset stomach, vomiting, and skin irritation to as serious as acquiring neurodegenerative disease, liver failure, and death. In addition to direct exposure, there is concern over the bioaccumulation (build-up in tissues) of toxins in fish and shellfish that humans may ultimately consume.

The cyanotoxins most commonly found in the United States include anatoxins, cylindrospermopsin, and microcystins. Anatoxins are neurotoxins, and one of the most common variants is anatoxin-a, exposure to which may result in coordination loss, involuntary muscle contractions, and respiratory failure. Cylindrospermopsin is toxic to both the liver and kidney. Microcystins are the most common toxins found in freshwater and pose a threat to drinking and irrigation water.

As hepatoxins, microcystins can not only cause liver damage, but they can also affect kidney function and the reproductive system.

The U.S. Environmental Protection Agency (EPA) has listed microcystins and cylindrospermopsin on its Contaminant Candidate List, which identifies substances of potential concern requiring further assessment. Additionally, the EPA's June 2015 recommendations on cyanotoxins for water managers include a 10-day health advisory to be established if certain levels of microcystins and cylindrospermopsin are identified. For children under six years, a health advisory is recommended at concentrations of 0.3 µg/L microcystins and 0.7 µg/L cylindrospermopsin. For ages six and older, a health advisory is recommended at concentrations of 1.6 µg/L microcystins and 3.0 µg/L cylindrospermopsin.

Common cyanotoxins can be removed from drinking water with a variety of treatments, including physical removal and inactivation. The treatment varies depending on the type of cyanotoxins present. Physical removal methods include treatment with granulated or powered activated carbon, nanofiltration, and reverse osmosis. Inactivation of some cyanotoxins can be achieved by adding various chemical oxidants, such as chlorine and ozone.

Elise C. Hunter

See Also: Bioaccumulation of Environmental Contaminants; Drinking Water Quality and Regulation; Environmental Protection Agency; Environmental Toxicology; Neurotoxicants; Water Pollution; Waterborne Diseases; Watershed Management, Health Implications of; Wetlands and Healthy Waterways

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DDT EXPOSURE

DDT exposure refers to the exposure of people to the chemical compound dichlorodiphenyltrichloroethane (DDT), which was commonly used as an agricultural and public health insecticide until banned in the United States and many other countries in the early 1970s. Governments banned DDT after scientific evidence indicated that it caused serious environmental and wildlife problems and had the potential to adversely affect human health. The compound continues to be used in some countries, primarily in Africa, because of its effectiveness at controlling mosquitoes that spread malaria. The World Health Organization (WHO) advocates for its use in such cases, where, according to WHO, its malaria-fighting benefits outweigh its health and environmental risks.

Human exposure to DDT typically occurs by eating meat, fish, dairy products, and other foods contaminated by the compound. Exposure can also occur by touching (and thereby absorbing) DDT and by inhaling DDT. After DDT gets into the body, metabolic processes break it down into a number of chemical products, or metabolites. Among these metabolites is dichlorodiphenyldichloroethylene (DDE), which, along with DDT, gets stored in adipose (fatty) tissues in the body. Upon repeated, chronic exposure to DDT, these compounds tend to accumulate in the adipose tissues. In women who are pregnant, the compounds can be transferred to their fetuses, and in women who are breastfeeding, the compounds can be transferred to their nursing infants.

DDT has not been used legally in the United States since 1973. However, once in the body, DDT and DDE can remain at measurable levels for many years, with DDE persisting for even longer periods. According to a 2009 report published by the Centers for Disease Control and Prevention, only a small portion of the U.S. population had measurable levels of DDT in their blood serum during the data-collection period of 2003–2004. However, most people had measurable levels of DDE (evidence of previous exposure to DDT). The data indicated that the blood serum levels of these compounds were 5 to 10 times lower during the early 2000s than they were during the 1970s.

The health problems of DDT exposure are not as well documented and verified as the environmental problems. Low doses over limited amounts of time may cause no health problems. Low doses over longer periods have been linked to minor changes in levels of liver enzymes, though no definite health problems in humans. However, exposure to high doses—even a single high dose—can result in nausea, vomiting, tremors, and seizures. Studies conducted on laboratory animals suggest that high levels of DDT exposure may also lead to serious problems with the liver (including liver cancer), adrenal gland, and reproductive system. The degree of these serious risks in humans is uncertain, with the Environmental Protection Agency classifying DDT and DDE and "probable" human carcinogens. Ongoing research is being conducted to better quantify the health risks of DDT and its metabolites.

In the environment, DDT, DDE, and another breakdown product called dichlorodiphenyldichloroethane (DDD) can persist for very long periods—possibly hundreds of years—and these compounds can spread vast distances in the upper atmosphere. DDT can still be detected in many Superfund hazardous waste sites in the United States as a result of buried waste products dating to before the 1973 ban. DDT may also be found in U.S. air and soil as a result of its continued use as an insecticide in Mexico. (After the compound evaporates into the air in Mexico, it can travel through the atmosphere to the United States, where it then gets deposited on the ground with precipitation.)

As in humans, DDT becomes stored in the adipose tissue of wildlife. It further accumulates in increased concentrations at higher levels of the food chain so that predator species typically have a greater concentration in their bodies than prey species. During the 1970s, DDT was linked to the population declines of certain birds of prey species, including bald eagles. The main DDT-caused mechanism blamed for the population declines was eggshell thinning, leading to the breaking of eggs and the deaths of the unhatched birds. Rachel Carson's 1962 best seller, *Silent Spring*, exposed the hazards of DDT to both wildlife and humans and is credited with inspiring the modern environmental movement.

A. J. Smuskiewicz

See Also: Carson, Rachel; Centers for Disease Control and Prevention; Environmental Protection Agency; Environmentalism; Hazardous Waste Disposal; Persistent, Bioaccumulating, and Toxic Chemicals; Pesticides and Herbicides; Superfund Act

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DEEPWATER HORIZON INCIDENT

On April 20, 2010, an explosion and fire on the Deepwater Horizon offshore oil drilling rig, owned by Transocean and contracted by BP (formerly British Petroleum), killed 11 people, injured 17 others, and released 3.2 million barrels of oil into the northern Gulf of Mexico. (A barrel is 42 gallons, or 0.16 cubic meters.) The oil spill, located 41 miles (66 kilometers) off the Louisiana coast, contaminated an

An oil slick and smoke from the burning Deepwater Horizon oil rig in the Gulf of Mexico in 2010. Oil leaked from the ruptured underwater well for 87 days, becoming the worst oil spill in American history and causing extensive environmental damage. (AP Photo/Gerald Herbert)

estimated 68,000 square miles (176,000 square kilometers) of surface seawater and approximately 500 miles (805 kilometers) of coastline over an 87-day period, making this the worst oil spill in U.S. history. While a comprehensive study of the health and environmental impacts of the Deepwater Horizon incident will take years to complete, the immediate effects on the environment have been detrimental.

In October 2009, BP commenced drilling the Macondo well 5,000 feet (1,524 meters) below the Gulf's surface. The Deepwater Horizon, a dynamically positioned floating drill rig, replaced the existing rig in January 2010. Drilling continued until the beginning of April 2010, when the total depth of the operation had reached 18,360 feet (5,596 meters). In the days leading up to the incident, there was a series of complex and interdependent mechanical failures, human errors, engineering design flaws, and operational implementation mistakes that caused drilling system leaks, pressure buildup, and subsequent explosions. Specifically, various components of the pipe transporting oil from the well failed, causing leaks and uncontrollable flow of oil. Furthermore, the pressure tests that were supposed to identify such incidents reported false and inaccurate information that prevented employees on the rig from being aware of what was transpiring until the problem was well underway. Once the employees finally became aware of the malfunction, the uncontrollable influx of oil was diverted to a mud/gas separator instead of the preferred approach of discharging the material directly overboard. This diversion overwhelmed the separator because it could not process the uncontrolled volume of oil, resulting in the spread of hydrocarbons throughout the rig. Finally, the blowout preventer (BOP), which was responsible for preventing leaks from the well in emergency situations, failed for a number of reasons, including not having a sufficient battery charger. The failure of the BOP resulted in the release of millions of barrels of oil into the ocean, and because the leak was 5,000 feet (1,524 meters) below the surface, capping the well to stop the leak posed an unprecedented challenge.

As a result of oil having a lower density than water, much of the leaked oil reached the surface of the Gulf, where it was spread by wind and ocean currents, forming an oil slick that spanned about 5,000 square miles (12,950 square kilometers), roughly the size of Connecticut. An estimated 20 percent of the oil combined with bacteria, phytoplankton, and other substances in the Gulf water and sank to the seabed. Additionally, some of the oil remained in the column of water between the seabed and surface due to dispersants that were used during the cleanup to enhance biodegradation.

Dispersants are chemicals that break down oil into smaller particles so that microorganisms such as bacteria can more efficiently degrade them. As the oil biodegrades, it sinks below the surface, which often helps in the cleanup effort because it prevents the oil from washing up on the coast and contaminating coastal ecosystems. During the spill, not only were dispersants applied to the surface, a common practice during an oil spill, but dispersants were also applied at the source of the leak on the ocean floor. While over 1.4 million gallons (5,300 cubic meters) of dispersants were used during the spill, the extent to which the dispersants were successful in managing the spill and minimizing environmental impacts is unclear. While the dispersants removed much of the oil from the surface, their presence in the water column likely made the oil more accessible to wildlife.

After the Deepwater Horizon rig sank, workers from BP, Transocean, and governmental agencies promptly attempted to seal the leak 5,000 feet (1,524 meters) below the surface. A number of those attempts failed, including efforts to close the BOP with a remotely operated vehicle, to capture the oil spewing from the broken pipe with a device connected to another drilling vessel, and to plug the well by injecting heavy mud into the BOP. Finally, on July 15, 2010, the leak was successfully sealed by installing another BOP above the faulty one and drilling two relief wells that plugged the main well.

The overall impact of this unprecedented oil spill on human health and the environment is difficult to calculate due to both the magnitude of the spill and the depth at which the oil spill occurred. Much of the focus on human health effects has been on response workers and volunteers and on Gulf Coast residents who came in direct contact with the oil. Within a few days after the spill, the National Center for Environmental Health of the Centers for Disease Control and Prevention (also known as the CDC) coordinated with federal, state, and local authorities to establish surveillance programs to monitor any health effects attributable to the oil spill. The CDC identified several potential pathways of exposure: direct contact with the skin, inhalation of oil vapors or particulate matter generated by burning oil, and ingestion of contaminated water or food. The first two pathways, dermal exposure and inhalation, were determined not to pose a threat to residents. And to minimize the harmful effects of these two pathways to response workers and volunteers who came in direct contact with the oil, the National Institute for Occupational Safety and Health of the CDC developed guidelines and recommendations for minimizing exposure, such as wearing certain personal protective equipment. Regarding the third exposure pathway, ingestion of contaminated water and food, more than one-third of federal waters in the Gulf and many state-managed waters were closed for seafood harvesting shortly after the spill began. Following seafood safety testing, most Gulf Coast waters have been reopened.

Using funds received from a court settlement with BP, federal and state authorities are continuing to carry out projects to monitor, rehabilitate, and restore watersheds and ecosystems in the Gulf Coast region, including coastal areas in Alabama, Florida, Louisiana, Mississippi, and Texas.

Anthony G. Papetti

See Also: Disaster Preparedness and Response; Fish Consumption Advisories; Ocean Dumping and the Pacific Garbage Patch; Oil Spills, Health Consequences of; Water Pollution

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DEFORESTATION

Deforestation is the act of clearing a forested area of trees. Around the world, large-scale deforestation occurs to make room for agriculture, ranching, and human settlements. Deforestation can have profound adverse effects on human health and well-being, particularly for rural and indigenous communities that rely on forests, as well as for people around the globe. Billions of people rely directly on forests for their basic needs: food, energy, and shelter. Many other indirect effects can result from the loss of the services that forests provide (e.g., erosion protection, pollination, and local temperature control) and from increasing global temperatures and other impacts of climate change, which is in part driven by deforestation. Furthermore, evidence is emerging that deforested areas can act as incubators for insect-borne and other infectious diseases.

About 30 percent of the world's total land area is covered by forests. According to the UN Food and Agriculture Organization, more than half of the world's forests have been lost since 1950, and each year a net amount of around 12 million acres (5 million hectares) of forests are lost. Deforestation occurs around the world but is most prevalent in tropical and subtropical areas. Countries with especially high rates of deforestation include Indonesia, Brazil, and Congo.

There are different methods and scales of deforestation. The most damaging is slash-and-burn, where all trees are cut, and then the site is burned to remove all vegetation, usually to prepare the land for agriculture. In addition, in some cases, forests are clear cut (all trees cut), and then herbicides may be used to prevent

Deforestation in the Amazon rainforest of Brazil. Forests help reduce climate change by absorbing carbon dioxide from the air, and much of the world's population depends on forests for food, energy, and shelter. (iStockphoto.com)

new growth from competing with the desired use of the land (e.g., a tree plantation). Other deforestation methods are less intense—for example, selective logging, which employs different methods to remove particular desired trees from the forest while leaving other trees and vegetation intact and can have fewer adverse effects on the forest, wildlife, and surrounding communities.

In forest-dependent communities, deforestation can have many adverse effects on human health and well-being. Deforestation can (1) decrease access to plants and animals that are important for food and medicine; (2) increase the frequency and intensity of erosion and flooding; (3) reduce local water quality; (4) decreases access to wood fuels; (5) increase temperatures beyond healthy limits; (6) impede the ability to make a living from the sale of forest goods and services; (7) increase the spread of disease; and (8) remove the sources of long-held cultures and traditions. In addition, slash-and-burn methods can result in significant health impacts as smoke from fires impairs air quality, sometimes over large areas.

Forests and trees outside of forests are also critically important for human health because millions of people rely on them for food, both to increase nutritional quality and for diversity of diet. People gather fruits, nuts, insects, and other food products such as honey from forests, and they also hunt food animals that live in forests. In some places, forest debris such as leaves is used to feed domesticated animals. In addition, forests provide other products, such as latexes, resins, oils, and craft materials that are important to communities that live in forested areas. Forests are also home to plants and animals that provide important natural medicines as well as compounds that are used to develop medicines. For example, aspirin (used to relieve pain and reduce fever and inflammation) is derived from the bark of willow trees and Taxol (a common cancer drug) from the bark of Pacific yew trees.

Forests are particularly important to the water cycle. They absorb rain and release water vapor into the atmosphere, and they also absorb pollutants (e.g., pesticides from farms and oils from roads) from rainfall as it flows from uphill areas of the watershed. Their roots stabilize steep or loose soils, preventing them from washing into water sources or, in arid areas, blowing away. Forests are often better at stabilizing soils and absorbing water than agricultural plants. Without forests, especially in rural areas, severe rains are more likely to cause damaging flooding and erosion, and the quality of drinking water is more likely to be impaired, affecting human health locally. Flooding resulting from deforestation can also damage agricultural lands and reduce the amount of water that is stored by the landscape for future agricultural uses.

Deforestation also impedes the ability of some people to make a living from the sale of forest goods and services, which is key to keeping many communities out of poverty. Poverty alleviation is critical to improving human health because it increases the ability of people to pay for basic needs and services like food, shelter, clean water, and health care. Also, deforestation removes critical sources of energy from rural communities. About one-third of the world's population relies on wood to provide a cheap and easily accessible source of fuel for cooking, heating, and sterilizing water. Wood also provides affordable shelter for many people. However, overdependence on wood can contribute to deforestation in some areas.

The phenomenon of more trees translating to cooler temperatures is well documented in urban areas, and it is also presumably important in forested landscapes. Some scientists believe that in tropical areas, because humans are living close to their thermal tolerance, even small increases in temperatures, such as those resulting from local deforestation, can have a series of adverse effects on health. These effects include reducing the ability of local people to accomplish critical daily tasks such as tending agricultural fields.

Deforestation is also a cause of increases in infectious diseases. About 15 percent of emerging infectious diseases are directly associated with forests. Most of these forest-associated diseases are viruses, with HIV and dengue being the most common examples. The causes for the spread of infectious diseases are complex, but in general, deforestation changes the abundance and distribution of both disease vectors (e.g., the mosquito) and host. For example, in deforested areas, humans may be more likely to come into contact with forest-associated diseases and vectors, and with hosts that carry them, and disease vectors may be more likely to bite humans if their normal wildlife hosts have declined due to deforestation.

In addition, significant human health impacts can result from slash-and-burn deforestation as smoke from fires impairs air quality, sometimes over large areas. For example, in the tropical forests of Southeast Asia, the majority of landscape fires result from deforestation (tropical forests rarely burn naturally), and this region has experienced high mortality rates as a result of smoke from these fires.

Deforestation can also affect the health of people who live farther away from the deforested areas. The removal of forests from hillsides surrounding upstream water sources can cause landslides that result in large amounts of sediment and even pollutants entering the drinking water supplies of downstream residents. Deforestation can increase the prevalence of disease vectors that can infect local as well as more distant populations, and in urban areas and nearby, deforestation can reduce the ability of the landscape to absorb pollutants that impair air quality. Large-scale deforestation is also a primary cause of species loss, including species that are or could be important sources of medicines for human populations around the world. About 70 percent of the world's species live in forests.

Finally, deforestation is one of the leading causes of rising levels of greenhouse gases in the atmosphere, responsible for 6 to 17 percent of global carbon dioxide emissions per year. The world's forests store around 40 times more carbon than the amount that is released each year through the burning of fossil fuels. But as trees are cut down, they not only release their stored carbon as carbon dioxide into the atmosphere, but they are then also not available to absorb additional greenhouse gases from the atmosphere. This results in accelerating the pace and severity of climate change and associated effects on human health and the environment.

Melisa L. Holman

See Also: Ambient Air Quality; Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Drinking Water Quality and Regulation; Endangered Species and

Human Health; Greenhouse Effect and Global Warming; Infectious Diseases; Socioeconomic Status and Health

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DIOXIN POLLUTION

Dioxin is a form of pollution that is highly toxic. The term "dioxin" is used to refer to a group of chemical compounds with similar chemical and biological characteristics that bioaccumulate in the food chain and are persistent in the environment. Most human exposure to dioxin occurs through food consumption, mainly meat, dairy products, fish, and shellfish. However, the inhalation route of exposure (i.e., dioxin air pollution) can also be significant.

There are many different forms of dioxin, but they all fall under three related chemical families:

- Chlorinated dibenzo-p-dioxins (CDDs)
- Chlorinated dibenzofurans (CDFs)
- Certain polychlorinated biphenyls (PCBs)

CDDs and CDFs result from combustion processes, such as burning coal or oil in an electric utility power plant or burning household trash in a backyard barrel or pit. Forest fires can also produce CDDs and CDFs. PCBs, which are manufactured chemicals, are no longer produced in the United States, but they can still be found in certain products (e.g., transformers, capacitors, and oil for motors and hydraulic systems) manufactured before the 1979 PCB ban went into effect. (The ban stopped the production of PCBs and phased out most uses.) Dioxin can also be formed during industrial operations, such as the production of certain chlorinated organic compounds, and small quantities can be produced by the pulp and paper bleaching process.

The most toxic dioxin compound is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), and this is also the dioxin compound that has been most extensively studied. Often, when scientists discuss dioxin, they are referring to this specific compound. However, a health risk assessment of dioxin exposure usually takes into account all related dioxin compounds that present a significant risk and not just the 2,3,7,8-TCDD form.

Dioxin can contaminate drinking water and crops when airborne emissions from combustion processes settle on bodies of water. Also, wastewater discharged from some chemical factories may contain dioxin, potentially contaminating drinking and irrigation water. While dioxin levels in the air and water have been declining, these persistent chemicals break down very slowly, and some of the human exposures to dioxin that occur today may be from contamination that happened years ago.

Dioxin can cause cancer, reproductive and developmental problems, and impairment of the immune and endocrine systems. Additionally, short-term exposure to high concentrations can cause skin lesions (e.g., chloracne) and altered liver function. The half-life of dioxin in the human body is estimated to be between 7 and 10 years. There have been several incidents where dioxin released to the environment caused widespread health concerns, including a toxic cloud of dioxin-containing gases that descended on Seveso, Italy, in 1976, following a chemical plant accident. Dioxin was also widely dispersed when the herbicide Agent Orange, which contained trace amounts of highly toxic 2,3,7,8-TCDD, was used by the United States during the Vietnam War.

Detailed information about 2,3,7,8-TCDD, including research results and conclusions about health effects, can be found in the U.S. Environmental Protection Agency's *Integrated Risk Information System*, the National Institute of Environmental Health Sciences' *Dioxins Fact Sheet*, and the National Institute for Occupational Safety and Health's *Current Intelligence Bulletin 40*.

Richard Crume

See Also: Bioaccumulation of Environmental Contaminants; Electric Power Generation, Health Implications of; Environmental Protection Agency; Integrated Risk Information System; National Institute for Occupational Safety and Health; National Institute of Environmental Health Sciences; Open Burning of Waste; Persistent, Bioaccumulating, and Toxic Chemicals; Polychlorinated Biphenyls; Seveso Dioxin Incident

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DISASTER PREPAREDNESS AND RESPONSE

Disasters require quick response by emergency personnel to save lives and protect property. The coordination of emergency response activities among various federal, state, and local governmental agencies, aid organizations like the Red Cross, and even the National Guard can be a daunting task. To facilitate coordination and ensure the best possible response to disasters and emergencies, the U.S. government created the National Preparedness System (NPS).

Responding to the September 11 Terrorist Attacks

The ability of newly enrolled members to receive either an initial health evaluation or monitoring exam can help identify illnesses they may not have realized were 9/11-related.

An Interview with the World Trade Center Health Program

National Institute for Occupational Safety and Health

The World Trade Center (WTC) Health Program provides medical monitoring and treatment for responders to the September 11, 2001, terrorist attacks at the World Trade Center and related sites in New York City, the Pentagon, and Shanksville, Pennsylvania. Additionally, the program provides services for survivors who were in the New York City disaster area. We contacted the program to ask about their services and the health challenges faced by their members.

The WTC Health Program provides a variety of services to emergency responders, recovery and cleanup workers, and others exposed to the dust cloud in the disaster area following the September 11, 2001, terrorist attack. Which services do you feel have been most valuable in helping victims cope with the disaster and recover from injuries?

The WTC Health Program offers a variety of benefits to members, depending on their needs. The ability of newly enrolled members to receive either an initial health evaluation or monitoring exam can help identify illnesses they may not have realized were 9/11-related. For those certified (i.e., approved) for treatment for a 9/11-related illness, the treatment and medication benefits are vital. Many members also benefit from being a part of a program that understands their needs and experiences.

Some health conditions, such as cancer, may take years to develop. What steps has the WTC Health Program taken to monitor victims to ensure they receive the appropriate treatment in the future?

The program has been reauthorized for 75 years and covers many different health conditions that are noted on our list of WTC-related health conditions. In addition, many cancers have been added to the list. If an individual is diagnosed with cancer and is a member of the WTC Health Program, they can be evaluated to determine if the cancer is 9/11-related. If so, the member will be certified, and their treatment will be covered. We also offer screening for lung, breast, colon, and cervical cancer in addition to annual monitoring for responders and certified-eligible survivors. The WTC Health Program also has a process in place for individuals to petition that new health conditions be added to the list of WTC-related health conditions.

Among your nearly 75,000 members, what are some of the more common health issues you have encountered? Are you seeing many cases of post-traumatic stress disorder and other mental health issues?

On our website (cdc.gov/wtc), we provide information on a quarterly basis about our membership and the health conditions we are seeing in these members. This includes the top ten health conditions we're seeing in members, and mental health conditions are on that list. [Some of the more common conditions are rhinosinusitis, gastroesophageal reflux disease, asthma, sleep apnea, respiratory disorder, post-traumatic stress disorder, cancers, depression, WTC-exacerbated chronic obstructive pulmonary disease, and anxiety disorder. See Chapter 3 of the Policy and Procedure Manual (cdc.gov/wtc/ppm.html) for more information.]

What advice do you have for students who are interested in careers with the CDC in areas related to healthcare and research for victims of traumatic events like the September 11 attacks?

The WTC Health Program is managed by our Clinical Centers of Excellence and Nationwide Provider Network (cdc.gov/wtc/clinics.html). Individuals interested in careers with one of these institutions should reach out to them directly. Individuals interested in research funding opportunities should visit the WTC Health Program Research Gateway (cdc.gov/ResearchGateway).

The focus of the NPS is to provide the mechanism by which the National Preparedness Goal is achieved. The goal is to ensure a "secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk." The NPS strives to achieve this goal by creating a comprehensive and systematic approach to preparedness that builds upon existing preparedness and emergency response programs while creating new capabilities where needed. Activities under the NPS are divided into the following six steps:

Step 1: Identifying and Assessing Risk. A risk assessment is a process whereby all possible threats and hazards in a community are identified. By determining the likelihood of these events, emergency responders can plan and train for possible disasters and emergencies and have the appropriate equipment available to assist with recovery. Risk assessments differ from community to community. For example, in the United States, the greatest threat to an East Coast community might be hurricanes, whereas a Midwest community might be more concerned with tornadoes and a West Coast community with earthquakes and tsunamis. Table 3 lists the most common declared disasters in the United States since 1953, the year the federal government began keeping standardized disaster records and issuing disaster declarations.

Step 2: Estimating Capability Requirements. Once the risks have been identified, communities need to assess their ability to respond to disaster and emergency situations. This assessment is aided with "planning factors" that define the types of risk a community is concerned with and the capabilities required to respond. For example, a community might have a planning factor for the possibility of a chemical spill from a local oil refinery and the need to treat 500 nearby residents for chemical exposure. By knowing the probability of an accident and the number of residents who may need treatment, local emergency response personnel can procure the appropriate first-aid supplies and conduct emergency exercises with the local hospital.

Step 3: Building and Sustaining Capabilities. The next step is to ensure that communities have the equipment, personnel, and training needed to respond to local threats and hazards. This could include fire and safety equipment, evacuation centers, emergency food and water, front-end loaders for moving debris, portable generators, and emergency responders trained for likely disasters and emergencies. Because funds are rarely available to provide for every need, communities often enlist the services of local private and nonprofit organizations, faith-based groups, and aid organizations.

Table 3. Federally declared disasters in the United States, 1953–2016.

Incident Type	Number
Fire	989
Severe storm	894
Flood	773
Hurricane	313
Tornado	160
Snow	160
Severe ice storm	61
Typhoon	55
Drought	46
Earthquake	29
Coastal storm	24
Other*	81

*Freezing weather, toxic substances, fishing losses, mud/landslide, volcano, dam/levee break, human caused, tsunami, terrorist, chemical (Federal Emergency Management Agency).

Step 4: Planning to Deliver Capabilities. Planning to respond to a disaster or emergency can be quite a complex undertaking due to the number of organizations potentially involved and the need to respond quickly. The NPS systematically identifies organizations that can provide needed services, and it coordinates planning and training among these organizations. Additionally, the NPS ensures that the management structure and chain of command are clearly defined and the roles and responsibilities of individuals and organizations are unambiguous. Without careful planning, chaos may result while in the throes of an emergency, services may not be delivered, and injuries may occur.

Step 5. Validating Capabilities. Having a well-developed plan for disaster and emergency preparedness does not guarantee a successful response when an incident occurs. Practice exercises simulating real-life incidents are necessary to ensure adequate equipment and supplies are available, personnel understand their roles and responsibilities, and coordination is optimized. Additionally, emergency response personnel outside the community may be called upon from time to time to perform independent assessments of a community's readiness. Sometimes comprehensive evaluations are also conducted to measure progress toward implementing the disaster and emergency response plan.

Step 6. Review and Updating. Plans should be reviewed and updated on a regular basis because threats and hazards can change over time, aging infrastructure can introduce new threats and hazards, and vulnerable populations can shift within a community. It is essential that disaster and emergency planning adapt to these changing circumstances through an established process of regularly reviewing and updating plans.

The NPS can be thought of as an umbrella organization that comprises the activities of a number of disaster and emergency preparedness programs at all levels of government. One of the most important of these programs is the National Incident Management System (NIMS), which provides a standardized set of incident management practices designed to ensure a consistent approach across government, nongovernmental organizations, and the private sector. The goal of the NIMS is for all organizations to work together seamlessly, with clearly defined and uniform procedures, lines of communications, and command structures.

Also under the NPS is the Incident Command System (ICS), which is a management system designed to facilitate disaster and emergency response activities within six functional categories: command, operations, planning, logistics, intelligence and investigations, and finance and administration. The goal of the ICS is to integrate these response activities within a common organizational structure.

Another disaster and emergency preparedness system under the NPS umbrella is the National Prevention Framework (NPF), which focuses specifically on acts of terrorism on U.S. soil. The goal of the NPF is to avoid, prevent, or stop imminent terrorist acts, based on intelligence about a credible, specific, and impending terrorist threat or an ongoing attack. An example of an NPF response would be to install concrete barriers around a building to shield it from or deter a potential terrorist attack based on intelligence that one may occur. The NPF encompasses each of the following core capabilities: intelligence and information sharing; screening, search, and detection; interdiction and disruption; forensics and attribution; planning; public information and warning; and operational coordination.

The federal government alone cannot respond to all disaster and emergency situations. Instead, an integrated response is required involving all levels of government, local organizations, and nonprofit agencies. Individuals and families also have an important role to play by being prepared for disasters and emergencies in their communities and staying informed.

Richard Crume

See Also: Bioterrorism; Emergency Planning and Community Right-to-Know Act; Federal Emergency Management Agency; National Incident Management System; Natural Disasters

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DONORA INCIDENT

On October 27, 1948, a blanket of smog covered the town of Donora, Pennsylvania, for five days. Donora is about thirty miles (48 kilometers) southeast of Pittsburgh, and it was home to a zinc plant and a steel mill that often released smoke and fumes into the air. But the smog in October 1948 was a lethal mixture of carbon monoxide, sulfur dioxide, fluorine, and heavy metal dust that was trapped under a cold layer of air and mixed with a dense, natural fog. This toxic mixture burned the eyes, noses, and throats of the town's residents and eventually led to the deaths of 20 people.

A Key Moment in Environmental History

No single environmental event resulted in passage of the Clean Air Act or formation of the Environmental Protection Agency (EPA), but several events, including the Donora smog incident in 1948, played a major role. The significance of this role was underscored by former EPA regional administrator, W. Michael McCabe, who in 1998 commented:

> *Before there was an Environmental Protection Agency, before there was an Earth Day, before Rachel Carson wrote* Silent Spring, *there was Donora.*

The Donora incident helped popularize the concept of smog, originally a mixture of smoke and fog, which today is considered mainly ground-level ozone pollution.

Donora and the nearby town of Webster were home to roughly 14,000 people, and the towns shared a valley with the zinc plant and steel mill, both owned by U.S. Steel. Because of the topography of the land, the pollutants released into the air were often poorly dispersed. Some reports note that the chemicals emitted by the plants inhibited grasses and plants from growing in the area, and earlier in the century, landowners sued U.S. Steel for property damage and crop loss. U.S. Steel implemented strategies to monitor and mitigate the smog they produced, such as building taller chimneys and donating limestone to farmers with acidic soils, but a long-term solution aimed at protecting public health was never established.

The residents of this region had become used to smog collecting in the valley and to the smoky air that came with it, but the air pollution episode of 1948 was different. It was yellowish and thicker than what people were accustomed to, and by the end of the third day of smog, the area's eight doctors were overwhelmed with patients. Volunteer firefighters administered oxygen to people who had trouble breathing, and a temporary care center and morgue was set up in Donora's community center. People with respiratory problems and heart conditions were advised to leave town, as were the elderly, but the smog and increased traffic made for poor travel.

Five days after the smog episode began, U.S. Steel's furnaces were shut down, and later that day, rain aided in dispersing the smog. The local board of health reported roughly 6,000 cases of smog-related illness and 20 deaths. But the total number of fatalities was never confirmed because health officials did not account for the higher mortality rate in the months following the incident.

A report from the U.S. Public Health Service (PHS), released in October 1949, found inconclusive results about the cause of the smog. Because the zinc plant and steel mill employed around 5,000 local inhabitants, some reports say residents were reluctant to blame the local industry for fear of losing their jobs. However, around 100 people sued U.S. Steel after the PHS report was released. The company paid $256,000 in settlement funds in 1951 but accepted no responsibility. The plants closed by 1966 after it was no longer feasible to maintain operations due to declining metal prices, and today the population of Donora has dropped to about 4,800.

The deaths in Donora motivated the public to pressure federal agencies for air quality reform. In 1955, the Federal Air Pollution Control Act was passed, which was followed by the Clean Air Act of 1970. Thus, the town's motto became, "Clean Air Started Here." In 2008, on the 60th anniversary of the incident, Donora opened a museum dedicated to remembering the town's industrial past and the killer smog of 1948.

Mallory L. Daily

See Also: Air Pollution; Ambient Air Quality; Clean Air Act; Crops and Vegetation, Air Pollution Damage to; Hazardous Air Pollutants; London Smog Disaster; Ozone and Smog in the Urban Environment; Public Health Service; Respiratory Disease and Air Pollution; Seveso Dioxin Incident

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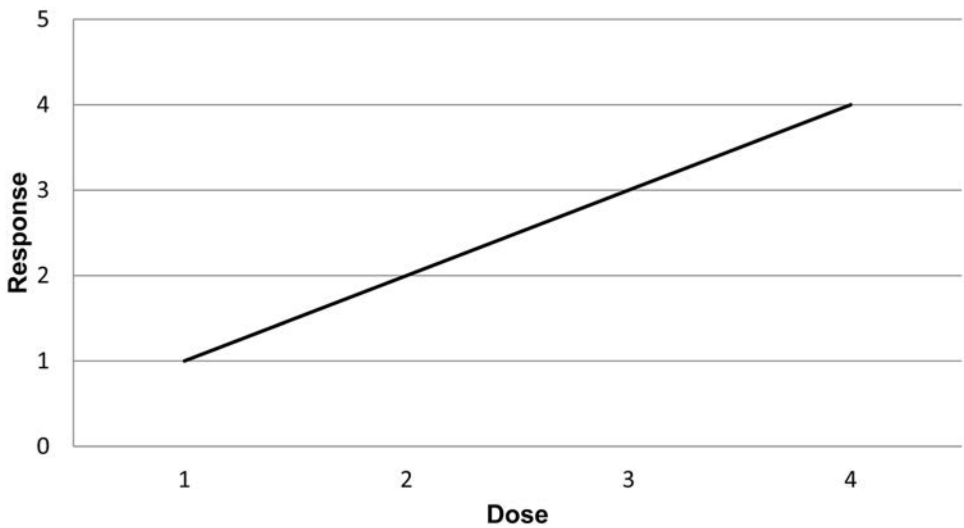
DOSE-RESPONSE ASSESSMENT

Environmental exposure to biological, chemical, or physical hazards creates the potential for vulnerable individuals to experience a range of undesirable health outcomes. The main goal of dose-response assessment is to attempt to describe the relationship between a specific exposure and health outcome. Dose-response assessment is a key principle in public health and has specific applications in environmental health.

In addition to other methods, individuals working in the fields of public and environmental health often use the criteria for causality outlined by Sir Bradford Hill in the mid-1960s as an approach to begin to understand causal relationships among characteristics being studied. Sometimes alternatively referred to as "biological gradient," the dose-response relationship is considered one of the criteria used to assess causality in public and environmental health.

Observation of dose-response between two factors provides strong evidence that the factors are associated with each other in some way. Dose-response is often depicted using a graph or curve plotting two factors together, with the exposure (dose) plotted on the horizontal *x*-axis and the health outcome (response) plotted on the vertical *y*-axis, as in the following simplified illustration.



Simplified dose-response curve illustration

This illustration provides a visualization of the relationship between the exposure and health outcome (dose and response) and how that relationship may change as exposure increases or decreases. (The above simplified relationship is linear, but in practice this is not always the case, particularly at high and low doses.)

Because there are many biological, chemical, and physical agents in the environment that have the potential to be hazardous to human health, measuring the level of exposure to any of the agents is essential in understanding the dose-response relationship. Measuring exposures is often referred to as quantitative exposure assessment. When measuring the exposure, the dose of the agent under study may be categorized in three ways: external, internal, and tissue. Each measure of dose is related to the other, but some distinctions must be made.

External dose is the amount of a substance that is administered to a subject, often an animal, during a controlled experiment. In an observational (nonexperimental) setting, the external dose is the amount of a substance that a person may be exposed to, such as the level of noise produced by a machine in a work area.

Internal dose is the amount of a substance that enters the body. Internal dose is often measured by taking a urine or blood sample and applying an analytic method to determine the amount of a substance that was present in the body at the time of the sample. For example, the internal dose of cadmium can be measured from a sample of blood. The dose would typically be measured in micrograms of cadmium per liter of blood, or µg/L. It is important to be aware of the units being used to measure the dose of the substance of interest.

Tissue dose is a measure of the amount of a substance found in a specific tissue, such as measured in a fat or bone biopsy. However, external and internal measures of dose are most commonly used.

"Response" is a term used to describe the observation of a health outcome or health event. Individuals are often grouped into those exposed and those unexposed to a particular substance or agent, and the number of health outcomes or events of interest that occur are counted in each group and compared. For example, people exposed to dust may experience coughing, and coughing would be considered the response being studied. In this example, the amount of dust could be measured and quantified, and the number of people who cough after being exposed to each level of dust could be counted. These steps are necessary to begin to assess the relationship between dust exposure and the health outcome of coughing. The goal of this assessment is to understand the level (dose) of dust exposure that causes people to begin coughing (response).

The health outcome or response could be an acute condition, like coughing, or it could be a disease that has a long period of development (i.e., a long latency period). For example, a researcher may be interested in a particular type of cancer as the health outcome to be studied. In addition to counting events or the development of a particular disease, the researcher might be interested in the severity of a health condition or level of a health indicator as the outcome. For instance, a researcher might measure blood pressure and body weight for a group of individuals and plot the levels of blood pressure against the body weight measurements to assess the relationship between the two characteristics.

Dose-response is used to describe an association between an exposure and outcome. For a dose-response to be present, there must be a relationship between the exposure and outcome such that for every unit increase in the exposure, there is an increase (positive dose-response) or decrease (negative dose-response) in the outcome. Consider food consumption and body weight. It is commonly known that if all other factors are held constant, increasing calorie consumption will result in an increase in body weight, and a decrease in calorie consumption will result in a decrease in body weight. Calorie consumption and body weight can be described as having a dose-response association. It is important to note that the dose-response relationship may not always be linear. The relationship could have a curve to it (e.g., it is considered a quadratic relationship), or it could have a threshold, where a certain level of exposure or dose of a substance must be experienced before any effect or outcome is observed.

Overall, dose-response assessment is a very useful tool in understanding the relationship between a specific exposure and health outcome, and the concept of a dose-response relationship is essential to the field of environmental health.

Jessica M. Madrigal

See Also: Environmental Toxicology; Integrated Risk Information System; Threshold Dose

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DRINKING WATER QUALITY AND REGULATION

Drinking water quality and regulation refers to the degree to which drinking water is safe for public consumption as well as the government regulatory requirements meant to improve and ensure safety. Drinking water in the United States is among the highest quality and safest in the world as a result of technologically advanced water sanitation systems and strict regulatory standards. Nevertheless, cases of unsafe water and resultant illnesses occasionally occur in some of the more than 150,000 public water systems serving more than 300 million people across the country. Such cases are usually attributed to accidents or other changes in the usual water treatment and delivery systems.

One such prominent case received much publicity in January 2016, when U.S. president Barack Obama declared a state of emergency regarding the lead contamination of the public water supply in Flint, Michigan. The contamination was caused by a change made in 2014 to the source of the city's water supply, switching it from Lake Huron and the Detroit River to the Flint River. Officials who decided on and implemented that change failed to order treatment of the Flint River water with anticorrosion chemicals. Thus, the water caused the interior surfaces of old pipes to corrode, resulting in lead from the pipes contaminating the water flow. Lead poisoning can cause serious developmental and learning problems in children, and an unusual number of such problems has been reported for children living in the area. In March 2017, Michigan state officials reached a court

Water Quality Worldwide

Following centuries of serious problems, water quality around the world has substantially improved, according to the World Health Organization (WHO). The WHO reports that 91 percent of the earth's human population had access to safe drinking water in 2015, with 2.6 billion people gaining access since 1990. Despite this progress, at least 1.8 billion people still relied on drinking sources contaminated with feces, and such contaminated water was responsible for causing more than half-a-million diarrhea-related deaths each year.

settlement with citizens and environmental groups over this issue, agreeing to provide almost $100 million to replace the problematic old supply pipes.

Numerous types of contaminants can make drinking water unsafe for public consumption, including microorganisms, chemical disinfectants, other inorganic and organic chemicals, and radionuclides. Examples of microbial contaminants include *Cryptosporidium*, *Giardia lamblia*, and enteric viruses, all of which have sources in human and animal feces and are causes of gastrointestinal illness. Disinfectant chemicals are typically added to drinking water by city authorities to kill microbial contaminants, although these chemicals accidentally added at excessive levels can be potentially dangerous. Such disinfectants are primarily chlorine-containing compounds, which can cause eye and nose irritation, stomach discomfort, nervous system conditions, and anemia.

A wide variety of inorganic and organic chemicals may contaminate drinking water from various pollution sources, such as agricultural runoff of pesticides and fertilizers, factory and other industrial discharges, erosion of natural mineral deposits, corrosion of household plumbing systems, and leaching from water storage tanks. A few examples of these contaminants are (1) arsenic, which increases the risk of cancer and circulatory and skin problems; (2) benzene, which can lead to cancer and anemia; (3) cadmium, mercury, lead, and other metals, which can cause kidney damage; (4) polychlorinated biphenyls, which can cause nervous and reproductive problems and increase the risk of cancer; and (5) trichloroethylene, which can lead to liver and kidney problems and cancer. Radionuclides, such as alpha and beta particles, radium, and uranium, may enter water systems from the decay of natural and human-made mineral deposits. These radioactive substances raise the risk of cancer and kidney damage.

Drinking water quality is regularly tested and monitored throughout the United States, usually by city and county officials following federal standards. If any violations of standards are found, public warnings are typically issued, and system owners and operators are given deadlines for correcting the problems. Common laboratory tests used to evaluate water quality include (1) total coliform and heterotrophic plate counts, which indicate and measure the presence of particular harmful bacteria, and (2) turbidity measurements, which can also indicate the degree of disease-causing microbial contamination. Other laboratory tests, such as plasma-atomic emission spectrometry, atomic absorption, ion and gas chromatography, gamma ray spectrometry, and liquid scintillation, are used to analyze water samples for the content of specific chemical contaminants.

In the United States, the Environmental Protection Agency (EPA) is the main federal agency charged with establishing and overseeing implementation of standards for drinking water quality. The EPA applies its standards to the practices of state and city governments and private companies engaged in testing, treating, and supplying drinking water. The agency reviews each drinking water standard every six years and, if necessary to maintain or improve public health, revises the standard.

The primary law through which the EPA obtains its authority for these regulatory activities is the Safe Drinking Water Act of 1974 (including amendments enacted in 1986 and 1996). This act, which applies to all above-ground and underground waters that are or might be used for drinking, authorizes the EPA to establish minimum health-related standards to protect tap water. These standards are known as the National Primary Drinking Water Regulations (NPDWR). All owners and operators of public water systems are required to comply with the NPDWR standards, which are based on the best available peer-reviewed scientific data.

An important part of the EPA's requirements regarding public drinking water quality is that owners and operators of community water systems publish annual water quality reports known as Consumer Confidence Reports. These reports, which water suppliers must send to their customers each year by July 1, are required to contain all information on water quality that is relevant to members of the supplied communities.

A.J. Smuskiewicz

See Also: Clean Water Act; Cyanobacteria Toxins; Environmental Protection Agency; Fluoridation of Water; Groundwater Pollution and Depletion; Lead Poisoning Prevention; Safe Drinking Water Act; Water Pollution; Waterborne Diseases

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DROUGHT AND DESERTIFICATION, HEALTH CONSEQUENCES OF

Drought is known to cause more deaths and displace more people than any other natural disaster, with more than 1.8 billion individuals around the world expected to experience absolute water scarcity by 2025. Although a natural cycle repeatedly occurring over the past 10,000 years throughout North America, droughts are expected to become more intense and more frequent due to anthropogenic climate change. Increased intensity in agricultural practices has also made the land less resilient to drought due to soil depletion.

In the 1930s, the United States experienced a severe drought that lasted nearly a decade, with four distinct drought events occurring in rapid succession without time for the land or people to recover. This "drought of record" for the nation encompassed 77 percent of its land area. The Great Plains region, covering parts of Colorado, Kansas, New Mexico, Oklahoma, and Texas, came to be known as the "dust bowl" due to the drought's exacerbated effects on poor land management practices, leading to severe dust storms. The definition of drought varies across the literature and can be broadly categorized as either meteorological, agricultural, hydrological, or ecological, depending on the primary area of impact and disciplinary approach.

Like other extreme weather events, droughts can lead to both short- and long-term health consequences. For example, individuals who experience economic and job losses may suffer adverse mental health effects, including stress, anxiety, and depression. Some studies have shown an increased rate of suicide among people living in farming communities due to the direct connection between their livelihoods and land degradation. A decrease in rainfall puts added pressure on farmers to used recycled water to irrigate their crops, which, if not handled properly, can increase the risk of pathogen contamination. Reduced precipitation can also result in increased exposure to disease due to the development of new stagnant vector breeding pools and the spread of valley fever, a lung infection caused by fungus in dry and dusty soil.

During periods of drought, wildfires and dust storms can lead to higher levels of airborne particulate matter. Poor air quality can worsen asthma and other chronic respiratory diseases and increase the risk of contracting respiratory infections such as bacterial pneumonia. As droughts often lead to decreased food production and reduced water quantity and quality, a corresponding increase in the incidence of illness and diminished living conditions can occur. The public health impacts of drought vary across communities due to preexisting socioeconomic factors that exacerbate or mitigate related effects. Related impact factors may include the structure and capacity of existing water systems, economic development in the region, and the presence of local social networks.

Desertification is the process by which arable dryland becomes desert due to climate change impacts such as drought and due to land-use practices such as overgrazing, overcultivation, and deforestation. The process of land degradation includes rapid changes in vegetation cover, shifts in plant community composition, and loss of soil resources. Functioning as a positive feedback loop, vegetation loss can modify regional precipitation patterns through decreased evapotranspiration and, in turn, exacerbate the impacts of drought. Land cover changes at this scale are destabilizing and presumed to be permeant and irreversible.

Around the world, drylands support a population of over 2 billion people, with 90 percent living in developing countries. Most studies show desertification affecting 10 to 20 percent of all drylands, with a geographic focus on Africa and Asia. Under the UN Convention to Combat Desertification, the United States has increased its own efforts to identify and mitigate national areas of ongoing desertification. Due to the common phenomena of drought and heightened risk of fire and land degradation throughout the western United States, more than 17 states west of the Mississippi River are currently experiencing or especially vulnerable to desertification. While many populations living in affected areas have learned to adapt to periods of drought, the process of desertification can overwhelm existing resources and provoke unprecedented stress on the land and people.

The rapid or permeant loss of drylands leads to several health consequences. Globally, desertification is a primary cause of famine and food insecurity, resulting in higher rates of malnutrition among vulnerable populations. Reduced food and water supplies can also lead to poor hygiene and increase the risk of waterborne and foodborne diseases. Because desertification leads to a permeant change in land use, many affected populations must migrate to new regions, threatening their mental and physical health and creating potential geopolitical issues. Without basic infrastructure, many individuals are more susceptible to extreme weather conditions and experience higher rates of respiratory disease due to atmospheric dust and other particulate matter. Just as with drought, migrating populations face a heightened risk of depression, anxiety, and trauma related to impoverished living conditions. Because the human health impacts from desertification are the result of complex interactions involving poverty, environmental degradation, and resource conflict, intervention strategies must be multidimensional.

Rachel L. Lamb

See Also: Ambient Air Quality; Asthma; Climate Change and Human Health; Deforestation; Infectious Diseases; Natural Disasters; Particulate Matter and Bioaerosols Pollution; Respiratory Disease and Air Pollution; Waterborne Diseases

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EARTH CHARTER

The Earth Charter is an ethical framework, guiding global citizens to respect and care for all life forms in the pursuit of a just, peaceful, and sustainable global community. As humanity's pace of development increases and population grows, the charter is meant to provide guidelines for sustainable development, international standards, and codes of ethics. It is the result of decades of multinational collaboration.

In 1987, the UN World Commission on Environment and Development stated the need for a new set of guidelines that would help the global community facilitate sustainable growth. At the 1992 Rio Earth Summit, a charter draft was begun, and in 1994, Mikhail Gorbachev (founder of Green Cross International and former president of the Soviet Union) and Maurice Strong (secretary-general of the Rio Summit and founder of the Earth Council) began drafting the framework, with help from the Dutch government and advice from individuals and organizations across the globe. In 1997, an independent commission was formed to bring the global community to agreement on the charter and to facilitate its creation. A first draft was released that same year at the Rio+5 Forum; a second draft was released in 1999, and the Earth Charter was officially approved in 2000 at the UN Educational, Scientific, and Cultural Organization

The Legacy of Maurice Strong

Maurice Strong, an industrialist and billionaire, worked for years to convince nations to take more responsibility for the environmental degradation he witnessed overtaking the world. He became secretary general of the UN Conference on the Human Environment in Stockholm in 1972 and 20 years later organized the UN Earth Summit in Rio de Janeiro. Strong went on to become the first executive director of the UN Environment Programme. Maurice Strong and Mikhail Gorbachev are credited with launching the first Earth Charter initiative, with support from the Dutch government. Born in 1929 in Oak Lake, Manitoba, Canada, Maurice Strong's family was so poor it collected lumps of coal that had fallen off of passing trains, using the coal to heat their house. He died in 2015 at age 86.

headquarters in Paris, France. It was formally released later that year at the Peace Palace in the Netherlands.

The Earth Charter is a six-page document that lays out the following four independent principles for a sustainable way of life for all individuals, organizations, institutions, businesses, and governments:

Respect and care for the community of life, calling on citizens to respect and care for all life forms, preserve our environment for future generations, and create just, peaceful, and participatory sustainable democratic societies.

Ecological integrity, including the preservation of ecological systems and prevention of harm to these systems, and the study of and education about sustainability.

Social and economic justice, including the elimination of poverty, the need for all economic institutions to allow equal opportunity for all, gender quality, and access to a natural and social environment.

Democracy, nonviolence, and peace, calling on citizens to advance a culture of tolerance and peace, incorporate sustainability practices into formal education, and support democratic institutions.

The Earth Charter's goals are promoted by the Earth Charter Initiative, which is a volunteer-based collection of individuals and organizations throughout the world with the goal of advancing the principles outlined in the charter. The initiative is supported by Earth Charter International, which is directed by a secretariat, based at the University of Peace in Costa Rica, and a council. Earth Charter International is advised by international leaders and funded by private donations from individuals and foundations.

Hana Elliott

See Also: Biosphere, Environmental Threats to; Environmental Justice; Environmentalism; Renewable Energy, Health Implications of; Sustainable Development and Health; United Nations Environmental Programme

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EARTH DAY

On April 22 each year, citizens all over the world celebrate Earth Day. It is considered to be the largest civic observance in the world, celebrated by over 1 billion people in 192 countries. Through celebrations, volunteer cleanup events, and peaceful demonstrations, the ultimate goal of Earth Day is to raise awareness about environmental issues.

Earth Day was founded on April 22, 1970, by the U.S. senator from Wisconsin, Gaylord Nelson. Inspired by the student-led antiwar protests of the 1960s, Nelson stated, "My primary objective in planning Earth Day was to show the political leadership of the Nation that there was broad and deep support for the environmental movement." The first Earth Day was a large-scale, grassroots event that generated participation by 22 million Americans. Throughout the United States, peaceful rallies and demonstrations were held, supported by celebrities such as actor Paul Newman and singer Pete Seeger, and Congress went into recess to take time to address environmental issues with their constituents. It was a success that not even Senator Nelson anticipated, later commenting that the remarkable thing about Earth day was that it organized itself.

Later that year, Congress authorized creation of the U.S. Environmental Protection Agency and passed the Clean Air, Clean Water, and Endangered Species Acts. Not only did Earth Day influence political organizations, but it also had enormous effect on nation's perception of environmental issues. According to polling conducted in 1971, 25 percent of Americans agreed that environmental issues should be a national priority, a huge increase over the same polling question asked in 1969.

By 1990, the Earth Day movement had gained global attention with the support of over 200 million people in 141 countries. This helped spur the global community to hold the first UN Earth Summit, taking place in Rio de Janeiro in 1992. In 1995, Nelson was awarded the Presidential Medal of Freedom, the highest honor awarded to American citizens, for his role in founding Earth Day.

Gaylord Nelson's Crusade for the Environment

In the 1970s, when a river was so polluted it actually caught on fire, Gaylord Nelson spoke up. He insisted that Americans deserved the safety that comes from knowing the world we live in will not make us sick. He warned that our leaders should never let partisan politics divert us from responsibility to our shared environment. He inspired us to remember that the stewardship of our natural resources is the stewardship of the American dream.

—William J. Clinton, "Remarks on Presenting the Presidential Medal of Freedom," September 29, 1995. Online by Gerhard Peters and John T. Woolley, *The American Presidency Project*.

An Earth Day celebration in Atlanta, Georgia. Earth Day is celebrated annually on April 22 by over 1 billion people around the world to raise awareness about environmental issues. (Russ Ensley/Dreamstime.com)

Today, a multitude of environmentally minded organizations promote the principles of Earth Day throughout the world, and many local organizations host their own Earth Day activities. In some communities, Earth Day has become a week-long or month-long event for festivals, celebrations, and various educational, environmental cleanup, and tree planting events.

Hana Elliott

See Also: Biosphere, Environmental Threats to; Earth Charter; Environmentalism; United Nations Environmental Programme

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EBOLA VIRUS

The Ebola virus is a serious infectious agent that causes Ebola virus disease, which is also known as Ebola hemorrhagic disease. The Ebola virus is one of at least 30 known viruses that are capable of causing viral hemorrhagic fever syndrome, which is often fatal.

The Ebola virus is an RNA virus with a lipid envelope. An RNA virus, as opposed to a DNA virus, is far more likely to mutate during its frequent replications due primarily to coding or copying errors. This high mutation rate increases the likelihood that the pathogen can cross species lines, gaining the ability to infect new hosts, including humans. The African-derived Ebola virus infections are transmitted from unknown animal hosts, possibly fruit bats, to humans or nonhuman primates (or both), probably through direct contact with body fluids like saliva or blood. As human encroachment and habitat destruction increases, the probability of Ebola and similar disease outbreaks rises.

The five separate species of the Ebola virus are *Bundibugyo ebolavirus*, *Reston ebolavirus*, *Sudan ebolavirus*, *Tai Forest ebolavirus*, and *Zaire ebolavirus*. The *Bundibugyo ebolavirus* caused the 2007–2008 outbreak in Uganda and has a reported 25 percent mortality rate. The *Reston ebolavirus* was initially isolated in monkeys from a single Philippine exporter, and it has not been documented to cause disease in humans. Most of the reported deaths from the Ebola virus were caused by *Sudan ebolavirus* and *Zaire ebolavirus*.

The Ebola virus is named after the Ebola River in the Democratic Republic of the Congo, where in 1976 an outbreak occurred in Yambuku. Following that outbreak, the Ebola virus was first identified as a possible new strain of the closely related Marburg virus. There have been 24 Ebola virus outbreaks since 1976, which the U.S. Centers for Disease Control and Prevention and others have succeeded in containing. For example, there was an outbreak in 1994 in Côte d'Ivoire and another in 1995 in Kikwit, Democratic Republic of the Congo. The 2013–2016 outbreak of *Zaire ebolavirus* in West Africa, principally in Guinea, Sierra Leone, and Liberia, is the largest outbreak to date, resulting in at least 11,310 confirmed deaths.

Ebola viruses are all zoonoses and damage the microvasculature, which results in greater vascular permeability. They are also all filoviruses and, therefore, have a filamentous form with a diameter of about 80 nanometers. (A nanometer is one-billionth of a meter.) The Ebola virus is not airborne, and it appears extraordinarily unlikely that it would ever become so. The incubation period for African-derived Ebola virus infections is typically three to eight days in primary cases (i.e., infection directly from the animal host) and slightly longer in secondary cases (i.e., infection from another infected human). Symptoms include fever, severe diarrhea, and vomiting, and infection is associated with a high mortality rate. Several vaccines are under development, including an experimental vaccine that is very promising for some strains of the virus.

Victor B. Stolberg

See Also: Centers for Disease Control and Prevention; Communicable Diseases; Infectious Diseases; Zoonotic Diseases

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E-CIGARETTES

An e-cigarette is an electronic nicotine delivery system that uses a battery and electrical heating element to vaporize a liquid called e-juice or e-liquid. The e-liquid contains propylene glycol or glycerol (or both), flavoring agents, and varying levels of nicotine, ranging from no nicotine at all to approximately 36 mg/ml. (However, only a small percentage of e-liquids on the market contain no nicotine.) Once the user draws on the e-cigarette, the e-liquid is vaporized and becomes a visible aerosol, often called a vapor (although it is not actually a gas), which is inhaled by the user. A thicker vapor cloud and stronger flavor can be produced by manually applying a few drops of the e-liquid directly to the heating element, a process called dripping.

There are several types of e-cigarettes, each differing by size, power, and customizability. Disposable e-cigarettes are designed to look similar to conventional cigarettes and contain a cartridge with an atomizer that heats the e-liquid. Rechargeable e-cigarettes are similar in design to disposables but can be recharged for repeated use and often have a component that regulates the duration or number of puffs. Pen-style e-cigarettes are slightly larger with greater battery capacity and have a refillable cartridge. The largest e-cigarettes are tank-style units that are often called "mods" because they can be modified. These units have larger rechargeable batteries, and users can customize them to control the battery size (e.g., by adding variable voltage batteries), the heating element, and other aspects that may affect safety. These modifications affect the battery life and the "throat kick" of the vapor (i.e., the sensation in the throat left by inhalation). Because of the variety of e-cigarette types and variation in e-liquid ingredients, including nicotine levels and type and amount of flavoring agents, it is difficult to draw general conclusions about the safety and risks of e-cigarettes.

E-cigarettes were first marketed in the United States in 2007, and by 2011, there were over 400 e-cigarette brands on the market. There are many unanswered questions about e-cigarettes, including (1) whether they are effective smoking cessation tools; (2) if they lead to smoking initiation among nonsmokers; and

(3) what the health risks are for users, nonusers exposed to secondhand vapor, and dual users who use e-cigarettes and also smoke conventional cigarettes. Scholars debate whether e-cigarette use among youths reflects experimentation with multiple tobacco products or actually encourages conventional cigarette smoking, but a recent longitudinal study found that e-cigarette users were more likely than nonusers to report initiation of tobacco use when the one-year follow-up was conducted. Regardless of whether it is a gateway to combustible tobacco use, vaping (another term for e-cigarette use) may expose users to toxicants and nicotine. Despite these concerns, consumption has increased rapidly, with e-cigarettes becoming the most commonly used tobacco product among U.S. adolescents in 2014. It was not until August 2016 that e-cigarettes were regulated as tobacco products by the Food and Drug Administration (FDA).

Although e-cigarettes do not involve combustion and, therefore, exposure to combustion-related chemicals and carcinogens (as do conventional cigarettes), e-cigarettes still pose health and safety risks. For example, the e-liquid contains several toxicants. One of those is diacetyl, a flavoring agent that is approved for use in foods (i.e., consumption through ingestion), but inhalation of the agent has been linked to the development of an irreversible respiratory disease, bronchiolitis obliterans, also known as “popcorn lung” disease. Studies have also found in e-cigarettes chemicals such as formaldehyde (a known carcinogen), particularly when these devices are used at high voltages. E-cigarette use also exposes users to other toxic chemicals, including acetaldehyde, acrolein, cadmium, lead, and nickel. Some studies report direct exposure to certain chemicals at levels that increase the risk of cancer-related health effects among e-cigarette users.

Evidence is also emerging about the potential effects of passive (i.e., secondhand) exposure to e-cigarettes. The following chemicals are inhaled by users and then exhaled into the environment, affecting indoor air quality and increasing the risk of secondhand exposure among nonusers: flavoring agents, formaldehyde, glycols, nicotine, and nitrosamines (a group of carcinogens found in tobacco). The few studies so far that have examined secondhand exposure (involving both laboratory and in-home studies) have shown that the levels of cotinine (a biomarker measure of nicotine exposure) for nonsmokers passively exposed to e-cigarette vapor are similar to those of nonsmokers exposed to tobacco smoke. Furthermore, these levels are higher than those found in nonsmoker homes with neither e-cigarette nor conventional cigarette smokers. The effects of passive exposure include respiratory ailments and symptoms such as nausea, headache, and irritation of the eyes and throat.

Another risk associated with e-cigarettes is poisoning, which can occur through ingestion, inhalation, or absorption (through skin or eyes) of the e-liquid. The Centers for Disease Control and Prevention reported that the number of e-cigarette-related calls to poison control centers increased from 238 in 2011 to 3,692 in 2014, and over half of the calls involved children under the age of five. Reported adverse health effects included nausea, vomiting, and eye irritation.

In addition to the health risks described here, there have been numerous cases of injuries resulting from the devices overheating or their batteries exploding during use or recharging. The U.S. Fire Administration reported that there were 25 separate incidents of explosion and fire involving e-cigarettes between 2009 and August 2014. Although none of these incidents were fatal, in most cases the injuries were serious, including first- and second-degree burns, fractured bones in the face and mouth, one case reporting loss of vision requiring surgery, and another involving possible paralysis. Reports indicate that the battery or other components were ejected at a rapid speed under pressure, and in many cases, the devices were of a specific type (vape pens) and were charging at the time of explosion. The Fire Administration posits that the cause of these explosions was failure of the lithium-ion batteries, although the impact of this failure is different in e-cigarettes compared with other devices equipped with lithium-ion batteries due to the unique positioning of the battery in e-cigarettes. This positioning leads to the battery or container being propelled across the room at a high velocity.

Due to the relatively recent emergence of this product, few definitive conclusions can be drawn about the environmental health risks of e-cigarettes. Yet, evidence continues to mount about the public health impacts of e-cigarettes and concerns about safety. Thus far, there is evidence that the risks vary by type of e-cigarette, by the contents of the e-liquid, and by the conditions of use (e.g., alone or in combination with cigarettes and the intensity of use). These issues point to the need for quality control and product standards to increase safety.

Georgiana Bostean

See Also: Cancer Risk from Environmental Exposure; Centers for Disease Control and Prevention; Formaldehyde; Tobacco Smoke, Secondhand and Thirdhand

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ECOSYSTEMS, IMPORTANCE OF

Ecosystems consist of a web of organisms that interact together and with the physical environment. Through these interactions, ecosystems provide "services" that are essential to life on the earth, including human life (see Table 4). Ecosystem services are grouped into four categories: supporting, provisioning, regulating, and cultural. Humans derive many health and well-being benefits from healthy ecosystems, including food, water, fuel, medicine, disease and climate regulation, and culture.

The availability of healthy food is a basic ecosystem service that greatly affects human health. Terrestrial and marine ecosystems, both natural and managed, supply the world's wild and cultivated foods. Human communities in poor, rural areas are often directly dependent on local ecosystems to supply sufficient nutritious food, but urban communities also ultimately rely on ecosystems for their food supplies. Lack of sufficient food plays a significant role in diseases in poor, developing regions that have high mortality rates. And in wealthier countries, human health is adversely affected by the substitution of natural, nutrient-dense foods with processed foods that supply insufficient nutrients and greater quantities of fat, sugar, and chemicals.

Around the world, many human communities rely on healthy ecosystems to protect and deliver supplies of clean water. Lakes and rivers capture, store, and deliver freshwater; forests stabilize soils to prevent excess sediments from entering water supplies; and wetlands naturally remove contaminants, such as chemicals and other toxins. Furthermore, when healthy ecosystems are replaced by other land uses, such as human settlements or farms, new sources of pollutants are introduced into water supplies, and fewer ecosystem services are available to protect that water. In some cases, ecosystems offer more effective and less costly water storage and purification than man-made systems.

Table 4. Ecosystem services.

Ecosystem Services Categories	**Supporting**	**Provisioning**	**Regulating**	**Cultural**
Definition	The basic natural processes that are required to support all other ecosystem services	The ability to provide products that humans rely on in sufficient quantity and of sufficient quality	The ability to maintain natural processes so that they support human life	The "nonessential" human well-being elements that ecosystems supply
Examples of ecosystem services	Nutrient cycling, soil formation, primary production	Food, water, wood and fiber, fuel, medicines	Climate, flood, and disease regulation; nutrient and waste management; water purification	Aesthetics, education, spirituality, recreation

For example, beginning in the early 1990s, the city of New York instituted rules and regulations against activities (e.g., deforestation) that would impact the ability of healthy upstream ecosystems to protect the quality of the city's water supply. Today, most of the city's water is filtered only by natural ecosystems, making it the largest unfiltered water supply in the United States. New York has determined that protecting these upstream ecosystems is less expensive and possibly healthier than investing in constructing and maintaining treatment plants and using higher levels of disinfecting chemicals to maintain water quality.

Ecosystems harbor plants and animals that are the sources of natural medicines and more than half of synthetic medicines. These natural and synthetic medicines are used by millions of people to treat and cure disease and for other medicinal purposes. For example, aspirin (used to relieve pain and reduce fever and inflammation) is derived from the bark of willow trees, digitalis (which treats heart disease) from foxglove plants, and Taxol (a common cancer drug) from the bark of Pacific yew trees.

Humans also rely on ecosystems to provide sources of fuel and energy, including the burning of wood and other biomass products, wind energy, and hydropower. These energy sources are important to health because they provide fuel for cooking food and boiling unsafe drinking water and heat in cold environments. In poor, developing countries, if sustainable sources of fuel are not found nearby, people must spend more time looking for fuel, thereby decreasing time spent cooking, growing food, or attending school.

The ability of infectious disease agents, such as viruses, bacteria, and parasites, to infect humans is regulated by healthy ecosystems. These disease agents can increase in prevalence when ecosystems are damaged because they are very sensitive to changes in their environments. In addition, ecosystems regulate the vectors that carry disease agents and spread them to humans, such as mosquitoes and rodents. For example, ecosystem degradation and landscape modifications (e.g., agricultural ditches that increase the pooling of water) can increase mosquito breeding sites. Deforestation also removes animals that prey on mosquitos or serve as alternate hosts, thereby increasing the mosquitos available to infect humans.

Natural ecosystems are also key regulators of our local and global climate. Forests, peatlands, grasslands, wetlands, mangroves, and seagrass beds all help to absorb carbon dioxide and other greenhouse gases from the atmosphere, therefore mitigating climate change. Most scientists believe that climate change will, on balance, have adverse effects on human health, including increased disease and mortality resulting from more frequent and severe heat waves, food and water scarcity, and the spread of infectious diseases.

Healthy ecosystems can also help communities adapt to the effects of a changing climate. Forests, wetlands, mangroves, and coral reefs help to protect at-risk communities from increasing temperatures (e.g., forests create shade) and from storms and rising sea levels (e.g., coastal ecosystems buffer wind and waves).

In addition to the more direct human health benefits, ecosystems also provide services that are important to human well-being and culture, including recreation, tourism, scenery, inspiration, spirituality, a sense of place, a source of traditions, and education.

Some scientists believe that increases in large-scale, human-caused impacts to ecosystems (specifically, habitat destruction and climate change) are degrading ecosystem services and driving major threats to human health and well-being around the world. The biggest of the threats resulting from the degradation and loss of ecosystems include increasing infectious diseases, drought, scarcity of safe food supplies, natural disasters, and forced human migration due to habitat loss and decreasing resources.

Melisa L. Holman

See Also: Climate Change and Human Health; Coral Reefs and Food Supply; Deforestation; Drinking Water Quality and Regulation; Drought and Desertification, Health Consequences of; Food Supply, Environmental Threats to; Greenhouse Effect and Global Warming; Infectious Diseases; Natural Disasters; Watershed Management, Health Implications of

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ELECTRIC POWER GENERATION, HEALTH IMPLICATIONS OF

Electric power generation has major health implications. While likely not as significant as health issues related to diet, exercise, and tobacco smoking, electric power generation is one of the greatest causes of illness in the United States, especially as the transportation sector becomes electrified and transportation pollution shifts from the tailpipe to the power plant.

Table 5 shows the percent of total electric generation contributed by various sources in the United States, as reported by the U.S. Energy Information Administration. These percentages have changed dramatically in the past five years and will continue to do so. Specifically, coal's percentage has dropped over five years, from around 50 percent to its current 30 percent of total generation, and this trend will continue as the use of renewable energy (hydroelectric, wind, biomass, solar, and geothermal) and natural gas for electric power production continues increasing. This increase has been rapid over the past five years. In contrast, nuclear power's percentage of total generation has held steady and will likely continue to do so for the foreseeable future.

Table 5. Percentage of total U.S. electric generation by various sources (2016).

Source	Percentage of Total Generation
Natural gas	34
Coal	30
Nuclear	20
Hydroelectric	6.5
Wind	5.6
Biomass	1.5
Petroleum	1.0
Solar	0.9
Geothermal	0.4

The life cycle (extraction, transportation, combustion, and waste disposal) of fossil fuels, such as coal and natural gas, causes myriad health problems. The extraction of coal is a dangerous process for workers and generates significant pollution. For example, 29 coal miners died in 2010 in an explosion at Massey Energy's Upper Bad Branch coal mine in West Virginia. Massey Energy's chief executive officer, Don Blankenship, was eventually criminally convicted for conditions leading to the explosion. However, coal miners face other health threats, such as black lung disease, even when the coal company management is not engaged in criminal activity.

Coal mining also creates air and water pollution, especially the mining technique known as mountain top removal, and the water pollution from coal mining contains carcinogens and other toxic substances that can cause birth defects and developmental disabilities.

The increased use of natural gas to generate electricity has largely coincided with the increased reliance on the extraction process known as hydraulic fracturing (commonly called fracking). In fracking, a mixture of water, sand, and chemicals, some of which may be highly toxic, are injected at high pressure into wells to fracture rocks and release the natural gas. An unfortunate consequence of fracking is that fracking chemicals and the natural gas itself have sometimes contaminated residential and commercial drinking water supplies. For example, a study by Stanford University scientists found that fracking and other oil and gas operations had contaminated groundwater with benzene, toluene, and other chemicals in Pavillion, Wyoming. Coal mining and fracking also release a significant amount of methane, which is a very potent greenhouse gas.

Hundreds of millions of tons of coal are transported to power plants by trains traveling long distances, sometimes over a thousand miles. In addition to the air pollution from the train locomotives, the coal train cars are uncovered, allowing coal dust containing toxic substances, such as lead and mercury, to be released into the air and deposited into nearby waterways. Coal train accidents can also release large volumes of coal into waterways.

Natural gas pipelines require compressors to move the gas. Compressors are a significant source of air pollution, particularly nitrogen oxides, often causing exceedances of the national ambient air quality standard near the compressor. Natural gas also can leak out of the pipelines and storage facilities. For example, a massive natural gas leak from a storage facility in the Los Angeles suburb of Porter Ranch, spanning a four-month period beginning in 2015, drove over 1,000 families from their homes, and some families believed they became sick from exposure to the natural gas.

Once natural gas and coal arrive at the power plant, it is combusted in the plant, creating huge volumes of air pollution. This air pollution includes greenhouse gases, the principal one being carbon dioxide, as well as methane and nitrous oxide. Additionally, the air pollution comprises fine particulate matter, sulfur dioxide, nitrogen oxides, carbon monoxide, lead, mercury, hydrogen chloride, sulfuric acid mist, and other noxious pollutants.

Fine particulate matter from coal-burning power plants causes over 12,000 premature deaths per year, greater than the number of deaths caused by alcohol-impaired drivers. Fossil-fuel power plants are also significant contributors to ground-level ozone, commonly referred to as smog. In 2016, 116 million people (over 35 percent of the U.S. population) lived in areas exceeding the U.S. Environmental Protection Agency's national ambient air quality standard for ozone. Ozone causes asthma attacks and other respiratory distress as well as premature mortality. Ozone and other air pollutants have contributed to the dramatic increase in asthma, and currently about 7.4 percent of adults and 8.6 percent of children suffer from this condition. Asthma rates are significantly higher among people living in poverty, suggesting an environmental justice issue.

Air emissions from coal-burning power plants represent the largest anthropogenic source of mercury, although mercury emissions are declining due to the decreasing use of coal for generating electricity and to recent rules to reduce mercury emissions. Mercury emitted from power plants can be deposited into waterways, and in 2007, a study found that as many as 600,000 babies per year had mercury levels high enough to cause irreversible brain damage, resulting from pregnant women eating mercury-contaminated fish.

Fossil-fuel power plants also create water and solid waste pollution. This includes thermal pollution (hot water discharged into cooler lakes and streams) and toxic metals, such as mercury, lead, selenium, arsenic, hexavalent chromium, and cadmium. Water becomes contaminated when it is used to move and dispose of coal ash and to operate some types of pollution control devices, such as scrubbers that remove sulfur dioxide, hydrochloric acid, mercury, and other contaminants from flue gases. Although these control devices reduce air pollution by removing pollutants from flue gases, they transfer the pollutants to discharged water and a waste slurry, resulting in no net decrease in pollution.

While natural gas-burning power plants produce very little solid waste, coal-burning power plants in 2012 generated 110 million tons (100 million metric tons) of coal ash and other solid waste (down from 140 million tons, or 127 million metric tons, in 2010). Over 100 power plant solid waste disposal sites have resulted in contaminated groundwater, wetlands, creeks, and rivers in multiple states. At many sites, the contamination has migrated off-site, resulting in pollution levels that exceed drinking and surface water quality standards. In addition to the leaking of contaminants from these waste sites, there have also been catastrophic failures. For example, in 2008, the Tennessee Valley Authority, a government-owned utility, spilled 1.1 billion gallons (4.2 million cubic meters) of toxic fly ash slurry at its Kingston coal-burning plant in Tennessee.

Commercial nuclear power plants use enriched uranium as their fuel. The mining of uranium can cause adverse health impacts to miners. Radon decay products are generally considered the greatest radiation-related health risk. For example, radon's alpha emitters can cause lung cancer. Other radioactive materials in mine tailings can also cause cancer as they seep into public water sources. In addition, silica dust and diesel exhaust pose risks of lung cancer and other illness for miners.

Although infrequent, nuclear power plant accidents can have catastrophic consequences. For example, in 1986, a nuclear reactor in Chernobyl, Ukraine, exploded, leading to huge releases of radioactive materials into the atmosphere. Following the explosion, the government evacuated about 115,000 people from the most heavily contaminated areas, and another 200,000 people were evacuated in subsequent years. Since then, a large increase in thyroid cancer has occurred among nearby residents who were young children and adolescents at the time of the accident. Other major accidents at nuclear power plants include the Three Mile Island incident in Pennsylvania in 1979 and the 2011 Fukushima Daiichi incident in Japan.

Nuclear power plants also generate radioactive solid wastes. Although these plants have operated for decades, no permanent storage facility exists to dispose of their high-level radioactive waste materials. Thus, the radioactive wastes are being stored at the nuclear power plants themselves, either in spent fuel pools or dry casks. In addition to concerns about exposure to radiation during normal plant operation (e.g., as radioactive wastes are transferred and stored), there are concerns about the possibility of terrorist attacks on nuclear power plants and spent fuel storage facilities. The U.S. Department of Energy's latest attempt to find a permanent radioactive waste storage facility involves a consent-based siting process where the federal government is negotiating with communities, tribal governments, and states to accept the radioactive wastes and become hosts of permanent storage facilities.

Robert Ukeiley

See Also: Air Pollution; Ambient Air Quality; Arsenic Pollution; Asthma; Black Lung Disease; Carbon Dioxide and the Carbon Cycle; Chernobyl Incident; Climate Change and Human Health; Coal Ash Disposal; Drinking Water Quality and Regulation; Environmental Justice; Environmental Protection Agency; Fukushima Daiichi Incident; Groundwater Pollution and Depletion; Hazardous Waste Disposal; Hexavalent Chromium; Hydraulic Fracturing; Land Disposal of Waste Materials; Lead Poisoning Prevention; Mercury Pollution; Nuclear Safety; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Radioactive Wastes; Respiratory Disease and Air Pollution; Thermal Pollution; Three Mile Island Incident; Toxic Substances in the Environment; Water Pollution

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ELECTRONIC WASTE DISPOSAL

When we throw away old or broken electronics, such as televisions, computers, and cell phones, they become waste materials that require disposal. Proper electronic waste (e-waste) disposal has become an issue of growing importance as personal electronics use has exploded worldwide over the past few decades. The United Nations-backed initiative, Solving the E-Waste Problem (STEP), defines "e-waste" as "a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use." The U.S. Environmental Protection Agency estimates that in this decade the quantity of e-waste has been increasing by between 5 and 10 percent each year.

Why Electronic Wastes Are Shipped Overseas

To reduce disposal costs, discarded consumer electronic devices are sometimes shipped overseas for reprocessing, often to less developed countries having few worker safety rules. In Guiyu, China, over 150,000 workers recover valuable metals from electronic wastes by burning the wastes in open piles. Toxic dust and gases contaminate the air, and acid baths used to extract metal from circuit boards run into local streams. It is estimated that over 80 percent of the children of Guiyu have lead poisoning. As China tightens recycling regulations, electronic waste reprocessing is shifting to other countries, such as India and Africa.

In the United States, only about a quarter of discarded electronics are collected for recycling, with the rest going to landfills or simply disappearing. Proper accounting for e-waste is notoriously difficult, and an estimated 6 million tons (5.4 million metric tons) of e-waste go missing each year globally. Where does it go? Much of it may be stored in homes, basements, and garages, perhaps due to uncertainty about disposal options or sentimental attachment. Additionally, some e-wastes are smuggled on the black market to less developed countries, where workers remove the precious metals (e.g., gold) and then dump the remainder. (These workers are often subject to unsafe and even illegal working conditions.) Unfortunately, some recycling centers in developed countries are just fronts for illegally shipping the e-wastes overseas.

Improper e-waste disposal can lead to significant health hazards. Although properly manufactured electronics are not toxic when in use, the production process can be incredibly complex, involving toxic materials that can contaminate the environment. (Silicon Valley is one of the leading areas for toxic Superfund site cleanups). Some of the toxic materials commonly used in electronics are lead, mercury, cadmium, and flame retardants. Flame retardants are a special concern because they bioaccumulate in our fatty tissues over time, leading to neurological disorders and endocrine disruption. (Many flame retardants are being phased out and replaced with safer chemicals.) Toxic metals are also known to cause neurological and other health problems in human.

A pile of discarded computer monitors. The toxic materials used in discarded computers, cell phones, televisions, and other electronics can leach into the environment when not recycled or disposed of properly. (Shutterstock)

A number of large corporations have earned praise from environmental e-waste watchdog groups for their e-waste recycling practices, including providing drop-off locations, prepaid return shipping, and guarantees to export only to legitimate recycling centers. When properly recycled, a number of important components can be recovered to be used as raw materials in the manufacturing of new devices, thereby reducing mining operations and associated environmental degradation.

In the United States, 25 states currently have e-waste recycling program legislation, and all but one state use the "producer responsibility" model, where the manufacturer pays for collection and recycling of their products. The exception is California, where consumers pay a fee at the time of purchase to be used for a statewide recycling program.

Aaron Dorman

See Also: Endocrine Disruptors; Environmental Protection Agency; Hazardous Waste Disposal; Land Disposal of Waste Materials; Lead Poisoning Prevention; Mercury Pollution; Municipal Solid Waste Management; Neurotoxicants; Persistent, Bioaccumulating, and Toxic Chemicals; Recycling; Superfund Act; Three Rs of Waste Management

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EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT

One of the most infamous environmental incidents of recent times was the 1984 release of toxic methyl isocyanate gas from a Union Carbide chemical plant in Bhopal, India. Thousands of nearby residents died from breathing the gas, and many more were injured. Because of this incident and a less serious release from a Union Carbide plant in Institute, West Virginia, Americans became increasingly concerned about emergency preparedness and the availability of information on chemical hazards. The U.S. Congress passed the Emergency Planning and Community Right-to-Know Act (EPCRA) in 1986 to address these concerns.

The act established emergency planning and reporting requirements covering industrial facilities using hazardous and toxic chemicals. The goal of the act was to improve chemical safety and protect public health by providing public access to information on chemicals, including their uses and releases to the environment. Generally, the chemicals covered by the act include those causing cancer or other adverse health and environmental effects. The act has the following four major sets of requirements:

Emergency Planning: Local governments are required to prepare emergency response plans establishing procedures for chemical accidents, and state governments oversee and coordinate preparation of the plans. Specifically, the plans must (1) identify facilities handling extremely hazardous substances, describe transportation routes for the substances, and present emergency response procedures; (2) designate community and facility coordinators; (3) establish emergency notification procedures; (4) define areas and populations that could be affected by a release; (5) list local emergency equipment and facilities and identify responsible personnel; (6) provide evacuation plans; (7) establish an emergency responder training program; and (8) provide a strategy for implementing emergency response plan exercises. This planning is required for any of 689 hazardous chemicals and chemical categories that are currently listed by the U.S. Environmental Protection Agency (EPA) and exceed threshold quantities. The plans must be updated annually.

Emergency Release Notification: If a release occurs that meets or exceeds the minimum reportable quantities established by regulation, the facility must immediately notify the Local Emergency Planning Committee (LEPC) and either the State Emergency Response Commission (SERC) or the Tribal Emergency Response Commission (TERC). The information to be provided during a notification includes the chemical name, whether it is considered an extremely hazardous substance, an estimate of the quantity released, the time the release took place, the duration of the release, whether the release occurred in air or water or on land, known or anticipated acute or chronic health risks, any medical advice for exposed individuals, appropriate precautions such as evacuation or sheltering in place, and the name and phone number of a contact person.

Hazardous Chemical Storage Reporting: The Occupational Safety and Health Administration requires employers to have safety data sheets for all hazardous chemicals stored or used. The EPCRA requires facilities having these safety data sheets for chemicals above specified threshold quantities to submit the sheets (or a list of chemicals covered by the sheets) to local fire departments, the LEPC, and either the SERC or the TERC. The information submitted must include acute and chronic health risks and hazards related to fire, to sudden releases of pressure, and to reactivity. Various requirements are in place for submitting annual inventory forms and for reporting about new chemical use, increased chemical use above threshold levels, and new information discovered about chemical hazards.

Toxic Chemical Release Inventory: The Toxics Release Inventory is a large database of information related to chemical use at industrial facilities, which must report annually on chemicals that are a threat to human health and the environment. The purpose of the inventory is to make information on toxic chemicals widely available to the public, governments, industrial facilities, and other organizations. The inventory includes information about releases of toxic chemicals (including lead, mercury, dioxins, and other persistent, bioaccumulative, and toxic chemicals) and activities involving energy recovery, pollution prevention, and the recycling, treatment, and transfer of toxic chemicals. Inventory data have been used in numerous ways, such as identifying sources of chemical releases, analyzing potential health and environmental hazards, planning emergency response activities, and encouraging pollution prevention. Details regarding covered facilities, toxic chemicals, and reporting thresholds are available online at the EPA's Toxics Release Inventory website (epa.gov/toxics-release-inventory-tri-program).

Although not under the EPCRA, the EPA's Risk Management Plan rule (mandated by the Clean Air Act) establishes related regulations and guidelines for preventing chemical accidents at facilities using certain hazardous substances. The goal of the rule is to help local fire, police, and emergency response personnel prepare for emergency releases of hazardous chemicals to the atmosphere. Facilities having listed toxic or flammable substances exceeding threshold quantities are required to implement a risk management program and submit their risk management plan to the EPA. The plan must include potential effects of an accidental release, an accident history, evaluation of potential release scenarios, and prevention and emergency response programs. Approximately 12,500 facilities have Risk Management Plans on file with the EPA, including petroleum refineries, gas plants, chemical manufacturers, water and wastewater treatment plants, chemical and petroleum terminals, food manufacturers, packing plants, and agricultural chemical distributors.

Richard Crume

See Also: Bhopal Incident; Cancer Risk from Environmental Exposure; Clean Air Act; Disaster Preparedness and Response; Environmental Protection Agency; Occupational Safety and Health Administration; Persistent, Bioaccumulating, and Toxic Chemicals; Safety Data Sheet; Toxics Release Inventory

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ENDANGERED SPECIES AND HUMAN HEALTH

Endangered species face a high risk of extinction because so few individuals of the species remain in the wild. The rapid increase in the number of endangered species is often cited as one of the world's worst environmental crises. The decline and extinction of species of all types profoundly affect the ability of ecosystems to function and provide services, including those important to human health (such as pollination and water filtration). It also limits the number of species, many of which are not yet discovered, that will be available in the future to provide products important to human health and well-being, such as medicines.

The International Union for Conservation of Nature (IUCN) evaluates the status of a wide range of species around the world to determine their risk of extinction according to set criteria. The IUCN rates species threatened with extinction as vulnerable, endangered, or critically endangered. According to the IUCN, in 2015, there were more than 22,000 threatened species in the world (see Table 6). However, in this study, the IUCN was only able to assess the status of 4 percent of all identified species. Of the taxonomic species groups where the IUCN was able to evaluate the status of more than 80 percent of described species, which included mammals, birds, amphibians, and gymnosperms (plants that produce seeds without seed coverings including conifers), between about 10 and 40 percent were classified as vulnerable, endangered, or critically endangered.

Table 6. IUCN threatened species in 2015 (vulnerable, endangered, and critically endangered).

Group	Number of Threatened Species	Species Assessed as Percentage of Species Described
Mammals	1,200	100
Birds	1,373	100
Reptiles	931	44
Amphibians	1,961	87
Fishes	2,248	39
Insects	1,011	0.5
Mollusks	1,949	8
Other invertebrates	1,204	Varies
Plants	10,896	7
Fungi and protists	11	0.04
Total	**22,784**	**4**

Scientists have identified approximately 1.9 million species on the earth, but many scientists believe that millions more remain undiscovered. Before humans appeared, approximately one species per every million species went extinct each year because of natural phenomena. Today that rate is as much as 100 times greater, and some scientists believe we are entering a sixth great extinction event, following the last major extinction period at the time of the dinosaurs, 65 million years ago. Some scientists estimate that at the current rate, half of all higher (multicellular) life-forms will be extinct by 2100. Scientists believe that this high rate of extinction is mostly due to human causes. Habitat loss is the primary cause of species endangerment and extinction. Other predominant causes include invasive species, overharvesting of species, pollution, disease, and climate change. The decline and extinction of species can affect human health and well-being directly through the loss of sources of food, medicine, energy, and livelihoods or indirectly through impacts to ecosystem services.

In 1973, the U.S. Endangered Species Act (ESA) was created to protect and recover endangered species and their habitats because of the aesthetic, ecological, educational, historical, recreational, and scientific values these species provide to human society. The U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service are charged with administering the ESA and have the responsibility for listing terrestrial, freshwater, and marine species as threatened or endangered in the United States. In addition, under the Convention on International Trade in Endangered Species of Wild Flora and Fauna, a voluntary, multilateral treaty, more than 180 countries and other parties have agreed to prevent international trade from endangering more than 35,000 species of plants and animals.

Some wild animal species that are sources of food for humans are threatened or endangered, especially fish species, such as Atlantic salmon and bluefin tuna. In addition, wild food species may rely on many other species in the food chain to sustain population levels that can support human consumption. If any species forming a link in the food chain declines or becomes endangered, such as plankton that is being harmed by changes in sea temperatures, the entire food chain can be disrupted, thereby affecting those species that are sources of food for humans and other species.

In addition, many traditional and prescribed medicines are derived from the world's species. In the United States, researchers estimate that more than half of the 150 most popular prescribed drugs contain or are derived from natural compounds. Yet, less than 1 percent of plant species have been tested for potential medicinal properties. Some experts estimate that because of the current rate of extinction, the field of medicine will fail to discover one potential major drug every two years. Loss of medicinal species before they are discovered could have untold impacts on future human health. For example, habitat loss has already impacted species with important medicinal values, such as the Pacific yew, rosy periwinkle, Houston toad, Gila monster, and horseshoe crab.

Conversely, the widespread use of wild species in traditional medicines, sometimes without proof of the efficacy of these medicines, is also a major cause of the endangerment of some species. For example, rhinoceroses, water buffaloes, Chinese alligators, sun bears, and tigers are all threatened or endangered at least in part because of hunting or illegal poaching for use in traditional medicines.

Species losses can also impact humans economically. For example, if a commercially important species, such as Atlantic salmon or bluefin tuna, becomes endangered, this affects not only the humans who eat the species but also those that make their living from the species. In addition, the decline of charismatic megafauna such as tigers, elephants, and great apes can impact ecotourism-based livelihoods as well as economies on a national scale. For example, the FWS estimates that wildlife-related recreation (e.g., wildlife watching, fishing, and hunting) generates more than $100 billion in revenue to the United States each year.

The decline and extinction of species also affect the overall level of biodiversity in an ecosystem, which is an important contributor to biological and human health. The diverse species in an ecosystem, from top predators to the smallest soil microbes, interact to contribute to the services that ecosystems provide, including essential services that humans rely upon (e.g., clean air, plentiful fresh water, climate regulation, pest and disease regulation, and pollination). Because of these interactions, if one species becomes endangered or extinct within an ecosystem, its decline or loss can affect many other species and, consequently, ecosystem services important to humans.

The disruptions caused by the loss of any one species can be hard to predict. The loss of some species may be more detrimental for an ecosystem than the loss of other species. When this occurs, the more detrimental species are known as keystone species because of the integral roles they play in maintaining overall biodiversity and ecosystem health (e.g., through maintaining healthy levels of food species through predation or pollination). Keystone species or species groups that are endangered or in decline include honeybees that pollinate many important edible plant species and coral reef species that provide habitats for many marine animals, including those important for human consumption. The loss of these species would have profound effects on biodiversity, ecosystem services that are important to humans, and even national economies.

Melisa L. Holman

See Also: Biodiversity and Health; Biosphere, Environmental Threats to; Coral Reefs and Food Supply; Deforestation; Ecosystems, Importance of; Food Supply, Environmental Threats to; Invasive Species and Human Health

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ENDOCRINE DISRUPTORS

The National Institute of Environmental Health Sciences defines "endocrine disruptors" as "chemicals that may interfere with the body's endocrine system and produce adverse developmental, reproductive, neurological, and immune effects in both humans and wildlife." The so-called endocrine disruption hypothesis was first popularized in the 1996 publication, *Our Stolen Future*, by Dr. Theo Colborn (1927–2014) and colleagues.

A striking example of the deleterious human health effects of endocrine disruption was the catastrophic administration of diethylstilbestrol (DES), a potent pharmaceutical estrogen, to 5 to 10 million pregnant women in the United States between 1938 and 1971. Female fetuses of pregnant women, so-called DES daughters, experienced increased risks for developing childhood clear cell adenocarcinoma of the vagina, otherwise extremely rare in adults and almost nonexistent in girls. DES daughters were also shown to experience increased risks for infertility, spontaneous pregnancy loss, ectopic pregnancy, and breast cancer, whereas "DES sons" were at heightened risk for genital abnormalities. Therapeutic endocrine disrupting compounds include ethinyl estradiol (used in pharmaceutical contraceptives), finasteride (used for treatment of benign prostatic hyperplasia and male pattern baldness), and estrogen (used in replacement therapy for postmenopausal women).

The endocrine system comprises ductless glands that synthesize and secrete chemical messengers—hormones—directly into the blood stream for dissemination across the body. Hormones bind specific receptors distributed throughout target tissues and organs, where they elicit various biologic effects. This hormonal signaling regulates myriad physiologic processes, including metabolism, reproduction, mood and behavior, and fetal and infant development. Endocrine disruptors are structurally similar to and compete with internally produced (endogenous) hormones for binding to nuclear and cell surface receptors, thereby stimulating (agonistic) or inhibiting (antagonistic) responses. Endocrine disruptors also mediate hormone synthesis and secretion, alter bioavailability of hormones in the blood stream, and modify the metabolism and excretion of endogenous hormones, thereby impacting concentrations circulating in the blood.

Many commercial and industrial pollutants are endocrine disruptors, as demonstrated by a large body of experimental in vitro and in vivo research. Much of the scientific research to date has focused on estrogenic, androgenic, and thyroid hormone effects. Bisphenol A (a plastic monomer more commonly known as BPA), benzophenones (ultraviolet filters used in sunscreens), and paraben esters (preservatives used in foods, drugs, and cosmetics) elicit weak estrogenic effects through estrogen receptor binding. In contrast, dioxins, which are by-products of industrial processes, increase metabolism and excretion of endogenous estrogen, and as such are antiestrogens. Trace elements, including arsenic, cadmium, lead, and mercury, also act as endocrine disruptors, binding to the estrogen receptor with agnostic or antagonistic effects. Other agents antagonize the androgen receptor, including several phthalate diesters (found in plastic goods and personal care products) and dichlorodiphenyldichloroethylene, a long-lived metabolite of the now largely banned organochlorine insecticide dichlorodiphenyltrichloroethane, better known as DDT. Changes in thyroid hormone levels, which are associated with altered bioavailability, are reported with exposure to polychlorinated biphenyls (industrial compounds used as dielectrics and lubricants and more commonly known as PCBs) and perfluorinated alkyl substances (industrial surfactants and commercial stain repellents), as just two examples.

Exposure to environmental endocrine disruptors is suspected by some investigators to contribute to human disease. Infertility in women and men, congenital malformations of the reproductive system, thyroid disorders, and cancers of the breast, endometrium, testicles, and prostate are most commonly reported. Additional evidence links endocrine disruptors to obesity, diabetes, and high blood pressure. Many endocrine disruptors are transferred across the placenta and pass into breast milk, fostering exposure among fetuses and newborns. Substantial experimental and observational research supports neurocognitive deficits and an increased risk for aberrant behavior in exposed offspring.

Despite a large and growing body of evidence, human health impacts for environmental endocrine disruptors remain controversial. Some investigators argue that unrealistic dose-exposure scenarios used in experimental research are not valid proxies for human experience and that chronic exposure to moderate and high doses of naturally occurring (biogenic) endocrine disruptors have no apparent adverse impact. Phytoestrogens, for example, are biogenic estrogenic compounds and include coumestrol, daidzein, and genistein, all found in soybeans, alfalfa sprouts, chickpeas, and flax seeds. However, although individuals may be exposed to limited quantities of individual endocrine disruptors with weak biologic effects, mixtures of such agents may manifest additive or even synergistic effects leading to human disease. Furthermore, hormones follow nonlinear dose-response curves (e.g., low or moderate doses having proportionally greater effects than high doses), and thus, low-level exposures to endocrine disruptors may be of greater biologic relevance than presumed. Clearly, additional investigation is necessary to resolve the discord and inform policymakers on effective strategies for protecting human health.

Michael S. Bloom

See Also: Arsenic Pollution; Bisphenol A (BPA); DDT Exposure; Dose-Response Assessment; Environmental Toxicology; Heavy Metal Pollution; Lead Poisoning Prevention; Mercury Pollution; National Institute of Environmental Health Sciences; Polychlorinated Biphenyls; Reproductive Health and Environmental Exposures; Toxicogenomics

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ENERGY STAR

Energy Star is a voluntary energy-efficiency labeling program for consumer products and buildings. By reducing the consumption of energy, the program reduces operating costs while cutting down on air pollution from fossil-fuel burning electric power plants, including climate change gases that cause carbon pollution. By cutting air pollution, the Energy Star program helps protect public health and the environment.

There are more than 70 categories of products that may qualify for the Energy Star label. The label can also be applied to new homes, commercial buildings, and industrial plants. The Energy Star program is operated by the U.S. Environmental Protection Agency (EPA), which started the program in 1992 pursuant to Clean Air Act Section 103(g). The U.S. Congress provided further authority for Energy Star in 2005 pursuant to Energy Policy Act Section 131. For a new home to carry the Energy Star label, it must be 15 percent more efficient than a home built to the 2009 International Energy Conservation Code and up to 30 percent more efficient compared to a typical new home.

For products, the Energy Star label is generally earned if the energy efficiency of a particular model is in the top 25 percent of all models in its category. In addition, the purchaser must be able to recover the additional purchase cost, if any, of that particular model through energy savings over a reasonable period of time. The EPA claims that the Energy Star program has had significant positive impacts, such as saving $295 billion on utility bills and preventing 2.3 billion tons (2.1 billion metric tons) of greenhouse gases through December 2013.

In 2010, Energy Star suffered a severe setback when the Government Accountability Office issued a report claiming that the Energy Star program awarded its label to fake products, including a gasoline-powered alarm clock and a space heater with a feather duster attached to it.

Since then, the Energy Star program has become more stringent. Now, to ensure program integrity, before the Energy Star label can be applied to a product or building, third-party certification must be obtained. For products, testing must be conducted at EPA-recognized laboratories, and "off-the-shelf" verification testing is performed each year for a percentage of Energy Star products.

For new homes, verification of energy efficiency must also be by a third-party organization. Verification can either follow a prescriptive path, where certain specific energy-efficiency improvements must be implemented, or a performance path, where a customized set of improvements must achieve a certain level of energy efficiency. Both paths require the completion of checklists applying to the thermal enclosure system, HVAC system quality installation rater, HVAC system quality installation contractor, and water management system builder.

For commercial buildings, certification is achieved by a licensed professional (i.e., a professional engineer or registered architect) using Portfolio Manager, an online tool used to measure and track energy and water consumption as well as greenhouse gas emissions. The licensed professional must verify that all energy use is accurately accounted for, building characteristics are correct, the building is properly functioning, and indoor environmental criteria have been met. Similar to commercial buildings, for industrial plants, a professional engineer must certify that the plant's energy performance meets Energy Star criteria.

According to the EPA, the Energy Star label is well recognized, with 85 percent of people in the United States recognizing the blue Energy Star label and 75 percent saying that the label was an important factor in their decision to purchase an Energy Star product. The Energy Star program is separate from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, which issues mandatory energy-conservation standards for various consumer products and certain commercial and industrial equipment. This program was created by the Energy Policy and Conservation Act of 1975.

The Energy Star program excludes many highly efficient "low-tech" products. For example, while electric and natural gas clothes dryers can obtain the Energy Star label, clothes lines and drying racks, which use no energy other than the sun, cannot. The Energy Star program is perhaps the best known among a number of energy-efficiency certification programs for buildings but not necessarily the most stringent. For example, under a certification program run by Passive House Institute US, a certified house will use 90 to 95 percent less energy for heating and cooling and 60 to 70 percent less energy overall.

Robert Ukeiley

See Also: Air Pollution; Carbon Dioxide and the Carbon Cycle; Clean Air Act; Climate Change and Human Health; Electric Power Generation, Health Implications of; Environmental Protection Agency; Greenhouse Effect and Global Warming

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ENVIRONMENTAL AUDITING

Environmental audits are used to determine whether a company is in compliance with federal, state, and local environmental regulations and laws and with company environmental policies. Additionally, environmental audits are sometimes performed for government agencies, universities, and nonprofit research organizations for the same purpose. Environmental audits help ensure that pollution is reduced to mandated levels so that exposure to workers and the public is minimized. Planning authorities, government agencies, and private businesses also use environmental auditing to determine the condition of a parcel of land and its suitability for some future use.

There are principally two types of environmental audits performed in the United States: compliance audits and management systems audits. A compliance audit is usually associated with determining legal compliance with federal, state, and local rules and permits, and they are typically multimedia in approach (e.g., involving air and water pollution and waste disposal). A management systems audit is used to assess whether an organization's management structure and commitment to environmental protection are sufficient to ensure compliance with all applicable rules and policies.

An early step in the auditing process is to decide whether an internal or external audit is required. An internal audit is performed by the organization itself, whereas an external audit is conducted by an independent entity (e.g., a consultant or firm that specializes in environmental auditing). Internal audits can help organizations identify and correct weaknesses in their environmental compliance plans. External audits can be used to assess the compliance status of an organization and whether fines or other penalties should be assessed.

After the need for an internal or external audit is determined, a team of auditors is formed, the rules or policies to be audited are identified, and a procedural plan for conducting the audit is developed. The audit results are communicated both verbally and in writing to management, and if deficiencies are noted, a detailed action plan for correcting the deficiencies is developed. Later, a follow-up audit may be performed to ensure all deficiencies have been corrected.

An Environmental Management System (EMS) is a framework that helps an organization achieve its environmental goals through consistent review, evaluation, and improvement of its environmental performance. The decision to implement an EMS is based on the assumption that ongoing review and evaluation of an organization's environmental performance will help identify and avoid future environmental problems before they occur and create continuous opportunities for improvement. This proactive approach can help reduce the risk of noncompliance and improve safety and health practices for employees. An EMS can also help address nonregulatory issues, such as energy conservation, and promote stronger operational control and employee stewardship.

The basic elements of an EMS include (1) reviewing the organization's environmental goals; (2) analyzing its environmental impacts and legal requirements; (3) setting environmental objectives and targets to reduce environmental impacts and to comply with legal requirements; (4) establishing programs to meet these objectives and targets; (5) monitoring and measuring progress in achieving the objectives and targets; (6) ensuring employee environmental awareness and competence; and (7) reviewing progress of the EMS and making improvements. By routinely repeating this cycle, continuous improvement in environmental management and compliance will occur.

Environmental auditing was initiated in the United States in the 1970s to quantify risks associated with a company's environmental practices and procedures and to assess compliance with applicable regulations and policies. At the time, the U.S. Securities and Exchange Commission (SEC) encouraged environmental auditing as an improvement tool for companies trading in stock markets, particularly those companies that were potentially poor environmental performers and risks to investors. To help determine the financial stabilities of companies, the SEC encouraged the results of environmental audits to be included in year-end financial reports.

Joe Elkins and Richard Crume

See Also: Environmental Impact Assessment; Laboratory Quality Assurance; Occupational Safety and Health

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ENVIRONMENTAL EPIDEMIOLOGY

Epidemiology is the study of the distribution and determinants of health, morbidity (rate of disease), and mortality in human populations. Environmental epidemiology focuses on the environments where people live, work, and play. Specifically, this branch of epidemiology examines how environmental exposures in air, food, water, or land contribute to or are associated with illnesses or diseases. These exposures are typically outside of the control of an individual and occur at low levels in the surrounding environment. Environmental epidemiology studies evaluate associations between environmental exposure and various health outcomes through testing hypotheses and providing analytical evidence.

Environmental epidemiological studies provide a unique perspective on environmental determinants of health outcomes. However, there are some limitations in the epidemiological approach that should be considered when evaluating environmental exposures and health outcomes:

- Long Latency Periods: the time interval between exposure and disease onset can be very long (sometimes decades), especially when considering cancer outcomes.
- Low Incidence and Prevalence: the cases of outcome of interest may be infrequent, making it difficult to ascertain the effect of exposure on health outcomes.
- Difficulties in Exposure Assessment: the methods for measuring exposures, especially low-dose exposures, may require the use of indirect estimates of exposure (i.e., distance from exposure source).
- Non-Specific Effects: adverse health outcomes may be associated with one or many different environmental exposures.

Despite these limitations, epidemiological studies have been extremely useful in environmental health investigations. One example of this is the largest waterborne disease outbreak in documented U.S. history. On April 5, 1993, the Milwaukee Department of Health had numerous reports of gastrointestinal (GI) illness, resulting in widespread absences in schools and hospital employees. With a nonspecific effect like GI illness, public health officials had difficulty determining the source of the exposure. Two days later, laboratory results identified the presence of cryptosporidium (a microscopic parasite) in stool samples from residents in the Milwaukee area. Because of how widespread the GI illness was and the presence of cryptosporidium in stool, drinking water was deduced as the culprit, and drinking water records were analyzed. As a result, a boil-water order advisory was issued for Milwaukee, and the southern water plant was temporarily closed on April 9. In total, there were an estimated 403,000 people who experienced GI illness (mostly watery diarrhea and abdominal cramps) during the outbreak and 69 deaths. Following the cryptosporidium outbreak, the Milwaukee Water Works renovated and improved their water sanitation facilities. With the use of water

Cryptosporidium

Cryptosporidium, or "crypto," is a microscopic parasite that can cause watery diarrhea, stomach cramps, dehydration, nausea, vomiting, fever, and weight loss. Symptoms last approximately one to two weeks in people with healthy immune systems. Crypto can be found in water, food, and soil that have been contaminated with human or animal feces infected with the parasite. Outbreaks of crypto have been linked to both drinking water sources and recreational water use. Because the parasite is protected by an outer shell, it can survive for long periods of time outside the body and is tolerant to chlorine disinfection.

plant records (exposure data) and the high incidence, public health officials were able to use epidemiological methods to link the cryptosporidium outbreak to an environmental exposure source.

Some environmental exposures, like cryptosporidium, affect health soon after the initial exposure. However, the effects of exposure to other environmental hazards, such as arsenic, can take years to emerge. Arsenic naturally occurs in the environment but can also be found in some man-made products, like pesticides and wood preservatives. For the general population, food and drinking water are the largest sources of arsenic exposure. The low doses that naturally occur in the environment, including drinking water, are generally not harmful. However, the naturally occurring arsenic levels are much higher in some regions of the world, including Bangladesh and Taiwan. Environmental epidemiology studies in areas where levels of arsenic in drinking water are high have found these long-term exposures to higher arsenic levels may result in changes in the skin (hyperpigmentation, hyperkeratosis, corns, and warts) and cancer.

Because many environmental exposures are involuntary, it is important to have research and a methodology that can evaluate the potential harmful impact of these exposures on human health. Though there are some challenges in conducting environmental epidemiological studies, these studies help identify the biological, chemical, physical, and social factors that contribute to environmental exposures as well as the health outcomes that are associated with these exposures. The results of environmental epidemiological studies will help public health officials find ways to reduce or eliminate these environmental exposures.

Jyotsna S. Jagai and Alison K. Krajewski

See Also: Arsenic Pollution; Drinking Water Quality and Regulation; Environmental Health Profession; Waterborne Diseases

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ENVIRONMENTAL HEALTH PROFESSION

The National Environmental Health Association (NEHA) represents about 5,000 professionals in the field of environmental health within the United States, with job descriptions ranging from academic research to wastewater management and food inspection. NEHA disseminates job opportunities, offers continuing education and credentialing programs, and publishes the *Journal of Environmental Health*, which includes both professional news and innovative science sections. The primary interest areas of NEHA are as follows:

- Air quality
- Water quality
- Food safety
- Healthy homes
- Preparedness
- Climate change
- Vectors and pests
- Health tracking

There are also state-level affiliates of NEHA, providing support for environmental health professionals at a more local level. A related organization representing health professionals, including environmental health, is the American Public Health Association, which has about 25,000 members and publishes the *American Journal of Public Health*.

Careers in the environmental health field can be categorized into four sectors: government, private, nonprofit, and academic. These career fields are described next.

Government Sector Careers. Environmental health professionals are employed in environmental health departments at all levels of government, from municipal and county government (e.g., the Los Angeles Department of Public Health) to state government (e.g., the California Department of Public Health) to federal government (e.g., the Centers for Disease Control and Prevention). Additionally, environmental health professionals may serve in other branches of government having environmental programs (e.g., the National Park Service and the National Oceanic and Atmospheric Administration). A wide range of federal environmental health jobs is listed at USAJOBS (https://www.usajobs.gov), the federal government's official employment website. Student internships are also available at many agencies.

Private Sector Careers. There are multiple specializations within the field of environmental health, and each has potential for distinct employment opportunities in the private sector. For example, toxicologists are employed at chemical and pharmaceutical companies to ensure the design of safe products, environmental scientists and engineers work at many different types of companies to design and build energy and environment infrastructure, and epidemiologists are employed at consulting firms to conduct research on population exposure to environmental toxicants. Opportunities in the private sector for work in the environmental health field are almost endless.

Nonprofit Sector Careers. Many environmental advocacy organizations hire environmental health professionals, recognizing the fundamental link between environmental conditions and human health. The large number of such organizations include the Environmental Defense Fund, Natural Resources Defense Council, Environmental Working Group, Ocean Alliance, and Sierra Club.

There are also many community nonprofit organizations focusing on local environmental issues.

Academic Sector Careers. Many professionals in the environmental health arena are working in academia, not only contributing to a better understanding of environmental health challenges but also helping train the next generation of environmental health leaders. There are multiple types of academic institutions, ranging from teaching-focused liberal arts colleges to research-intensive universities awarding doctoral degrees. Multiple career paths for environmental health professionals exist within these institutions, including classroom instruction, research, and campus environmental compliance and sustainability.

Matthew O. Gribble

See Also: Brower, David; Brown, Lester; Carson, Rachel; Carter Center; Chadwick, Alan; Children's Environmental Health; Cousteau, Jacques-Yves; Environmental Epidemiology; Environmental Protection Agency; Environmental Toxicology; Environmentalism; Fuller, Buckminster; Gore, Albert, Jr.; Lappé, Frances Moore; Leal, John; National Center for Environmental Assessment; National Institute of Environmental Health Sciences; Occupational Safety and Health; Public Health Service; Snow, John; Terry, Luther L.; United Nations Environmental Programme

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ENVIRONMENTAL IMPACT ASSESSMENT

In 1970, U.S. president Richard Nixon signed the National Environmental Policy Act (NEPA) into law. After decades of severe environmental degradation and contamination across the country, NEPA signaled a new effort to promote a harmonious relationship between humans and nature for both current and future generations of Americans. At the center of NEPA is a mandate for all federal agencies to act as responsible stewards of the country's natural resources. However, according to the law, responsible stewardship does not necessitate environmental protection at any cost. Environmental, social, and economic concerns must be evaluated and reconciled to manage tensions between limited resources and a rapidly changing world. The most rigorous tool used to evaluate competing considerations is the environmental impact assessment process.

Keeping Up with Federal Actions

Often the policymaking process for environmental health and other federal rules seems far removed from the average citizen. However, the goal of the *Federal Register* is to make policy decisions transparent and accessible to the American public. Serving as the daily "newspaper" of the federal government, the National Archives and Records Administration publishes in the *Federal Register* all federal agency regulations, proposed rules, public notices, executive orders, proclamations, and other presidential documents. Any person or organization has the right to comment on proposed rulemaking in writing or at public hearings, and the agency responsible for the rulemaking must respond to significant issues raised in these comments, thereby allowing citizens to directly participate in and influence the process of establishing rules and policies.

The White House Council on Environmental Quality (CEQ) is charged with overseeing the implementation of NEPA in collaboration with all federal agencies. Under NEPA, when an agency proposes an activity on public land, it is required to determine whether the activity will affect the quality of the human environment. NEPA also applies if the proposed activity crosses public lands, is funded in part or whole by federal money, or affects air or water quality regulated by federal law. The first step under NEPA is for the agency to assess the project proposal to determine the appropriate level of analysis: categorical exclusion (CE), environmental assessment (EA), or environmental impact statement (EIS).

A CE applies to any routine action that is already determined by the agency to cause no individual or cumulative effects on the quality of the human environment. An example of a CE is the rehabilitation of hiking trails within a national park. If a CE does not apply, the agency must prepare an EA to determine whether the proposed action or its alternatives have potentially significant environmental effects. The key and highly subjective word here is "significant." In determining significance, NEPA requires agencies to consider the geographic, biophysical, and social context of the action as well as the intensity or severity of the projected impacts. Beneficial or adverse impacts may include those related to public health and safety, unique risks, effects on endangered or threatened species, proximity to cultural or historic resources, and cumulative impacts.

Federal regulations are unclear about how much internal and external review is required before a final EA determination is made. Each year, thousands of EAs are prepared, and many are provided to citizens and communities to invite public feedback. However, unlike an EIS, a formal review and comment process is not required. The outcome of an EA is either a finding of no significant impact (FONSI) or a determination that a more detailed EIS is needed. If an agency submits a FONSI, the CEQ requires that the analysis be posted in the *Federal Register* for a 30-day review period.

An EIS represents the most rigorous review under NEPA. Before initiating an EIS, the agency must publish a "notice of intent" in the *Federal Register* and contact concerned public and private parties. As part of the EIS scoping process, the agency identifies any existing or required studies, defines the roles of all agencies involved, determines the relevant environmental issues, and describes the project's rationale. A major requirement of an EIS is to identify reasonable alternative actions and their corresponding environmental effects.

Once a draft EIS is prepared, it is published in the *Federal Register* for 45 days. During this period, the agency must consider and respond to public comments on the draft and determine the need for further analysis before preparing the final EIS. The public is invited to comment on the final EIS before the agency publishes their record of decision (ROD). A ROD is a public report that documents the agency's decision about a proposed action for which an EIS has been prepared.

Although the environmental impact assessment process is intended to aid agencies in making well-informed decisions, the agencies are not legally bound by the assessment findings. This means that an agency can continue with a project that is found to have significant impact on the quality of the human environment if a plan for mitigating the impact is established.

In August 2016, the CEQ issued final guidance to assist federal agencies in their consideration of greenhouse gases in the environmental impact assessment process. This action marks an effort by the CEQ to maintain the integrity of environmental review by incorporating pressing environmental threats, in this case potential contributions to or effects of climate change.

Rachel L. Lamb

See Also: Air Pollution; Climate Change and Human Health; National Environmental Policy Act; Water Pollution

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ENVIRONMENTAL JUSTICE

Environmental protection and environmental justice share basic goals, including the protection of public health from pollution and other forms of environmental degradation. However, the environmental justice movement specifically seeks to remedy the fact that racial minorities and low-income populations bear a disproportionate share of adverse environmental and public health impacts, even as they receive fewer benefits from the activities that generate pollution. The environmental justice movement attempts to solve this problem by securing a right to meaningful participation in decision making for all groups and communities affected by the positioning of waste disposal locations and polluting facilities.

Social Determinants of Environmental Health

Many people view health as being determined largely by individual health behaviors and tend to downplay or overlook the importance of more distal factors that influence our health behaviors and outcomes.

An Interview with Dr. Georgiana Bostean

Assistant Professor of Environment, Health, and Policy, Chapman University

Dr. Georgiana Bostean is an expert in social determinants of health and population health disparities. Her research examines the factors contributing to disparities in population health behaviors and outcomes, including e-cigarette use and cancer-related health behaviors, focusing particularly on vulnerable and underrepresented populations such as immigrant groups. Dr. Bostean's work has been published in a number of peer-reviewed journals and supported by funding from the National Science Foundation and University of California Office of the President.

When we are well and feeling good, we often take our good health for granted. However, there are many Americans who do not enjoy good health simply because of social determinants they may feel they have little control over or may not even be aware of. Can you expound on what social determinants are, in particular, those related to environmental health and the built environment?

Many people view health as being determined largely by individual health behaviors and tend to downplay or overlook the importance of more distal factors that influence our health behaviors and outcomes. The social determinants of health include the conditions in which we live that affect our health. Various aspects of the environment are among the social determinants of health, including the physical environment (both built and natural), the service environment, the social environment. The physical environment, such as the availability of safe bikeways or green space, may promote exercise and mental well-being. The service environment, which includes issues such as the availability of healthy food options or quality health care providers, shapes our eating habits and likelihood of seeking medical care. The social environment includes the extent of civic engagement among neighborhood residents, the nature of relations between social groups, the presence of crime, and trust in neighbors. These factors not only shape our health behaviors but also directly impact our mental and physical well-being.

Social determinants of health are key factors in understanding issues surrounding environmental justice, that is, the argument that low income and minority populations are often disproportionately exposed to environmental pollution. How can victims of environmental justice gain more control over these social determinants to improve their circumstances in life?

Many of the social determinants of health, and the resulting health inequities, are influenced by policies on education, economic development, and so on, which are ultimately products of economic and political factors. Unfortunately, it is often the communities with the least political power that are the targets and victims of environmental injustice. Research shows that point sources of pollution are disproportionately located in areas predominantly occupied by low income and minority populations. Improving these conditions requires social changes that can be brought about with involvement of those within and outside of the affected communities. For example, community activist groups have been successful in creating positive change in their communities by bringing together multiple stakeholders. In the case of lead contamination of drinking water in Flint, Michigan, when there initially was little local response to community concerns, advocates for the concerns of local residents, including university researchers, the ACLU, and the EPA, provided resources and brought visibility to the issue to facilitate action. Sometimes changes in political representation can also help when the existing political framework provides little or no action on an environmental health issue. Thus, voting is an important way community members can help bring about positive change and action toward environmental justice.

What would be a good career path for a recent college or university graduate wanting to improve the lives of others by addressing social determinants in the environmental health field?

The challenge of addressing social determinants of health, which are so closely intertwined with other aspects of our society, also creates opportunities in a variety of careers that are, at first glance, not directly related to health. For instance, an urban planner might address social determinants by developing safe and accessible active transportation resources and facilities or by creating micro-parks to encourage physical activity. A housing developer could improve opportunities for positive social relationships in a housing community through deliberate design elements that encourage social interaction. An education policymaker might influence the social determinants of health by recognizing how inequitable school funding contributes to population health disparities. An environmental manager could adopt a green infrastructure strategy for sustainable communities that preserves, builds, and connects critical natural landscapes. There are also a multitude of career paths directly related to environmental health, including environmental management and occupational safety and health. No matter what one chooses as a career path, there is likely an opportunity to improve the lives of others by addressing social determinants.

Many mark the beginning of the environmental justice movement with protests against the 1982 decision to locate a hazardous waste landfill in Warren County, North Carolina. The landfill was to receive soil containing the more than 30,000 gallons (114,000 liters) of toxic polychlorinated biphenyl dumped alongside North Carolina roadways in the previous decade. Of all North Carolina's counties, Warren County was among the poorest and had the highest proportion of African American residents.

Protests and lawsuits against the landfill's location ultimately failed, but they garnered national attention, including that of Congress. In 1983, responding to a congressional request, the Government Accountability Office issued a report confirming that in eight southeastern states, a correlation existed between the location of hazardous waste landfills and the racial and economic makeup of the surrounding communities. Subsequent research—such as *Toxic Wastes and Race in the United States*, published in 1987 by the United Church of Christ's Commission for Racial Justice—made clear that this correlation was the national norm, rather than the exception.

Efforts to craft environmental justice policy in response to evidence of what many called environmental racism led to a series of federal legislative proposals in the late 1980s and early 1990s, none of which were enacted. Following these failures, advocates pushed for the administrative aspects of land use decisions and the implementation of environmental laws to give greater priority to environmental justice principles.

They achieved a victory with President Bill Clinton's February 11, 1994, Executive Order No. 12,898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. That order instructed federal agencies to identify adverse health or environmental effects of their policies or programs on low-income communities and communities of color and to address instances where those effects were disproportionate. That order set off a nationwide wave of state-level environmental justice policy initiatives, which took the form of legislation and changes to administrative procedures. By 2014, all 50 states and the District of Columbia had instituted some form of environmental justice policy, whether via legislation, executive order, or regulatory guidance.

These policies provide varying degrees of support toward the goals of (1) requiring that data about risks and public health outcomes are collected and available and (2) ensuring that, based on analyses of those data, affected groups and communities can meaningfully participate in the processes that allocate the burden of adverse environmental impacts. By enabling greater opportunities for informed and meaningful community involvement, these environmental justice additions to federal- and state-level environmental laws and policies have aided community efforts to close polluting or toxic waste disposal facilities, to compel buyouts or other displacements of existing facilities, and to prevent the construction of new facilities.

Environmental justice continues to mature as a subfield of environmental law and policy. Advocates point out that the basic motive for environmental justice—the disproportionate allocation of environmental and public health burdens to poorer communities of color—persists. Efforts to realize the central goals of greater participation and fairer outcomes lack thorough implementation at the federal, state, and local levels. On the other hand, however, research has made clear that the causes of that disproportionate allocation are not always simple. Certainly, poorer communities of color sometimes lack the clout or organization of neighboring communities in the face of positioning decisions, but this is not the only mechanism by which these communities find themselves bearing the brunt of undesirable facilities. It is also sometimes the case that the members of poorer communities move closer to such facilities because those facilities make property values more affordable. In situations like these, the remedy for a community seeking to protect its public health from a proximate source of pollution will generally require a more complex response than pushing for the denial of a new permit.

As advocates have pushed for the implementation of environmental justice principles, their arguments have encountered resistance and hit stumbling blocks. A notable example is the case *South Camden Citizens in Action v. New Jersey Department of Environmental Protection*, decided by the Third Circuit Federal Court of Appeals in 2001. The legal question presented in that case was whether the New Jersey Department of Environmental Protection violated Title VI of the 1964 Civil Rights Act, which forbids intentional discrimination on the basis of race, by granting an air pollution permit to a cement production facility that would pollute the air of a predominantly African American community. The trial court said that the department had violated the act because its permit would foreseeably lead to a disproportionately adverse impact on a racially distinct group. However, that conclusion was overturned by the court of appeals because (1) the relevant provision of the act only forbids intentional discrimination, not mere disparate impacts on people of a given race and (2) the act did not create a legal basis for the plaintiffs to sue over an air quality permit.

Justin M. Gundlach

See Also: Environmental Protection Agency; Hazardous Waste Disposal; Land Disposal of Waste Materials; Polychlorinated Biphenyls; Socioeconomic Status and Health

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ENVIRONMENTAL PROTECTION AGENCY

The U.S. Environmental Protection Agency (EPA) is a cabinet-level agency of the federal government with a mission of protecting human health and the environment. To perform that mission, the EPA develops and enforces regulations, issues grants, studies environmental issues, sponsors partnerships with actors in the private sector (as well as state and local government), publishes reports and data, and educates the public about environmental issues. Consideration for public health and welfare features directly or indirectly in all of these functions.

The EPA was established in December 1970 after Congress approved President Nixon's plan to cobble together a new agency from offices then housed in the Department of the Interior; the Department of Health, Education, and Welfare; the Atomic Energy Commission; and the Department of Agriculture's Agricultural Research Service. It was no accident that the EPA's founding followed the first Earth Day in April 1970 and largely coincided with enactment of the Clean Air Act of 1970. All of these events reflected growing recognition by the public and politicians that pollution and pesticides were having increasingly harmful effects on human health and the environment.

Although Congress did not formulate the EPA's design, Congress immediately empowered the EPA to make unprecedented federal interventions into various sectors of the economy to regulate pollution. The EPA grew quickly from 1970 to 1980 as Congress passed a series of laws that still constitute almost the entirety of U.S. environmental law. These include the Clean Air Act (1970), Clean Water Act (1972), Federal Insecticide, Fungicide, and Rodenticide Act (1972), Safe Drinking Water Act (1974), and acts governing the production, transport, and disposal of hazardous waste—the Resource Recovery and Conservation Act (1976) and the Comprehensive Environmental Response, Compensation, and Liability Act (1980). While the EPA's budget in 1970 was $1 billion and its staff numbered 4,084, both of those numbers more than doubled by 1972 and by 1979 were $5.4 billion and 12,160, respectively. By 2016, the EPA's annual budget was $8.1 billion, and it employed 15,376 staff members (not including contractors), allocated across its headquarters office in Washington, D.C., 10 regional offices, and 27 laboratories. Those staff members include scientists, engineers, lawyers, and economists.

One of the EPA's chief functions is to develop and interpret scientific research. This takes a variety of forms. Some are prescribed in detail by statutes that also prescribe regulatory and enforcement functions. For example, the Clean Air Act instructs the EPA to set national ambient air quality standards for particular pollutants in the ambient air based on the levels the Clean Air Scientific Assessment Committee—a group of experts who do not work for the EPA—determines are safe for people to encounter. Other functions are the result of the EPA regulations that elaborate on nonspecific directives in regulatory statutes. For example, pursuant to the Federal Insecticide, Fungicide, and Rodenticide Act, the EPA conducts a multipart risk assessment of pesticides, examining their effects on ecology and human health and their cumulative effects over time on both.

Another form of the EPA's investment in scientific research follows from statutes through which Congress directs the EPA to study a specific problem independent of its regulatory or enforcement roles. For example, the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 directs the EPA to collaborate with the National Oceanic and Atmospheric Administration (NOAA) to improve scientific understanding of harmful algal blooms and related oxygen depletion (hypoxia) events. The act also directs the EPA and NOAA to develop greater capacity to predict, detect, monitor, and assess such events.

Another of the EPA's chief functions is to devise and update regulations that reflect both scientific understanding and the requirements codified in statutes addressed to the EPA. Such regulations can take many forms, including water quality standards, rules for the disposal of pesticide residue, and procedural requirements for the submission of claims relating to toxic waste cleanup. A recent example of the EPA's exercise of its regulatory authority relates to the greenhouse gases responsible for climate change. Once the EPA concluded that greenhouse gases endanger public health and welfare, the Clean Air Act required the EPA to issue regulations that limit the emissions of such gases from mobile sources (cars and trucks) as well as from new and existing stationary sources (including power plants, large factories, and oil refineries). The EPA's regulation of greenhouse gas emissions from mobile sources has taken the form of updated corporate average fuel economy standards, which add greenhouse gases to the targets of the existing standards (fuel economy and harmful air pollutants). The EPA's regulation of greenhouse gases from new or modified stationary sources has involved specifying new source performance standards, which prescribe pollution-limiting technologies for particular source categories such as fossil fuel-fired power plants. As for emissions from existing stationary sources, the EPA similarly issues regulations for particular source categories. However, these regulations tend to be more contentious because compliance necessarily involves changing the original designs or operations of the existing facilities or adding expensive pollution control equipment.

The third of the EPA's chief functions is to enforce compliance with its regulations, which it does both directly and through collaboration with state governments. Many statutes require polluters to request permits from the EPA or from state agencies before performing activities that generate pollution. After the permit is issued, the responsible agency monitors compliance with the permit's provisions. Noncompliance can lead not only to a rescission of a permit but also to civil fines and, if the noncompliance is found to be both egregious and deliberate, possibly criminal penalties. Particularly in the legal contexts of the Clean Air Act and

Clean Water Act, the EPA generally does not handle monitoring or compliance directly but rather provides oversight to the state agencies that interact directly with polluters.

Justin M. Gundlach

See Also: Clean Air Act; Clean Water Act; Earth Day; Emergency Planning and Community Right-to-Know Act; National Environmental Policy Act; National Oceanic and Atmospheric Administration; Pollution Prevention Act; Resource Conservation and Recovery Act; Safe Drinking Water Act; Superfund Act; Toxic Substances Control Act

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ENVIRONMENTAL REFUGEE

The term "environmental refugee" is typically used to describe people who are forced to leave their place of residence due to sudden or long-term changes in the local environment that make it impossible or impracticable to remain in that place. This definition encompasses people displaced by immediate threats, such as natural disasters, as well as those who must move due to a gradual deterioration in environmental conditions that compromises their well-being or livelihoods. Some examples of environmental degradation that lead to forced movement include drought, desertification (fertile land becoming desert), sea level rise, water and air pollution, soil degradation, and fishery depletion.

Climate Refugees

Climate refugees are a growing class of environmental refugees. These are persons forced to leave their homes due to climate change–related phenomena, such as sea level rise, drought, and intolerably high temperatures. It is difficult to accurately predict how many people will be displaced as a result of climate change, as this depends on the rate of greenhouse gas emission reductions. Based on the most recent scientific data, there is a very high chance that the global average surface temperature increase will exceed the precautionary target of 4°F (2°C) within the next century and could rise by 5°F to 7°F (3°C to 4°C) by 2100. An increase of this magnitude would almost certainly lead to severe, pervasive, and irreversible impacts on human and natural systems, rendering many areas uninhabitable and triggering massive displacement from vulnerable locations, such as low-lying islands, coastlines, and deserts.

There are no conclusive estimates for the number of environmental refugees or migrants worldwide. This is partially due to the lack of any comprehensive monitoring systems to track the status of such persons. Another reason for the lack of conclusive estimates is that it is difficult to define exactly who fits within this class. The line between forced and voluntary movement is often quite vague, and it is not always clear whether environmental factors were the predominant cause of the movement. In many cases, environmental conditions may be an indirect or secondary cause of movement, for example, drought contributing to conflict that ultimately leads to flight.

There is some debate as to whether the term "environmental refugee" should be used to describe such people, as they do not typically qualify as refugees within the legal meaning of that term. The International Organization on Migration (IOM) prefers to use the term "environmental migrants," which it defines as "persons or groups of persons who, for compelling reasons of sudden or progressive changes in the environment that adversely affect their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their country or abroad." One advantage of the IOM's definition is that it encompasses both forced and voluntary movement. This makes it possible to identify and monitor environmental migrants without making difficult decisions about what qualifies as forced movement.

With the number of environmental migrants on the rise, many stakeholders are concerned about the lack of effective laws and institutions to protect the rights of these people and to coordinate responses from national governments and other stakeholders. There have been a variety of recent proposals for a treaty to provide legal protection for such persons or an international coordination facility to organize responses to this phenomenon. These proposals range widely in scope. Some focus on providing protection to persons displaced by natural disasters or climate change, while others are aimed at coordinating national-level responses and would not entail any special legal status for environmental refugees. Unfortunately, these international proposals have not received significant attention from national decision makers. Therefore, domestic laws and regional agreements may play an important role in addressing this issue in the near future.

Jessica Wentz

See Also: Climate Change and Human Health; Drought and Desertification, Health Consequences of; Fishing Practices and Food Supply; Natural Disasters

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ENVIRONMENTAL RISK, COMMUNICATION OF

Communication of environmental risk is conveying the potential impact of environmental stressors on people. These stressors include chronic anthropogenic conditions and acute geophysical events, both of which can result in human suffering and loss. In communicating risk, public health officials and governmental agencies seek to raise awareness by sharing relevant information. Successful communication depends on both the framing and content of the message and on public perception of risk. This communication is accomplished through a variety of mediums, including government websites and social media.

Anthropogenic stressors in the environment usually arise from the use of technology and chemicals. This includes the impacts of climate change, pollution, antibiotic resistance, ecosystem devastation due to deforestation, soil degradation and erosion, and infectious disease. Geophysical stressors typically refer to extreme weather events like floods and hurricanes and to volcanoes, earthquakes, landslides, and wildfires.

The goal of risk communication is not just to spread information but also to ensure that people take appropriate action to reduce their environmental risk. According to the World Health Organization (WHO), successful risk communication depends on several factors. First, the public should be seen as a stakeholder, and the message should respond to current public concerns. Second, information needs to be framed for a lay audience. And third, the message should be both precise and transparent. In other words, it should acknowledge uncertainty about outcomes or probabilities and avoid "over-assurance." The WHO justifies the need for precise and transparent messaging by explaining that vague terms like "possible" can be interpreted to mean anything from a zero to 100 percent chance of occurrence. Furthermore, without specific information, most people are poor at estimating the risk of some event because they are biased toward events they remember and those that confirm their existing beliefs.

The content of the message should address how one is exposed to the risk, the consequences of exposure, who or what is responsible for the risk, and whether the risk is controllable. Because risk varies across a population, messages also need to address who is most susceptible. In general, children, pregnant women, older adults, and people with chronic diseases, such as cancer, diabetes, or HIV/AIDS, are more likely to suffer from environmental stressors. Other exposure factors may include time spent outdoors, place of residence, workplace, and diet.

Successful communication also relies on public perception of environmental risks. The WHO notes that public reaction is often far greater or far less than what scientific estimates of risk would justify. People are more concerned about risks when they are involuntary, inequitably distributed (i.e., perceived as unfair), unfamiliar, or poorly understood by authoritative sources. For example, geomagnetic storms (disruptions in the earth's magnetic field caused by waves of increased solar winds) are uncontrollable and, therefore, perceived as higher-risk even though the absolute risk to the public is low. Acute risks get far more attention than chronic risks even though the chronic risk may affect far more people. For example, outbreaks of food poisoning (acute risk) receive more attention on evening news programs than people becoming ill from obesity (chronic risk), although obesity is a much greater public health threat. Finally, messages that contain elements of blame, cover-ups, or crime increase public perception of risk, and when risk is communicated as part of a story with conflict, heroes, villains, and victims, people are more likely to pay attention.

Government agencies and public health organizations are generally responsible for communicating environmental risk. For example, the WHO leads and coordinates emergency response in nearly 200 countries. When needed, the WHO acts to set priorities, assess risk, and communicate this information to the public. In the United States, the Centers for Disease Control and Prevention, the Department of Health and Human Services, and the Food and Drug Administration all play a major role in communicating risk. Additionally, the Agency for Toxic Substance and Disease Registry helps health professionals educate the public about environmental risk.

These agencies use a number of mediums for communicating risk to a broad audience, including Internet websites, social media, radio, television, phone calls, and print media. Google, a multinational technology company, communicates risk using innovative forms based on Internet data. For instance, Google Flu Trends uses search engine queries to estimate influenza activity. (One independent study of this tool found it to be quite accurate in real time.) Since Hurricane Katrina in 2005, Google Crisis Response has been another emergency-response tool for assembling information about earthquakes, floods, tornadoes, and wildfires all over the world. Crisis Response has a resource page with emergency information and tools, a person finder, and crowdsourced geographic information.

Alisha K. Newton

See Also: Bhopal Incident; Cancer Risk from Environmental Contaminants; Environmental Health Profession; Integrated Risk Information System

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ENVIRONMENTAL TOXICOLOGY

Environmental toxicology studies the mechanisms and effects of natural and man-made chemicals in the environment by combining the fields of biochemistry, biology, ecology, economics, engineering, environmental chemistry, geochemistry, molecular biology, and social sciences to determine the risks of toxicants (i.e., adverse effects on the biosphere, wildlife, and human health). Environmental toxicology can be divided into the categories of environmental health toxicology (the study of the adverse effects of environmental chemicals on human health) and ecotoxicology (the study of the adverse effects of toxicants on organisms of an ecosystem).

Environmental toxicologists work in industry, consulting firms, universities, and government regulatory agencies to monitor the concentrations and fates of toxic chemicals. Additionally, they determine levels of exposure that occur from consumer products and in occupational settings to assess risks and find ways to keep exposure at safe levels. As a better understanding evolves of the complexity of the problems arising from exposure to natural and synthetic toxicants, environmental toxicology develops appropriate scientific tools to address these problems by exploiting advances in analytical chemistry and molecular biology to design high-throughput screening assays. A global history of harmful chemical exposures and improper disposal has led to significant threats faced by living organisms, and environmental toxicology is concerned with these urgent challenges, which have arisen from population growth, climate change, habitat loss, and stresses on food, water, and energy supplies in a rapidly changing world. The work of environmental toxicologists has led to legislation to ensure that the harmful effects of environmental toxicants are minimized for all species.

Environmental toxicology emerged in the early 1960s and has rapidly developed from traditional human toxicology to the study of toxic effects of pollutants in the environment. The historical development of toxicology began with early cave dwellers who recognized poisonous plants and animals and used their extracts for hunting and in warfare. The earliest written evidence of toxicology refers to chemicals used in tonics and poisons, particularly with reference to arsenic and mercury. In the 16th century, Paracelsus determined that specific chemicals were responsible for the toxicity of a plant or animal poison and documented dose-response relationships. In the late eighteenth and early nineteenth centuries, the Spanish physician, Mathieu Orfila, established the effects of poisons on bodily organs. And in 1962, Rachel Carson published *Silent Spring*, a book emphasizing the widespread and indiscriminate use of pesticides and other chemicals in the environment and advocating for their responsible use. Since its beginnings, environmental toxicology has changed from a largely descriptive science to one where the importance of mechanisms of toxic action is pursued.

Environmental toxicants can cause harmful effects on living organisms and habitats, producing changes in species diversity and number and altering the productivity and stability of the ecosystem. The degree of toxicity varies depending on where the organism is within a food web and if bioaccumulation occurs, whereby toxicants get stored in an organism's body and passed up a food chain. Persistent toxicants in our environment that target various organ systems in the body include dichlorodiphenyltrichloroethane (also known as DDT), heavy metals, polychlorinated biphenyls, and various pesticides, herbicides, and insecticides. Due to organic metal compounds being lipid soluble, they can enter the brain and nervous system and have secondary effects. Also, the renal, respiratory, and endocrine systems are commonly affected by environmental toxicants, and many metals found in the environment can interfere with normal enzyme function and be carcinogenic.

Environmental toxicants can be degraded naturally by either abiotic or biotic processes. Abiotic processes include photolysis, which occurs when light, primarily in the ultraviolet range, breaks chemical bonds, mainly in the atmosphere or in surface waters where light intensity is greatest. Additionally, hydrolysis of toxicants can occur when water, often in combination with light energy or heat, breaks chemical bonds by inserting an oxygen atom into the molecule, leading to the loss of some component of the molecule. Biotic degradation can occur at significant rates through bioremediation, whereby the actions of microorganisms, primarily bacteria and fungi, degrade chemicals as they derive energy from them, leading to mineralization, water, carbon dioxide, and basic inorganic constituents.

Simon Waldbaum

See Also: Arsenic Pollution; Carson, Rachel; Cyanobacteria Toxins; DDT Exposure; Dose-Response Assessment; Heavy Metal Pollution; Integrated Risk Information System; Mercury Pollution; National Air Toxics Assessment; National Institute for Occupational Safety and Health; National Toxicology Program; Naturally Occurring Toxins; Neurotoxicants; Occupational Safety and Health; Persistent, Bioaccumulating, and Toxic Chemicals; Pesticides and Herbicides; Polychlorinated Biphenyls; Toxic Substances and Disease Registry, Agency for; Toxicogenomics; Toxics Release Inventory

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ENVIRONMENTALISM

Environmentalism is a social, political, and philosophical movement concerned with protecting the natural environment, including the land, oceans, and atmosphere and the various life-forms within. Inspired by ecology, environmentalism promotes a sustainable relationship between humanity and the natural world. While many environmentalists would argue for preserving nature for nature's sake, much of the work conducted by environmentalists is concerned with protecting human health from environmental pollutants, such as man-made chemicals, human sewage, agricultural runoff, greenhouse gases, noise and light pollution, and radioactivity.

The Role of Art in Environmentalism

We all love our world in some aspect, and in that way, I hate that environmentalism is even a category.

An Interview with Chris Jordan

Internationally Acclaimed Photographic Artist

Chris Jordan is an internationally acclaimed photographic artist who has displayed his work at major exhibitions throughout the world, including the Nobel Peace Center in Oslo, Norway. Additionally, his work has been featured in the New York Times *("Chris Jordan's Great Big Beautiful Piles of Junk," by Philip Gefter) and over 100 other publications. Many of his pieces illustrate the magnitude of environmental pollution, for example, a geometric form that on close inspection comprises 28,000 barrels of oil, the amount consumed in the United States every two minutes. One of Jordan's latest projects was to photograph remote areas of Kenya where tribal people are struggling to survive as their lands are increasingly ravaged by climate change.*

You have said that when communicating the magnitude of environmental pollution to the public (e.g., nearly 40 billion plastic bottles discarded without recycling every year), people have difficulty conceptualizing these large numbers and relating them to anything they are familiar with. Is this what first inspired you to experiment with photographic art as a technique for communicating the seriousness of pollution?

I think what most inspires my work is my dawning sense of the magnitude of the disconnect that humanity is suffering from. Not being able to comprehend the enormity of our effects on the world is one component, but it goes much further than that. I believe we are suffering a collective psycho-spiritual disease that threatens our continued existence. We can't see the sickness itself, but we see evidence of it manifesting in the physical world in a thousand ways: pollution, extinction of species, environmental destruction on a global scale, violence, war, and so on. My hope is that by facing these issues as symptoms of a larger human problem, we can discern the shape and form of our disconnect, and perhaps, find more collective interest in healing it.

One of your better known works is the re-creation of Hokusai's famous print, *The Great Wave at Kanagawa*, illustrated with 2.4 million pieces of plastic, equal to the pounds of plastic pollution that enter the world's oceans every hour of every day. Has this and similar works helped raise awareness among naysayers about the urgency of addressing the environmental pollution problem?

I don't think it is possible to measure the incremental effect that one person's work might have on the complex living system that is our culture. But I, like many other people, dream of a great cresting wave of awakening consciousness in our world, and that is what I am trying to contribute to in some small way. That part gives me hope—stopping wars and healing our forests and oceans and atmosphere seem like impossibly huge tasks, but shifting consciousness is something we can do and that every one of us can contribute to. In one sense, that shift is already happening, and in another, the world is unraveling in the other direction just as fast, and both processes seem to be accelerating. What a time to be alive.

Many people do not fully appreciate the connection between a healthy environment and human health. Do artists have an important role to play in helping us understand this interdependent web of existence?

I believe that art is not an add-on luxury like dessert after a meal. Art is a primary ingredient in an evolved culture—a mirror for self-reflection and evolution, a window through which we can see our problems and behold the magnificence of life and ourselves, and a doorway through which we can step into a new story together. Look at what Germany's poets and artists did after World War II—they guided their nation in facing collective shame and grief, and in doing so, transformed their culture.

What advice would you have for a recent college or university graduate wanting to raise awareness about environmental pollution through the medium of art?

First, keep going! And look carefully into the world of advocacy and persuasion (examine it on a meta-level). Environmentalism can be disrespectful and tinged with unacknowledged irony and hypocrisy, to the point where it becomes ineffective and divisive. But it doesn't have to be like that. We all love our world in some aspect, and in that way, I hate that environmentalism is even a category. To be effective in inspiring change on the scale that is needed, environmental activism needs to evolve to a more inclusive and relational space, to honor the ironies and complexities of our existence. The discourse around racism and gender is more mature than environmental activism, so studying those conversations is a good learning ground. And I also believe in devotion to emotional/spiritual growth. The world is just so amazing—there is so much to learn and so much healing to achieve. I mean, take a pause and a breath and just consider this: right now, here in this moment, by the infinite grace of who-knows-what, you are alive, and as you sit reading this, your own consciousness resonates like a temple bell in the center of a mystery that is as vast as the Universe itself.

Environmentalism developed along with the Industrial Revolution in Europe in the 19th century, as cities encountered pollution from smoke and coal. One of the earliest environmental laws was the Alkali Act in Great Britain, passed in 1863 to regulate air pollution produced from the manufacture of soda ash. The legislation soon expanded to include other industrial pollutants.

In the United States, environmentalism has its foundation in the work of several important authors and conservationists. Ecologist and early conservationist John Muir (1838–1914) believed that nature had a right to protection, and he lobbied for the establishment of Yosemite National Park and other wild and natural areas. President Woodrow Wilson (1856–1924) later established the National Park Service to protect and conserve lands. Aldo Leopold (1887–1948) wrote the *Sand County Almanac* (1949), which held that respecting the environment is an ethical and moral principle.

A landmark event for environmentalism was the book *Silent Spring*, published in 1962 by biologist Rachel Carson (1907–1964). In particular, she criticized the use of the pesticide DDT without regard to its effects on human health. Public concern following the publication of *Silent Spring* led to the creation of the U.S. Environmental Protection Agency, which banned DDT in 1972.

The environmental movement continued to gain momentum throughout the 1970s, with Earth Day, first observed in 1970, celebrated worldwide every year since. In 1972, leaders from 114 countries met in Stockholm for the first UN Conference on the Human Environment, marking the beginning of international environmental politics. The 1970s also saw the creation of the Endangered Species Act and significant amendments to the Clean Air and Clean Water Acts.

Meanwhile in India, several dozen people hugged trees in their village to protect them from deforestation in what became known as the "chipko" movement, in reference to a Hindi word meaning "to stick to." The movement led to the use of the term "tree huggers" to describe environmentalists, becoming a touchstone for the environmental movement worldwide.

Alisha K. Newton

See Also: Carson, Rachel; Clean Air Act; Clean Water Act; DDT Exposure; Deforestation; Earth Day; Ecosystems, Importance of; Endangered Species and Human Health; Environmental Protection Agency; London Smog Disaster

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EPIGENETICS

Epigenetics refers to changes to chromosomes that affect the activity and expression of genes on the chromosomes. These changes may be prompted in people's cells by exposure to certain environmental factors, such as particular chemical compounds, drugs, foods, or beverages. Some epigenetic changes are prompted in cells of the developing fetus by exposure to certain chemical conditions in the womb. Epigenetic changes, which have the effect of activating or deactivating genes (i.e., turning them on or off), are heritable. Although the expression of the genes is affected, the DNA sequences of the bases that make up the genes remain unchanged. Thus, epigenetic changes are not the same as mutations, in which DNA sequences are altered. The end result of some epigenetic changes is the development of certain diseases, such as some types of cancer, autoimmune disorders, or even psychological disorders.

Investigations into the relationship between environmental chemicals, epigenetic processes, and disease development constitute a relatively recent and growing area of scientific and medical research. Knowledge in this area is not as well established as that regarding the relationship between environmental chemicals and disease-causing genetic mutations. Consequently, the applications of epigenetics research findings to clinical practice and public health are somewhat limited. In the United States, epigenetics research and potential clinical applications are a major focus at the Centers for Disease Control and Prevention and the National Institutes of Health.

Evidence from animal and human studies indicates that exposure to various types of environmental chemicals can prompt epigenetic changes in gene expression. These chemicals include metals (e.g., arsenic, cadmium, chromium, methylmercury, and nickel), air pollutants (e.g., benzene, black carbon, and particulate matter), endocrine disrupters and reproductive toxicants (e.g., bisphenol A, diethylstilbestrol, dioxin, and persistent organic pollutants), and peroxisome proliferators (e.g., dichloroacetic acid, trichloroacetic acid, and trichloroethylene).

Metals, depending on the particular agent, are known or suspected to prompt epigenetic changes associated with cancers, cardiorespiratory conditions, depression, anxiety, and learning deficiencies. Certain air pollutants may lead to epigenetically altered gene function so as to increase risks for cancers, cardiovascular disease, and other health problems. Endocrine disrupters are most harmful to the DNA of immature, developing bodies (i.e., fetuses, infants, and children). Among the changes promoted by estrogen-mimicking endocrine disrupters is the activation of genes responsible for female sexual and reproductive traits, including abnormal female traits in males. Research suggests that peroxisome proliferators may lead to cancer and liver damage, among other epigenetic-related conditions.

There are several mechanisms by which epigenetic changes can affect gene expression and function, including DNA methylation, histone modifications, and microRNA (miRNA) expression. The details of how these mechanisms can lead to epigenetic changes remain uncertain, although some general steps have been uncovered.

Most scientific research concerning epigenetics has involved studies of DNA methylation, in which a DNA base sequence in body cells (either the base cytosine or the base adenine) is tagged (i.e., marked) by a methyl chemical group from the environment. This tagging affects the DNA by altering chromosomal stability and genome function. In different cases of DNA methylation, expression of certain genes may be either suppressed or enhanced.

Histone modifications involve changes to globular proteins called histones, around which the DNA molecule can wind. The interaction of the histones with DNA and nuclear proteins is then altered. Consequently, the chromatin structure, though not the base sequence, of the DNA is changed, leading to effects in gene expression either of a suppressive or an enhancing nature.

In microRNA expression, single-stranded miRNA units of 21 to 23 nucleotides in length are transcribed from the DNA codes, but they are not translated into proteins (as is normally the case). The lack of proteins interferes with messenger RNA function, and, in turn, gene expression is usually suppressed, although it can be enhanced in some cases.

Evidence has proven that epigenetic changes are heritable from one generation of somatic (body) cells to the next during the process of cell division. The evidence is less clear, however, concerning whether epigenetic changes are heritable across human generations, from parent to offspring. For such transgenerational inheritance to occur, the epigenetic changes would need to affect gametes, or sperm and egg cells. Most investigators believe that additional research is required to clarify the likelihood and prevalence of such heritable gamete epigenetic changes.

A. J. Smuskiewicz

See Also: Arsenic Pollution; Bisphenol A (BPA); Cancer Risk from Environmental Exposure; Centers for Disease Control and Prevention; Dioxin Pollution; Endocrine Disruptors; Environmental Toxicology; Hazardous Air Pollutants; Heavy Metal Pollution; Hexavalent Chromium; Lead Poisoning Prevention; Mercury Pollution; Particulate Matter and Bioaerosols Pollution; Persistent, Bioaccumulating, and Toxic Chemicals

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ESCHERICHIA COLI (*E. COLI*) INFECTION

Escherichia coli, or *E. coli* for short, is a ubiquitous infectious agent. It belongs to a family of gram-negative bacteria referred to as Enterobacteriaceae. German scientist Theodore Escherish isolated the bacteria from the human colon in 1885; hence the name "Escherichia coli." There are approximately 700 different serotypes (strains of the microorganism that generate different antibodies in the blood serum). Most types of the organisms do not cause disease. Rather, some of them are protective, as they constitute a part the body's defense mechanism typically referred to as the natural flora. Pathogenic *E. coli* (those which cause illness) exhibit with diarrheal disease or diseases outside the digestive system. There are six pathotypes (disease-causing types) of *E. coli*, which are associated with diarrheal infections and are referred to as diarrheagenic (causes diarrheal infections) *E. coli*:

- Shiga-toxin-producing *E. coli*, also known as verocytotoxin-producing *E. coli* (VTEC) or enterohemorrhagic *E. coli* (EHEC); EHEC is the most well-known cause of *E.coli*-related food poisoning.
- Enterotoxigenic *E. coli* (ETEC)
- Enteropathogenic *E. coli* (EPEC)
- Enteroaggregative *E. coli* (EAEC)
- Enteroinvasive *E. coli* (EIEC)
- Diffusely adherent *E. coli* (DAEC)

Pulsed-field gel electrophoresis (PFGE) is a genetic fingerprinting that is used to compare the different serotypes. The 0157: H7 serotype is the most notorious, known to be responsible for most gastrointestinal infections. The 0157: H7 serotype was first isolated in 1982, although there had been previous sporadic outbreaks caused by the serotype. Cases were not disclosed then because the infection did not constitute a reportable disease at the time.

The Non-0157 Shiga-toxin *E. coli* (STEC) can easily go undetected (missed) or misclassified with the 0157:H7 virulent (disease causing) serotype during isolation in the laboratory. Of the 66 percent of the presumed 0157:H7 serotype isolated by scientists between 2000 and 2007, it became clear that 10 percent of those were of the Non-0157 STEC serotype, which are not easily isolated in the laboratory because they do not ferment sorbitol (a sugar alcohol with a sweet taste slowly metabolized in humans). The STEC serotype is identified via a diagnosis of exclusion: screening for the 0157: H7 is conducted first, and if the result is negative, then we assume that the STEC serotype is responsible.

The 0157: H7 serotype, which liberates the "Shiga-toxin," is responsible for the majority of gastrointestinal illnesses associated with the disease. The toxins can contaminate foods and beverages, causing a severe dysentery-like disease. The 0157: H7 Shiga-toxin producing serotype causes the majority of infections within the United States. About 73,000 cases and 90 deaths are reported each year. In 2003, the United States spent approximately $405 million on *E. coli*-related illnesses.

E. coli can cause disease in humans because of its ability to liberate different types of Shiga-toxins. Shiga-toxins are virulent factors that determine the degree to which an organism can cause damage to the body. The term "Shiga-toxin" signifies that the toxin exerts action similar to that of the Shigella toxin, which causes dysentery. The virulent factors derive their appellations from Shiga-toxin (Stx): Stx1, Stx2, Stx3, and so on. With the help of these virulent (destructive) factors, the 0157: H7 *E. coli* serotype can destroy the internal linings (endothelial surfaces) of blood vessels and the intestines, leading to profuse bloody diarrhea and a hemorrhagic (bleeding) state; hence enterohemorrhagic *E. coli*.

Outbreaks of 0157: H7-related infections have been traced to foods of bovine origin. However, we cannot overlook other sources of infection: produce, alfalfa, spinach, radish sprouts, clover, and lettuce. Other potential sources include unpasteurized milk and juices, yogurt, dried salami, mayonnaise, game meats, raw cookie dough, and hazelnuts. The Non-0157 STEC serotype causes hemorrhagic uremic syndrome, a condition characterized by red blood cell destruction, acute kidney failure, and reduction in platelets count. Recent studies indicate that the Non-0157 STEC strains may now be responsible for 20 to 50 percent of all STEC infections in the United States. The 0157: H7 serotype constitutes a deadly strain because it has a very low lethal dose, coupled with the ability to resist temperatures up to 111°F (44°C) and freezing temperatures.

Ifeanyi Abuachi

See Also: Centers for Disease Control and Prevention; Communicable Diseases; Food Safety and Technology; Foodborne Diseases; Infectious Diseases

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ESTUARY POLLUTION

An estuary is the area of water where freshwater rivers and streams flow into the salty ocean. Estuaries mark the transition from land to ocean and from freshwater to saltwater. An estuary often is partly separated from the open ocean by small barrier islands, coral reefs, marshlands, or other areas of land, mud, or sand. These natural boundaries protect the estuary from the large waves and wind that can occur on the open ocean and provide crucial habitat for large numbers and varieties of wildlife, especially birds, sea life, and mammals. Migratory birds rely on estuaries for rest and food during their journeys. Estuaries also are referred to as the "nurseries of the sea" because many saltwater (or marine) species spawn their young in estuaries. Because over 75 percent of the fish caught by the U.S. commercial fishing industry rely on coastal estuaries for their habitat, the health of the waters in which these fish live directly impacts human health.

Estuaries are some of the most fertile feeding and spawning grounds found on the earth because the freshwater streams and rivers entering them previously washed over land, picking up substantial quantities of nutrients that support plant growth. These nutrients are critical to the productivity of an estuary. Plant life in the estuary, such as mangrove trees, marine grasses, and peat, acts as a giant filter, feeding on and retaining the nutrients that support plant growth. Plants, as well as the estuary's animals and sediments, also capture pollution, including herbicides, pesticides, heavy metals, sediments (dirt, sand, and silt), and excess nutrients, such as nitrogen and phosphorus (common fertilizers picked up by agricultural, lawn, and golf course runoff). By using or filtering out pollutants, estuaries literally clean the water, benefiting marine animals and the humans that consume them. However, high levels of pollution and excess nutrients have become a major threat to some estuaries in the United States.

Plant and animal life in estuaries is threatened by toxic substances, which can cause serious harm or death, and by excessive nutrients, which can produce excessive plant growth or algal blooms that deplete the water of oxygen and crowd out other species. Algal blooms in estuaries can result in the proliferation of algae species that produce powerful toxins that can harm or even kill fish and make swimming harmful to humans. Nutrient pollution is recognized as the largest threat to coastal estuaries, with over 60 percent of U.S. coastal rivers and bays affected to a concerning degree. Ironically, the introduction of excess quantities of clean freshwater, for example, from rivers controlled by dams, can also upset an estuary's ecology by reducing the salinity of its waters to levels at which estuarine species cannot reproduce or grow.

While pollution is carried to estuaries by rivers and streams, pollution can also be transported from stormwater runoff over agricultural lands, residential lawns, golf courses, and streets. City and industrial wastewater discharges and septic

Plant Life in an Estuary

The plant life in an estuary acts as a huge filter, trapping beneficial nutrients from the freshwater streams and rivers flowing into the estuary, literally cleaning the water and creating an incredibly fertile ecosystem that supports a huge variety of plant and animal life. However, this "filter" also traps harmful pollution and excess nutrients that can damage the ecosystem. As a result, many estuaries are threatened, as is the huge variety of plant and animal life that rely upon them.

tanks can also contribute to estuary pollution. To address the problem of estuary pollution and degradation, the Clean Water Act established the voluntary National Estuary Program, administered by the U.S Environmental Protection Agency. This program was updated in 2000 when the U.S. Congress passed the Estuaries and Clean Waters Act, which provides federal funding and technical assistance for regional efforts designed to protect and restore estuaries.

Estuaries protect human health and livelihoods in many ways. In addition to cleaning polluted waters and serving as a major source of the U.S. domestic fish supply, estuaries protect shorelines from natural disasters such as hurricanes, erosion, storm surge, and floods. Additionally, by absorbing floodwaters, estuaries can make the impact on inland areas less extreme. Because over half the U.S. population lives in coastal areas, with rapid growth continuing, the services provided by estuaries are more important than ever to human health and welfare.

Leah A. Dundon and Richard S. Davis

See Also: Clean Water Act; Cyanobacteria Toxins; Ecosystems, Importance of; Environmental Protection Agency; Industrial Effluents; National Estuary Program; Natural Disasters; Pesticides and Herbicides; Sewage Treatment and Disposal; Stormwater Runoff; Water Pollution; Wetlands and Healthy Waterways

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EUTROPHICATION

Eutrophication (also called hypertrophication) is a condition occurring in water systems where an abundance of nutrients results in rapid algae growth, called an algal bloom. The initial explosive growth of algae in the presence of excess nutrients often reaches a breaking point where algae can no longer be supported by the ecosystem, causing the algal bloom to die. When the organisms die, natural processes that break down the organic matter require oxygen, leading to hypoxia (low oxygen) in the surrounding water. Hypoxic conditions threaten aquatic species that require oxygen to live, leading to fish kills. Along with hypoxia, the settling of decomposing matter can cause shellfish bed losses. After the decaying matter settles, the water body may eventually recover. However, recurring cycles of eutrophication lead to water bodies filling in with sediments over time. Eutrophication is most often associated with lakes and estuaries.

Second Chance for the Chesapeake

The Chesapeake Bay, the largest estuary in the United States, was one of many severely degraded ecosystems that received national attention in the 1960s and 1970s. Recognizing the need for the estuary to be restored and protected, the U.S. Congress funded a $27 million study in the 1970s to understand the loss of wildlife from the area. The five-year study identified the main problem as excess nutrient pollution. In 1987, the Chesapeake Bay Agreement was enacted to reduce nitrogen and phosphorus loading into the bay. Today, the Chesapeake Bay Program continues the mission of restoring and protecting the estuary.

The result of eutrophication is poor water quality that affects organisms that depend on the water body directly or indirectly. Some algal blooms are known to produce poisonous toxins, particularly those associated with cyanobacteria in algal blooms, called cyanotoxins. Consumption of or contact with water containing cyanotoxins can have adverse effects on the liver and nervous system, irritate the gastrointestinal tract, and cause irritation to the skin, eyes, and throat. Additionally, the presence of dead and decaying organisms can release harmful substances that adversely affect water quality. The resulting decline in aquatic organisms may impact humans, who depend on fish and shellfish as a food source.

Eutrophication occurs both naturally and anthropogenically (caused by humans). Natural eutrophication may occur gradually over time, for example, when soils rich in nutrients wash into a small lake, causing it to slowly fill and convert to a land mass. This natural process can take centuries. Eutrophication was brought on by human actions, also called cultural eutrophication, and can be attributed to various causes, including agricultural practices, excess residential or commercial fertilization, and discharge of sewage or industrial effluents.

To grow, algae, like most photosynthetic organisms, require sunlight, carbon dioxide, and the macronutrients nitrogen (typically as nitrite, nitrate, or ammonium) and phosphorus (typically as phosphate). In a balanced and healthy aquatic ecosystem, there is often a limiting factor involving one or more of these requirements that keeps algae growth to a minimum. However, when eutrophication occurs, there is most often excess nitrogen or phosphorus, which permits algae growth to continue.

Fertilizers, a major cause of eutrophication, contain specific forms and amounts of nutrients, such as nitrogen and phosphorus, that are readily available for plant uptake. Eutrophication occurs when precipitation dissolves the nutrients in runoff water or carries nutrient-rich sediments to the affected water body. This issue is mainly associated with agricultural practices, but it also arises with overfertilization of residential properties and recreational areas like golf courses.

In the mid-1960s and early 1970s, environmental activists and concerned citizens in the United States argued for legislation that would protect the environment from pollution, including restoring degraded rivers and lakes to healthy conditions. Thousands of lakes and rivers across the nation were plagued by eutrophication. The scientific community had identified the problem, and a strong effort began in the 1970s to reduce or remove phosphates from laundry detergent, which was a major source of nutrients needed for plant growth. (Water treatment, while cleaning the water to legal standards, was not very effective in removing phosphates from wastewater.) Consequently, the U.S. Congress recommended reducing and eventually eliminating phosphates from detergents. Today, phosphate limits vary by state and local law, but the quantity of phosphates released from laundry detergents has been greatly reduced.

Eutrophication has widespread implications for water quality, and many areas in the United States and elsewhere continue to struggle with this problem. To reduce the adverse consequences of nutrient loading, municipalities may monitor point-source discharge water quality and enact discharge limits. Additionally, to reduce fertilizer and sediment runoff, agricultural areas may include buffer zones, which are unfertilized and vegetated strips of land between fertilized land and a water body. Organic agriculture practices reduce eutrophication by eliminating synthetic fertilizers and relying instead on natural fertilizers, such as compost and manure.

Elise C. Hunter

See Also: Cyanobacteria Toxins; Ecosystems, Importance of; Estuary Pollution; Hypoxia, Gulf of Mexico; National Estuary Program; National Pollution Discharge Elimination System; Organic Agriculture; Water Pollution; Watershed Management, Health Implications of; Wetlands and Healthy Waterways

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EXPOSURE PATHWAYS

There are three main pathways by which environmental chemicals can get into a human body: dermal (through the skin), ingestion (through the gut), and inhalation (through the lungs). Each of these pathways is called a route of exposure. The ingestion pathway is relevant not only for food and drink exposures but also for dust exposures, especially among young children who touch lots of things and then put their hands in their mouths. Less commonly, chemicals can pass into the body through the ocular route of exposure (through the eyes).

Many chemicals have multiple pathways of exposure. For example, the chemical 1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethyl-cyclopenta-γ-2-benzopyran is a common fragrance that is used in body lotions and perfumes (dermal exposure) because it is semivolatile and will be smelled (inhalation exposure). Within an exposure pathway, there may be multiple contributing sources of exposure. For example, arsenic may be found in drinking water, house dust, and rice. A biomarker (e.g., urine arsenic) can integrate across these exposure routes and provide a more holistic understanding of cumulative exposure than trying to sum known sources. However, biomarkers are affected by human biology and thus may be challenging to interpret.

The ingestion route of exposure is special because of the first-pass metabolism in the liver that occurs when a chemical is absorbed through the gut. Ingested chemicals are carried by the hepatic portal into the liver for metabolism prior to entering the bloodstream for systemic circulation. This first-pass metabolism reduces the bioavailability of the original chemical, although it creates metabolites that in some cases may be more toxic than the original chemical. In contrast, inhaled exposures may cross the lungs, directly entering the bloodstream, and skin-penetrating chemicals may directly enter into systemic circulation without being first metabolized by liver enzymes.

There is growing awareness that the microbiome that lives in the gut, in the lungs, and on the skin may modulate human exposure to chemicals. These microbial communities not only respond to environmental stimuli but also may function as “external” metabolic organs producing metabolites that then enter the human body.

Some exposures are involuntary, such as to air pollution or to secondhand or thirdhand tobacco smoke, and require regulatory approaches to control exposures. However, other exposures are voluntary, and for such exposures, evidence is emerging on how individual preferences, habits, attitudes, and behaviors may shape individual exposures to chemicals. This emerging field has contributions coming from a variety of disciplines, including behavioral economics, addiction research, marketing, and environmental epidemiology. One potential benefit of understanding how behaviors shape exposure is informing behavioral change interventions to reduce exposures. Many exposures are occupation-related, and the science of understanding and minimizing toxic exposures in the workplace is called industrial hygiene.

Matthew O. Gribble

See Also: Children’s Environmental Health; Environmental Toxicology; Industrial Hygiene; Occupational Safety and Health; Tobacco Smoke, Secondhand and Thirdhand; Volatile Organic Compound Pollution

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EXXON VALDEZ INCIDENT

The *Exxon Valdez* incident refers to an oil spill in Alaska's Prince William Sound on March 24, 1989. Just after midnight, the oil tanker ran aground on Bligh Reef, spilling 11 million gallons (42 million liters) of its 53 million gallons (200 million liters) of crude oil from its steel hull. Until the 2010 rupture of the British Petroleum Deepwater Horizon oil rig, the *Exxon Valdez* incident was the largest ever oil spill in U.S. waters by volume. Exposure to oil caused the deaths of thousands of birds, fish, and marine mammals in the area and threatened local Alaskan Native communities.

The *Exxon Valdez* oil spill was the first to prompt a large-scale response and cleanup effort. The National Oceanic and Atmospheric Administration (NOAA) mapped the oil by flying over the spill, modeled the spill trajectory, and identified the areas that were most vulnerable to contamination (e.g., seal pup sites and fish hatcheries). Efforts to contain the spill with skimmers, burn the oil, or use chemical dispersants were largely unsuccessful. To remove oil from shorelines, volunteers and workers washed the shore with pressurized hot water. These efforts resulted in the first research about environmental recovery from oil spills.

After three smaller oil spills in the summer of 1989, Congress passed the 1990 Oil Pollution Act to strengthen federal laws about oil spills. The act introduced an oil tax to be paid by oil companies for future cleanup operations and increased NOAA's authority to respond to oil spills.

Since the *Exxon Valdez* was a single-hulled tanker, oil tankers since have been required to have two hulls. Although double hulls do not guarantee protection from structural failure and oil spillage, they are much more secure, and single-hulled tankers were phased out in the United States by January 1, 2015.

Thousands of animal carcasses were recovered after the oil spill, poisoned by exposure to the organic compounds in the crude oil. In particular, orca pods present at the spill lost up to 40 percent of their members within two years. Birds and otters also died because the oil impaired the insulating effects of their feathers and fur.

Twenty-five years after the spill, NOAA reported that the rocky intertidal zone had recovered. However, intertidal communities were still recovering, with oil remaining in areas not exposed to weathering. By 2014, many species had also recovered, including bald eagles, river otters, salmon, and sea otters, although several other populations (e.g., clams and mussels) were still recovering.

The oil spill impacted more than a dozen Alaskan Native communities who subsist on fish and birds as well as the volunteers and workers who helped to clean up the shoreline. Many workers reported health issues, and the National Institute for Occupational Safety and Health received more than 1,800 compensation claims for respiratory system problems after the spill. Crude oil contains a large variety of organic compounds, many of which are volatile and potentially toxic. Acute exposure to these compounds can cause symptoms such as eye and skin irritation, coughing and shortness of breath, nausea, headache, and dizziness. Chronic effects from long-term exposure to some of the compounds can be much more serious.

The psychological impact of the oil spill is also salient to the *Exxon Valdez* incident. An ethnographic study found that not only those exposed to the oil spill but

Cleanup of the *Exxon Valdez* oil spill disaster in 1989. The oil tanker ran aground in Alaska's Prince William Sound, causing the deaths of thousands of birds, fish, and marine mammals and threatening local communities. (Photo courtesy of the *Exxon Valdez* Oil Spill Trustee Council)

also their families and friends experienced higher incidences of problematic drinking and drug use.

Alisha K. Newton

See Also: Deepwater Horizon Incident; International Environmental Law and Policy; National Institute for Occupational Safety and Health; National Oceanic and Atmospheric Administration; Oil Spills, Health Consequences of; Persistent, Bioaccumulating, and Toxic Chemicals; *Torrey Canyon* Incident

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FEDERAL EMERGENCY MANAGEMENT AGENCY

The Federal Emergency Management Agency (FEMA) is a federal agency that provides assistance to citizens and state and local governments in responding to disasters. Its goal is to ensure that the nation builds, improves, and sustains the capacity to prepare for, respond to, and recover from disasters, whether natural or human-caused, including acts of terror. During disasters, such as when Hurricane Harvey' unrelenting rainfall inundated vast areas of Houston, southeast Texas, and southwest Louisiana in August 2017, the FEMA coordinates the federal government's response.

President Jimmy Carter (1924–) created the FEMA in 1979 by merging a number of related agencies, including the National Fire Prevention and Control Administration, the National Weather Service Community Preparedness Program, the Federal Preparedness Agency, and the Federal Disaster Assistance Administration. Additionally, civil defense responsibilities were added from the Defense Civil Preparedness Agency. Later, in 2003, the FEMA became part of the Department of Homeland Security.

The FEMA headquarters office is located in Washington, D.C., with regional offices in Atlanta, Georgia; Boston, Massachusetts; Bothell, Washington; Chicago, Illinois; Denton, Texas; Denver, Colorado; Kansas City, Missouri; New York, New

FEMA Improvements Following Hurricane Katrina

Hurricane Katrina in August 2005 was one of the strongest storms ever to hit the United States, affecting about 90,000 square miles (233,100 square kilometers) along the central Gulf Coast and devastating large parts of New Orleans. The FEMA was severely criticized for its slow and bureaucratic response to this disaster, which displaced hundreds of thousands of people from their homes and caused over $100 billion in damage. As a result, the U.S. Congress passed the Post-Katrina Emergency Management Reform Act, which (1) improved the FEMA's ability to support states and tribes ahead of a disaster; (2) established the National Disaster Recovery Framework to guide recovery efforts; (3) strengthened search and rescue capabilities; (4) required the formation of Regional Emergency Communications Coordination Working Groups to coordinate communications among federal, state, local, and tribal emergency responders; and (5) established Incident Management Assistance Teams that are able to deploy within two hours and arrive on-site with 12 hours to support the local incident commander.

York; Oakland, California; and Philadelphia, Pennsylvania. Each regional office maintains a continuously operating (24 hours a day, seven days a week) Regional Response Coordination Center that can expand during an incident to become an interagency facility staffed by a variety of emergency support personnel. The FEMA's National Training Program provides training to emergency managers and response providers across the nation. The National Flood Insurance Program is also administered by the FEMA.

Under the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988, FEMA assistance is triggered by a presidential disaster declaration. The FEMA then assumes responsibility for coordinating government-wide relief efforts, with the goal of providing disaster assistance in an orderly and systemic manner. In passing the act, the U.S. Congress intended to improve intergovernmental coordination, encourage insurance coverage, provide federal assistance programs for losses, and encourage state and local governments to develop their own comprehensive disaster preparedness plans. Today, the act is the statutory authority for most FEMA disaster response activities.

The concept of government-sponsored emergency assistance is nothing new. In the United States, the first disaster legislation, An Act for the Relief of the Sufferers by Fire, in the Town of Portsmouth (more commonly known as the Congressional Act of 1803), provided federal financial relief to the New Hampshire town following a devastating fire. Since then, over 100 pieces of legislation have been passed in response to various natural disasters.

By the 1970s, over 100 federal agencies were involved with some aspect of emergency response to disasters and other hazards, including many parallel and redundant programs and policies at the state and local levels of government. Because of this complexity, disaster response programs had become unwieldy, and the National Governor's Association asked President Carter to centralize federal emergency functions. Thus, the FEMA was born.

Richard Crume

See Also: Bioterrorism; Disaster Preparedness and Response; Emergency Planning and Community Right-to-Know Act; Natural Disasters

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FISH CONSUMPTION ADVISORIES

From time to time, advisories are issued with respect to the consumption of fish. These fish advisories are of two major types: proactive and reactive. The proactive type is intended to promote a sufficient level of fish consumption that would most likely result in enhancing the health of consumers. Such advisories typically recommend a minimum level of fish consumption. The reactive type, on the other hand, is intended to avoid excessive consumption of fish such that the health of consumers would most likely be harmed, usually from the accumulation of toxic substances, particularly metals like mercury. These types of advisories usually recommend a maximum level of consumption.

In the mid-1970s, fish consumption advisories were first issued in the United States. These advisories typically provide guidance on limiting or avoiding consumption of certain types, sizes, or parts of fish, or they provide advice on the number of fish meals to be eaten over a period of time (e.g., a week) to obtain health benefits while limiting risks. Today, there are over 3,000 species-specific, water body-specific, or general fish consumption advisories in the Unites States.

The U.S. Environmental Protection Agency (EPA) develops information on fish and shellfish consumption and also prepares various guidance documents to help regional, state, local, and tribal environmental health officials with relevant information that can be used to inform safe eating guidelines and fish advisories. For example, regional fish consumption advisories have been issued in the past decade for places like the Mississippi Delta or the Great Lakes region. States can issue fish consumption advisories to protect individuals from the risks of eating contaminated fish from certain local areas, and states can also issue safe-eating guidelines to inform people about which fish from specific bodies of water are safe to eat. To develop a consistent risk-based approach to formulating fish consumption advisories, the EPA recommends standardized practices for sampling and analyzing fish, for the risk assessment methods to be used, for the procedures for making risk-management decisions, and for the approaches for communicating risk to the general public.

Fish consumption advisories have been issued for a total of 46 chemical contaminants. These contaminants accumulate biologically in the tissues of fish at concentrations that are many times greater than the concentrations in the water. The concentrations of these contaminants in fish tissues are typically increased at each successive step up the food chain. Thus, top predators in a food chain, like salmon, largemouth bass, or walleye, can have concentrations of these substances in their tissues that can sometimes be a million times greater than the concentrations in the water. In 1998, 99 percent of all fish consumption advisories were at least partially from chlordane, dioxins, mercury, polychlorinated biphenyls, and dichlorodiphenyltrichloroethane (DDT) (including DDT's degradation substances, dichlorodiphenyldichloroethylene and dichlorodiphenyldichloroethane). In 2004, the EPA and the Food and Drug Administration issued advice for women who might become pregnant or are currently pregnant, for nursing mothers, and for young children not to eat shark, swordfish, king mackerel, and tilefish, as these fish often contain high levels of mercury. Compliance by the public with fish consumption advisories is, unfortunately, often poor. Assessing the effectiveness of such advisories is critical to assuring the optimal health of consumers.

Victor B. Stolberg

See Also: Bioaccumulation of Environmental Contaminants; Environmental Protection Agency; Food Supply, Environmental Threats to; Mercury Pollution; Persistent, Bioaccumulating, and Toxic Chemicals

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FISHING PRACTICES AND FOOD SUPPLY

As more of the food we eat is produced in factories, fish remains one of the last food sources that we consume in large quantities and that originates in the wild. With these natural sources of seafood diminishing and estimates of the world's population reaching 9 billion by the year 2050, the need for sustainable fishing practices will become increasingly important over the coming decades.

Worldwide consumption of seafood continues to increase at staggering levels, posing a potential risk to food security in developing nations. China's consumption of fish alone increased tenfold during the period 1961–2003, from 3.2 million tons (2.9 million metric tons) to 33.3 million tons (30.2 million metric tons). Over that same period, the world's top five fish consuming nations saw an increase in consumption, from 16.8 million tons (15.2 million metric tons) to 63 million tons (57 million metric tons). Harvest from the world's freshwater sources alone quadrupled since 1950, with about 8.7 million tons (7.9 million metric tons) now being caught each year.

In 2003, farmed and wild caught fish accounted for 132 million tons (120 million metric tons) in global fish harvest. By 2012, the fish harvest had risen to 154 million tons (140 million metric tons) annually, and the Food and Agriculture

Organization of the United Nations predicts the average annual harvest to jump to 181 million tons (164 million metric tons) by 2022. With such highly increasing consumption rates, demand for seafood will continue to put tremendous pressure on global resources.

Aquaculture, or fish farming, is seen as a potential sustainable solution to depletion of the wild seafood supply. Aquaculture refers to breeding and harvesting in a variety of water environments, including ponds, rivers, lakes, and oceans. Marine aquaculture represents ocean-caught species, such as oysters, shrimp, clams, and fish. Breeding can take place in cages in the ocean or in man-made enclosures on land. Freshwater aquaculture breeds species that are native to rivers, lakes, and streams. This type of aquaculture takes place primarily in ponds, with the most predominant species being catfish, and to a lesser degree, trout, tilapia, and bass.

While there are significant benefits to aquaculture in helping to reduce seafood scarcity, there are also potentially undesirable side effects. For example, aquaculture poses significant environmental risks due to the buildup of nutrients and effluents on the ocean floor. As fish are bred and contained in cages at high densities in the ocean, the threat of solid waste and dissolved nutrients has the potential to build up and produce algal blooms, which can subsequently create dead zones near aquaculture sites.

Other negative effects can be seen in the impact that farmed fish can have on local wild fisheries. The concern is that due to the density of fish bred on farms, disease and outbreaks of parasites can have widespread damaging effects on schools of wild fish located nearby. These outbreaks were once treated by farmers with antibiotics, which raised concerns about how these treatments would affect the ecosystem. Recently, the use of antibiotics on fish farms has largely subsided, giving way to more effective and safer vaccination methods.

Another concern regarding the use of fish farms to increase seafood supply is the prospect of nonnative farmed fish escaping and competing with wild populations for food. The fear is that the farmed fish will further limit the supply of natural food for wild fish, with the possibility of also displacing native populations. An additional concern is the potential for farmed fish to interbreed with native fish, thus affecting the gene pool of wild populations. The development of genetically modified, sterile female fish used in farm populations has lessened these concerns considerably in recent years.

Although potential negative impacts of fish farms on the environment do exist, the benefits of increasing the food supply provide a tremendous upside. Furthermore, fish farms help avoid the adverse impacts associated with traditional fishing practices, such as overfishing, which leads to rapidly depleted wild fisheries and environmental damage that can disrupt ocean habitats needed for native species of fish to thrive and reproduce. Another common fishing practice, bottom trawling, involves dragging a large, weighted net across the ocean floor. As the net scrapes the ocean bottom, this method can promote the unintended effect of gathering endangered sea creatures and destroying centuries-old coral reefs used by a variety of sea life for sources of food and shelter.

Another controversial, yet common, fishing practice, known as cyanide fishing, is equally damaging to the health of ocean coral reefs. This technique involves dumping sodium cyanide into the water to stun fish without killing them, making them easier to capture. This method of fishing has become popular as a means of providing exotic reef fish to restaurants across Asia, with the trade-off of potentially destroying portions of the coral reef in the process.

Coral reefs in Asia have also suffered from a technique referred to as dynamite fishing. Under this method, explosives are set off deep underwater to send dead fish floating up to the top of the surface for easy capture. A by-product of this efficient form of fishing is the destruction of coral reefs, which often turn into rubble following an explosive blast.

Ghost fishing is a phenomenon that occurs when fishing gear, such as drift nets, is lost at sea. Drift nets can be hazardous to fish, dolphins, whales, and other sea creatures, particularly as the nets get snagged on seabeds and ensnare unintended victims.

Consumers of seafood have considerable access to educational information that can lead to better awareness of the issues surrounding fishing practices and food supply. One such resource is Seafood Watch, a program of the Monterrey Bay Aquarium, which is well known for its influential sustainable seafood advisory lists. In addition to online information, Seafood Watch offers pocket guides and mobile apps that provide seafood recommendations for consumers, based on sustainability principles regarding fish supply and sea creature habitats.

Anthony C. Holderied

See Also: Coral Reefs and Food Supply; Fish Consumption Advisories; Food Supply, Environmental Threats to; Hypoxia, Gulf of Mexico

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FLINT, MICHIGAN, CONTAMINATED DRINKING WATER IN

In 2013, the city of Flint, Michigan, made the decision to change the public drinking water supply from the Detroit Water and Sewerage Department (DWSD) to the Karegnondi Water Authority (KWA) as a cost-saving measure. Once the transition between water sources started in 2014, the city needed an interim source while the KWA pipeline was under construction, and it began to use the Flint River as a temporary source of public drinking water.

At this time, the Flint River water was not treated with the anticorrosion chemical that prevents lead particles and solubilized lead from being released from inside water pipes. Pipes with lead service lines or solder are especially vulnerable to releasing lead in the absence of this anticorrosion chemical. The lack of this chemical meant that Flint was in noncompliance with the Environmental Protection Agency's (EPA) Lead and Copper Rule.

One month into the switch to the Flint River, in August 2014, residents began to complain about the color and smell of their water. Soon after, *E. coli* and total coliform bacteria were detected in the water supply. Over the next year, tests showed that total trihalomethanes (or TTHM, a potential carcinogen for humans) and lead were present in the public water supply at unsafe levels.

It was during this time that the effects on humans began to get attention, particularly with regard to lead levels present in the public drinking water supply. Flint-based pediatrician Mona Hanna-Fisher conducted a study measuring blood lead levels (BLLs) in children and comparing results from before the water supply switch (2013) to postswitch (2015). Her study exhibited doubled BLLs between 2013 and 2015 and, in some areas with higher lead concentrations, showed children with triple the BLL during that period. These findings were particularly frightening to local residents because lead exposure in young children has been shown to lead to declines in intelligence, development, behavior, attention, and other neurological functions.

Volunteers help distribute bottled water to residents of Flint, Michigan. After changing the public water supply, unsafe lead levels were found in residential drinking water, a serious concern for young children. (AP Photo/Carlos Osorio)

In September 2015, 17 months after first subjecting its residents to the Flint River contaminated water supply, the city of Flint took its first action to protect residents by issuing an optional lead advisory, and one month later, the city's water supply was switched back to the DWSD.

In January 2016, President Obama declared a state of emergency in Genesee County, where Flint is located, meaning that Flint now had access to federal funding and Federal Emergency Management Agency equipment and resources. The EPA similarly issued an emergency order, stating that "the City of Flint's and the State of Michigan's responses to the drinking water crisis in Flint have been inadequate."

As 2016 progressed, criminal charges were filed against multiple officials and lawsuits against several corporations, including two water consultants: Veolia North America Inc. and Lockwood, Andrews, and Newnam Inc. Many consider the Flint water incident to be a failure at multiple levels of government to protect the public's health.

Hana Elliott

See Also: Drinking Water Quality and Regulation; Environmental Justice; Environmental Protection Agency; Heavy Metal Pollution; Lead Poisoning Prevention

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FLUORIDATION OF WATER

Fluoridation of water is the addition of a controlled or regulated amount of fluoride to the public water supply to discourage the development of dental cavities (tooth decay). Water fluoridation dates back approximately 70 years, and every major health organization in the United States believes that fluoridation of water is good for the maintenance of healthy teeth in all ages. Some authorities have tried to associate fluoridation of water with thyroid, kidney, and heart problems and even cancer. However, there has been no credible evidence to show that fluoridation poses any danger to health other than fluorosis of the tooth. Studies conducted in New Zealand, Great Britain, and the United States have all given credence to the dental-protective benefits of water and toothpaste fluoridation. The Centers for Disease Control and Prevention has identified water fluoridation as one of the 10 great public health achievements of the 20th century.

Fluoride is a mineral substance mined from phosphate rock that is released in its natural form from rocks into the soil, water, and air. This molecule is present in a wide variety of consumer goods and can be found dissolved in water throughout the world. Fluoride extracted from phosphate rock is sometimes used as an additive in beverages. Although phosphate rock is the same source from which people obtain fertilizers, fluoride is not a by-product of the fertilizer industry.

Standard 60, created by the U.S. Environmental Protection Agency, is used to regulate the quality and safety of fluoride in water and other mineral drinks. Standard 60 is designed to empower independent committees of health experts to ensure appropriate regulation of certain health measures, including water fluoridation. Based on this principle, community water fluoridation can be adjusted to achieve the optimal level of fluoride in water to protect individuals against tooth decay. This has been the most cost-effective way of delivering fluoride-protective water to the community, and it has been found to reduce tooth decay in children and adults by 25 percent.

In the 1930s, scientists discovered that children who lived in districts with high levels of fluoridated water had less dental decay, as compared with children in communities with lesser amounts of fluoride in drinking water. At that time, most children and adults were losing teeth as a result of dental decay and the subsequent painful dental extractions. Following extensive research, in 1945, the city of Grand Rapids, Michigan, became the first in the United States to fluoridate its community water system, adjusting the added amount to achieve its dental protective expectations. This process is now referred to as community water fluoridation. Because the practice has continuously proven to be useful, other cities in the United States gradually adopted the system, and by 2012, over 75 percent of the entire country had approved the practice of community water fluoridation.

The American Academy of Pediatricians, American Dental Association, and Centers for Disease Control and Prevention are all in agreement that fluoridation, especially in children, protects the teeth from decay following an oral bacterial invasion. However, there is one side effect: fluorosis. Fluorosis is the occurrence, often in children, of faint white lines on the surface of teeth enamel due to excess intake of fluoride. Studies show that fluorosis also occurs in communities having no prior history of water fluoridation. Fluorosis may be more concerning in children, especially those under the age of six, because their teeth are still growing under the gums.

In recent years, there has been an increasing introduction of toothpaste manufactured with fluoride as part of the active ingredients. Although this helps to boost the dental benefits resulting from fluoride use, it is important to regulate the daily intake of fluoride, especially for children, to prevent fluorosis. Reports indicate that there may be an excessive amount of fluoride in some well waters. Some researchers believe that fluoride may be contributing to increasing IQ in the United States, as IQ has increased among Americans by 15 points between the 1940s and 1990s. This claim is supported by evidence from children in China, Mongolia, and Iran who drink from high fluoride concentration water sources and have demonstrated very high IQs.

Ifeanyi Abuachi

See Also: Centers for Disease Control and Prevention; Drinking Water Quality and Regulation; Environmental Protection Agency

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FOOD SAFETY AND TECHNOLOGY

Food safety is an important concern given the continual advances in food processing technology. Federal agencies, such as the Food and Drug Administration (FDA), the Centers for Disease Control and Prevention, and the Environmental Protection Agency, as well as a variety of private organizations rely on technological advancements to improve food safety oversight. The use of technology is present in all components of food production, including development, processing, and distribution. Technology has increased our ability to strengthen food industry standards and to identify and resolve potential threats transferred within foods, such as harmful bacteria. Given the worldwide importing and exporting of food, the safety of our food supply remains an ongoing concern for the public. Advanced technologies help ensure food safety and support consumer confidence in the food supply.

The emergence of the academic discipline of food science has resulted in greater achievements in food safety by identifying integration opportunities and using advanced technologies. Without technological oversight, challenges to what is safe to eat and what is not would be left up to the consumer. Purchasing patterns would likely be driven by fears associated with the latest sources of contamination featured in the news cycle. The Institute of Food Technologists (IFT) in its food safety report indicates the need for the continued evolution of science and technology to ensure a food supply that is safe from internal and external compromises. The use of technology, from initial storage through distribution to retail channels, has resulted in enhanced safety measures and oversight.

Technology has assisted food scientists in developing new processes that monitor conditions during transfer. In addition, it has allowed for enhanced testing of foods for contamination, which helps to prevent foodborne illnesses and potential disease outbreaks. For example, the technological breakthroughs associated with the pasteurization of milk have given distributors and retailers the ability to track shelf life, avoid foodborne illnesses, and promote consumer confidence.

Technologies allow retailers to be aware of the currency of their products, removing expired products from the shelf that could potentially harm the customer. For example, the use of bar codes allows retailers, through the press of a button, to track batch numbers of products and provide real-time evaluation of stock. As safety concerns are balanced against shelf life, technology allows retailers to maximize delivery of products while avoiding costly ongoing inventory evaluations. The end result has promoted the integration of technologies into the food marketplace. According to the IFT, these technologies have a dual purpose of maximizing profits while protecting the health of consumers.

The inclusion of technology by the food industry has been spurred by the need to increase consumer perceptions relative to purchasing. This moves beyond the greater good premise and instead provides credibility of safety to each purchase. According to a study by the International Food Information Council Foundation, only 67 percent of study participants indicated some confidence in the safety of the U.S. food supply, with 14 percent of participants noting that they were not confident in the safety of their food. Despite these low percentages, experts believe that emerging technologies can provide the necessary oversight and resolve food safety management issues before they emerge.

In 2011, the FDA began implementing the Food Safety Modernization Act (FSMA). Technological advances and enhanced oversight have led to noticeable recalls of popular food brands. As the public and oversight organizations have continued to draw attention to pathogens and other food contaminants, the need for government actions and mandates, such as FSMA, has become an imperative. As food safety has emerged as an ongoing and significant social issue, where consumer confidence in brand products and the overall marketplace is essential, the inclusion of technological advancements allows for accountability and oversight in every exchange within the supply chain. The need for food technologies to continue to evolve and expand is an essential component in food safety.

The U.S. Department of Agriculture (USDA) oversees the agriculture, meat, poultry, chicken, and seafood industries, with safety and prevention of illness as its primary mission. As new technologies emerge, their success in the distribution, handling, and transport of food is reviewed by groups of food scientists operating in teams, such as the USDA's Agriculture Research Service (ARS). The efforts of the ARS and other food safety research teams are directed at developing food safety approaches aided by technological advances. In 2015, the USDA spent more than

$70 million on food safety research, which included websites, hotlines, and other informational services for the public. FoodSafety.gov serves as the initial gateway to federal food safety information for consumers about the food products they purchase.

Charles Daniel

See Also: Coral Reefs and Food Supply; Fishing Practices and Food Supply; Food Supply, Environmental Threats to; Foodborne Diseases; Organic Agriculture

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FOOD SUPPLY, ENVIRONMENTAL THREATS TO

Environmental threats to food supply refer to environmental problems that pose threats to the production, availability, and security of food and water supplies throughout the world. There are many such threats, including the effects of climate change, chemical pollution of the air, shortages of freshwater supplies, and shortsighted land-use practices.

Honey Bees and Food Supply

On average, about one of every three bites of food we eat at the dinner table originates with honeybee pollination.

An Interview with Dr. Dennis vanEngelsdorp

Assistant Professor of Entomology, University of Maryland

Dr. vanEngelsdorp is a leading expert on honeybee health and the decline of bee populations. At the University of Maryland, he manages the Honey Bee Laboratory, which focuses on an epidemiological approach to honeybee health, and he is a founding member of the

Bee Informed Partnership. The partnership conducts the largest and most comprehensive honeybee survey in the world, with the goal of improving best management practices for beekeepers.

In 1945, there were 4.5 million bees in the United States, but today there are just about 2 million. And in 2014 alone, some U.S. beekeepers lost 40 percent of their colonies. What are the factors leading to the decline in bees, and what can be done about it?

Over the years, honeybee colonies have been under stress due to several factors, including landscape changes that have destroyed forage, such as meadows. More recently, honeybees have also been threatened by varroa mites and pesticides. However, rather than honeybees going extinct, the greater problem may be beekeepers going extinct. This is because about 50 percent of honeybee colonies are lost every year, and the beekeepers are struggling to compensate by introducing new colonies. Under these circumstances, it is uncertain how long commercial beekeepers can continue profitable operations.

Many foods depend on honeybee pollination. If the population of honeybees continues declining, what does this mean for food supply and diversity and for human health?

There are only about 2,000 commercial beekeepers in the United States, and many farming operations and orchards depend on these beekeepers for providing pollinating bees. On average, about one of every three bites of food we eat at the dinner table originates with honeybee pollination. You can image the implications for food supply and diversity and for maintaining a healthy human diet if one-third of our food choices disappeared.

You have said, "Imagine if one of every three cows died. The National Guard would be out." Do we need this same sense of urgency about the precipitous decline in honeybees and potential reductions in our food supply?

Perhaps, but the situation with honeybees is different because the beekeepers are able to keep up with colony loss by making new colonies. This tends to hide the problem if you simply look at colony numbers.

You have also remarked that honeybees are like canaries in the coal mine. Are you concerned about the role that honeybees play in the global ecosystem and the potential for unforeseen consequences of honeybee decline?

Honeybees are not native to the United States. Of greater concern to the ecosystem is the fate of the native bee population, which could also be stressed if honeybees are any indication. Unfortunately, very little research has been conducted in this area.

What steps can young people, graduating from high school or college, take to protect our food supply by maintaining honeybee populations?

There are three actions young people can take to protect honeybee colonies and beekeepers. One is to become beekeepers themselves! Another is to buy local honey. Finally, plant a pollinator garden, with different plants maturing at different times of the year.

Many environmental problems associated with food supplies are related to the ever-growing size of the human population, which is expected to increase to between 9 billion and 10 billion by the middle of the 21st century. This population growth means that tens of millions of additional people must obtain access to food and freshwater every year. By 2050, the world may need to produce 50 percent more food than it is currently producing. Unfortunately, the challenges of dealing with environmental threats may make it difficult to meet this need. Consequently, malnutrition has the potential to rise substantially, particularly in poor, developing nations that are already struggling to meet their food and water needs.

Evidence suggests that droughts may be growing in frequency and severity in some regions, increasing the serious threats to food and water supplies. Many scientists believe that human-caused climate change is responsible for the worsening droughts. Computer models indicate that certain areas of the globe, including Africa and the Middle East, are likely to be the most adversely impacted by climate change for several reasons. Not only will the altered weather patterns likely bring more heat, drought, and disease to these regions, but the inadequate economic and infrastructure conditions in those areas make it difficult for the governments there to prepare or respond in meaningful, effective ways. In other areas, by contrast, climate change might produce altered weather patterns that could have some positive impact on agricultural yields. For example, crop productivity might increase in northern Europe as the weather there warms.

The warmer weather associated with climate change is generally expected to lead to decreases in the yields of various kinds of crops that are especially sensitive to heat, including corn and soybeans. In 2014, an international group of scientists (led by Amos P. K. Tai of the Chinese University of Hong Kong) estimated that global warming will likely decrease crop yields by approximately 10 percent by 2050. The adverse consequences of warmer weather stem partly from an increase in crop and livestock diseases caused by insects, fungi, and other pests as well as from the reduced air quality associated with heat.

Climate change affects the food supply of the ocean because of higher water temperatures, changes in salinity levels, and other factors. Such changes can have adverse effects on the populations of some fish species, and they can also alter the home ranges of certain species, making those species difficult for fishing vessels to find. In addition, warmer water leads to more disease-causing parasites in fish.

Air pollution is a threat to food production—especially the ground level ozone that is a primary constituent of smog. This gas, which develops in the air from chemical pollutants (oxides of nitrogen and volatile organic compounds) emitted by motorized vehicles and industrial facilities, can retard the growth of crops, kill crop seeds, and make crops more susceptible to damage from pests and harsh weather. Wheat is among the crops that are most threatened by poor air quality.

Another pollutant that is potentially harmful to crops is the carbon dioxide that is emitted by cars, factories, power plants, and other human and natural sources.

Carbon dioxide is essential to plant survival, as plants absorb it into their tissues and convert it into sugary food during the process of photosynthesis. However, the Environmental Protection Agency classifies carbon dioxide as a pollutant because it is the main greenhouse gas that is driving global warming. Some computer models suggest that crops and other plants may benefit from higher-than-normal levels of carbon dioxide by growing larger and faster, thereby increasing agricultural yields. Nevertheless, most scientists maintain that the overall effects of global warming will be negative to worldwide agricultural production. In addition, research has shown that increased carbon dioxide concentrations in the atmosphere lead to decreased concentrations of proteins and essential minerals in wheat, rice, soybeans, and several other important crops.

The expanding human population has put great stress on water supplies, with violent conflicts arising in the Middle East, Africa, and other regions as competing population groups, typically divided along ethnic and national lines, fight over access to the diminishing supplies. Freshwater supplies are expected to continue to decrease as droughts and climate change aggravate existing water shortages. Some nations have responded to the threat of "water wars" with creative solutions for obtaining more drinking water, such as through the construction of desalinization facilities that remove salt from seawater so that it can be consumed.

Unwise agricultural practices, combined with drought, have contributed to the loss of arable land through soil erosion, nutrient depletion, salinization, and desertification. Each year, more than 30 million hectares of formerly productive agricultural land turns into virtual deserts, according to UN estimates. This trend in land loss may accelerate as the extreme weather events linked to climate change, such as severe droughts followed by heavy rains and flooding, increase in frequency.

A. J. Smuskiewicz

See Also: Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Drought and Desertification, Health Consequences of; Heat Waves; Ozone and Smog in the Urban Environment; Population Trends, Health Implications of

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FOODBORNE DISEASES

Foodborne illnesses are illnesses caused by certain natural toxins and food products contaminated with pathogens (microorganisms that can cause disease). While more prevalent in developing countries, it is estimated that greater than 350 million cases of foodborne illnesses occur annually within the United States. The extensive list of foodborne pathogens includes a variety of organisms ranging from viruses and bacterial organisms to multicellular parasites. Most of these illnesses present as a nuisance, rather than as a life-threatening disease. However, some organisms can be very dangerous if ingested. With a few exceptions, symptoms of foodborne illnesses (which can include abdominal cramping, nausea, vomiting, and diarrhea) tend to present within hours of ingesting the microorganism.

The most common virus family leading to foodborne illness is the *Norovirus* (Norwalk-like virus) family. The *Hepatitis A* virus (HAV) and *Rotavirus* are not in this family, but they also cause very common and preventable viral infections. HAV causes foodborne illnesses in adults, while *Rotavirus* affects children. These illnesses can display a variety of symptoms, from no symptoms to severe illness lasting from days to months. HAV is a picornavirus, transmitted via the fecal-oral route, that causes liver inflammation. In healthy individuals, HAV is self-limited and does not cause chronic hepatitis, as opposed to the life-threatening *Hepatitis B* and *C* viruses. *Rotavirus* is in the reovirus family. *HAV*, *Rotavirus*, and *Norovirus* are all easily preventable with good hygiene, such as hand-washing practices and proper sanitation prior to preparing and consuming food. Additionally, *Rotavirus* and *Hepatitis A* both have vaccines available to prevent these viral infections.

Bacterial organisms from many families can also cause a variety of symptoms and threats. For example, there are many strains of *E. coli* that reside within the intestinal tract that can cause self-limited gastrointestinal disease when ingested. However, *Shiga* toxin-producing *E. coli*, also known as enterohemorrhagic *E. coli* (EHEC), can be very harmful to humans. *E. coli* O157:H7 is the most frequent EHEC disease-causing strain in the United States, and it presents with watery, bloody diarrhea. In this case, the Shiga toxin, rather than the organism itself, is the agent causing the disease. Studies have shown that there are more than 50 genetic strains of EHEC that can cause bloody stools, kidney failure, and multiple organ failure. Many of these strains can be found in undercooked ground beef, unpasteurized juice, or raw vegetables (such as alfalfa sprouts).

Listeria monocytogenes, another bacterial pathogen, is commonly found in deli meats and unpasteurized dairy products (such as feta cheese and brie) and causes listeriosis. During an outbreak of listeriosis, healthy individuals typically experience some nausea, diarrhea, and flu-like symptoms. However, in the elderly and individuals with human immunodeficiency virus (HIV), listeriosis can be fatal. In pregnant women, listeriosis can lead to the death of the unborn child, in addition to being harmful to the pregnant mother.

Clostridium botulinum (*C. botulinum*), which causes botulism, produces neurotoxins termed botulinum toxins A through G. Toxins A, B, and E are harmful to humans, and toxins C and D are harmful to animals. The neurotoxins work by blocking the release of acetylcholine, a neurologic compound important for muscle contraction. *C. botulinum* was initially found to be a very dangerous organism because the toxins can cause paralysis. However, scientists later discovered that the botulinum toxin has commercial uses. In fact, the botulinum toxin is now used for cosmetic purposes and to treat medical conditions, such as migraines, muscle spasms, and esophageal strictures. When this bacterium is ingested in sufficient amounts, it causes botulinum toxicity, leading to severe paralysis of all musculature (including the muscles needed to breathe). The treatment for botulism is mechanical respiratory support and antitoxin injections extracted from the horse variant of the bacterial organism.

Parasitic infections, while less common than viral and bacterial foodborne infections, can cause devastating illnesses. Cysticercosis is a cystic disorder that results from infection by the parasitic tapeworm *Taenia solium*, which lives within porcine species. When pigs or hogs are prepared and cooked, they must be appropriately handled to clear the pork meat of the parasitic larval cysts. A common misconception is that the infection results from undercooked pork meat. However, infection is actually caused by individuals handling human or porcine feces that contain the worm or larval cysts prior to preparing the food. The larval cysts are then ingested and the worm reproduces inside the human host, where they introduce more larval cysts into the stool, and the larva can spread to the brain and other organs. In the brain, this tapeworm's cysts can cause neurocysticercosis, which causes seizures, convulsions, and death. The treatment is initiated within a hospital setting because the treatment is also dangerous to the exposed patient and can be fatal if the treatment is too aggressive.

Diphyllobothrium latum is a tapeworm found in the freshwater fish of many countries, with higher prevalence in the Northern Hemisphere. It is acquired by ingesting raw fish that has been infected by the tapeworm. Salting the fish does not eliminate the risk because it does not kill or eradicate the worm's eggs. When ingested, this worm can lead to pernicious anemia (vitamin B_{12} deficiency anemia) and a slew of other symptoms. The best method of treatment is an injection of the small intestine, usually within the duodenum, with diatrizoic acid. Other treatments can potentially leave the head of the tapeworm attached to the intestinal lining, and this parasite can regrow from the remaining head.

Prion diseases (also known as transmissible spongiform encephalopathies) are progressive neurodegenerative disorders that can affect humans and animals. It is a rare condition in which an abnormal protein molecule is ingested by an animal or human and causes their native proteins to deform. These diseases are more prominent in communities that ingest animal brain matter. Some well-known prion diseases include mad cow disease, scrapie, and Creutzfeldt-Jakob disease, which afflict cows, sheep and goats, and humans, respectively. Other animals, such as felines and minks, have their own variants.

The best prevention of foodborne disease is to always practice good hygiene and proper sanitation practices prior to eating and preparing food for consumption. It is best to avoid eating food prepared by street vendors in developing countries and to understand that there is a risk of acquiring a foodborne illness every time raw meat or fish is consumed. Prior to international travel, individuals should always research the country to which they are traveling to ensure that they have acquired all relevant pretravel vaccinations. Also, a thorough review of travel websites will help the traveler understand and prepare for potential illnesses.

Howard W. MacLennan Jr.

See Also: Environmental Toxicology; *Escherichia coli* (*E. coli*) Infection; Food Safety and Technology; Infectious Diseases; Neurotoxicants; Norovirus Infection

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FORMALDEHYDE

Formaldehyde is a highly reactive, colorless to opaque gas with a strong, pungent odor, and it is highly flammable and explosive. As one of the oldest chemicals in the world, formaldehyde is produced in quantities of 20 million tons (18 million metric tons) each year across the globe. Formaldehyde is found in composite wood products, building insulation, glues, permanent press fabrics, paints and coatings, lacquers and finishes, paper products, preservatives in medicines, cosmetics and other consumer products, fertilizers, and pesticides. Additionally, formaldehyde is a common by-product of combustion, such as cigarette smoking and cooking. In the modern world, formaldehyde is ubiquitous in the environment.

Because formaldehyde is used commonly in consumer and building products as glue, most people have been exposed to some level of formaldehyde gas. Because the highest exposure levels occur in formaldehyde-based resin industries, workers

Formaldehyde and Vaccines

Formaldehyde is used in the production of certain vaccines to inactivate the targeted virus or bacteria, exposing individuals to another source of this ubiquitous chemical. In the production of vaccines, such as polio vaccine, formaldehyde is diluted and believed not to pose a concern to human health due to the minimal amount used. The body does not distinguish between formaldehyde in vaccines and formaldehyde produced naturally in the body, but according to the U.S. Food and Drug Administration, there is no evidence linking formaldehyde to an increased risk of cancer from the infrequent exposure associated with vaccines.

in certain industries making building materials and consumer goods such as furniture can be exposed to high levels of formaldehyde while at work.

Formaldehyde's carcinogenicity is well established. A 1980 study first documented the presence of squamous cell carcinomas in the nasal passages of rats. Human cancers, such as nasopharyngeal cancer, sinonasal cancer, and lymphohematopoietic cancer (specifically, myeloid leukemia), are caused by high, prolonged exposure to formaldehyde. In addition to cancer, formaldehyde can cause irritation to the skin, eyes, nose, and throat at even low exposure levels in the air. Other adverse health effects in humans include eczema and lung malfunctions. The primary exposure route for formaldehyde is inhalation.

To protect workers and the public, exposure limits have been set by several U.S. and international agencies. Additionally, the International Agency for Research and Cancer and the National Toxicology Program have both classified formaldehyde as causing cancer in humans. The World Health Organization has established a standard to protect workers who are exposed to formaldehyde of 0.1 milligram per cubic meter in the air, not to be exceeded for any 30-minute period. The U.S. Environmental Protection Agency's lifetime formaldehyde exposure limit for drinking water is 1 milligram per liter. The Occupational Safety and Health Administration has set a worker exposure limit of 0.75 parts per million for an 8-hour workday, 40-hour workweek.

To reduce exposure in the general population, the U.S. Department of Housing and Urban Development has set standards to reduce formaldehyde exposure from housing materials, such as plywood and particle board. Formaldehyde emissions should not exceed the recommended levels of 0.2 parts per million for plywood and 0.3 parts per million for particle board.

Because many products found in homes and buildings contain formaldehyde as a glue, indoor air concentrations of formaldehyde often exceed those found outdoors. Indoor formaldehyde levels typically range between 0.02 and 4 parts per million. In homes, elevated levels of formaldehyde can be reduced with good ventilation (e.g., using fans and opening windows), by sealing any unfinished manufactured wood surfaces, and by washing new permanent press clothing. Controlling indoor air levels can help alleviate odor, eye irritation, and other sensory effects associated with formaldehyde exposure.

Elizabeth Ann Glass Geltman and Nichole LeClair

See Also: Environmental Protection Agency; National Toxicology Program; Occupational Safety and Health; Occupational Safety and Health Administration; Personal Care Products, Health Issues with; Tobacco Smoke, Secondhand and Thirdhand; World Health Organization

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FUGITIVE DUST

Fugitive dust is solid particulate matter that is emitted to the atmosphere from an open source rather than from a confined flow stream such as an industrial smokestack. Example open sources include (1) vehicles traveling on unpaved roads and (2) wind erosion of unconsolidated soil surfaces (e.g., disturbed desert lands) that have been graded prior to construction projects. Fugitive dust causes health problems associated with inhalation exposure as well as risks related to low visibility in dust plumes (e.g., clouds of dust rising from a roadway or soil surface that can make driving hazardous). During high-wind events, dust can cause property damage from the saltating of sand-sized particles on surfaces.

Fugitive dust includes a wide range of particle sizes, from submicron to hundreds of microns in diameter. (A micron, also called a micrometer, is a unit of length equal to one millionth of a meter.) Particles in the respiratory size range are termed "PM10," which is defined as particles equal to or less than 10 microns in aerodynamic diameter. These particles are small enough to reach far into the lungs, where health can be compromised. Because PM10 is the particle-size basis for the national ambient air quality standards for airborne particulate matter, it also represents the particle size range of greatest regulatory interest.

Dust in the PM10 size range has a major effect on reducing visibility during (1) conditions of low winds with poor atmospheric ventilation and (2) high-wind events that generate wind erosion. The latter effects can be observed in large dust clouds passing over cities such as Phoenix, as covered periodically on television newscasts. These dust storms create roadway hazards resulting in multivehicle accidents and even fatalities. Damaging dust storms in the desert southwest have become more frequent as a result of extended drought and the continuation of land development that destroys native vegetation and other protective features of natural desert soil.

Fugitive dust can carry contaminates that were present in the surface material. In the desert southwest, research has found that the multitude of mineral, fungal, and pollen-related allergens dispersed by dust storms can adversely affect human health. Illnesses associated with desert dust include valley fever, silicosis, bronchial asthma, and allergic rhinitis.

Emission controls for unpaved travel surfaces are well developed, ranging from simple watering and the application of deliquescent salts to the use of chemical binders that are periodically reapplied. Newly explored control measures for wind erosion use natural material barriers for trapping saltating sand, thereby preventing damage to land areas and structures further downwind. These measures include cross-wind berms constructed of landscaping waste or soil that has been stabilized on the upwind face. Traditional chemical binders can be effective, but they are generally cost-prohibitive for reducing fugitive dust from large land areas, and they also leave potentially damaging chemical residues.

Chatten Cowherd Jr.

See Also: Air Pollution; Allergens in the Environment; Ambient Air Quality; Asthma; Drought and Desertification, Health Consequences of; Particulate Matter and Bioaerosols Pollution; Regional Haze Pollution; Respiratory Disease and Air Pollution

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FUKUSHIMA DAIICHI INCIDENT

The Fukushima Daiichi nuclear power plant accident occurred on March 11, 2011, on the northeastern coast of Japan. Earlier that afternoon, a massive magnitude 9.0 earthquake struck Japan, causing a tsunami in some areas as high as 130 feet (40 meter) to crash into the coast and flow inland up to 6 miles (10 kilometers). These two natural disasters accounted for more than 15,000 deaths.

Health Consequences of the Fukushima Daiichi Disaster

The most effective way to address the nuclear problem is through educating the public.

An Interview with Dr. Helen Caldicott

Physician, author, and public speaker on the medical hazards of the nuclear age

Dr. Caldicott has devoted more than four decades to educating the public on the medical hazards of the nuclear age and necessary changes in human behavior to stop environmental destruction. She is former president of Physicians for Social Responsibility and a recipient of 21 honorary doctoral degrees, and she was personally nominated for the Nobel Peace Prize by Dr. Linus Pauling (himself a Nobel Laureate). Additionally, Dr. Caldicott was named one of the most influential women of the 20th century by Smithsonian *magazine. A film based on a lecture she gave to students,* If You Love This Planet, *won an Academy Award in 1982 for best documentary. Her latest book,* Crisis without End, *documents the Fukushima Daiichi nuclear plant disaster.*

Following the Great East Japan Earthquake and tsunami on March 11, 2011, a meltdown occurred at three of the four Fukushima Daiichi nuclear power reactors, and 100,000 residents of nearby towns were evacuated. What is the likelihood that some of the evacuees or their offspring will experience radiation-related diseases at some point in the future?

Future adverse health effects are very likely, and in fact, they are already happening. There is a disproportionate number of thyroid cancer cases among children in the area, and other cancers are starting to show up. This is remarkable given that cancer normally has a longer incubation period than the few years that have passed since the meltdowns. New evidence has come to light indicating that perhaps a million premature deaths have occurred among the exposed population following the Chernobyl accident. Thus, there is no reason to believe there will not be many more health issues associated with Fukushima. Remember that radiation exposure does not just cause cancer. Other adverse health consequences can occur too, including sudden heart attacks, cataracts, and premature aging. There can also be a variety of cancer types. And anyone living through a nuclear emergency can experience long-term emotional and psychological distress.

The Fukushima Daiichi plant clearly was not prepared for the devastating tsunami that followed the earthquake. What lessons have we learned from this experience, particularly in protecting human health?

The only solution is to shut down all nuclear plants. Most are approaching the end of their lifespan anyway. Contrary to the opinion of many politicians and energy industry experts, nuclear power is not a solution—not even an interim solution—to global warming. There is a vast nuclear infrastructure associated with nuclear power, including the enrichment process, and these operations can generate vast quantities of greenhouse gases. Whereas countries like the United States are subsidizing coal, they instead should be subsidizing renewable energy sources like solar.

What would be a good career path for a recent college or university graduate wanting to prevent nuclear accidents and find alternatives to nuclear power?

The most effective way to address the nuclear problem is through educating the public. Thomas Jefferson said, "An informed citizenry is at the heart of a dynamic democracy." Education is the most powerful force for change.

The nuclear reactors survived the earthquake by shutting down immediately. But the following tsunami breeched the seawalls of the nuclear power plant, flooding the operation and damaging the emergency power generators, which fueled the cooling systems for the nuclear reactors. Without those generators, the nuclear reactors began to overheat, eventually exploding with hydrogen gas. Radioactive material, including volatile iodine-131 and caesium-137, began leaking into the air. The leak was rated "7" on the International Nuclear and Radiological Event Scale, the highest level on the scale. The only other event to be categorized this high was the Chernobyl incident in 1986.

Shortly after the incident, the Japan government raised the standard radiation dose limits for Japanese citizens. Some reports suggest this was an attempt to lessen the burden of having to evacuate more people, for example, the 300,000 residents of Fukushima City, about 45 miles (72 kilometers) away. Beef

Evacuees screened for radiation exposure following a release of radioactive gas from the Fukushima Daiichi nuclear power plant on the northeastern coast of Japan. A massive 2011 earthquake and tsunami severely damaged the plant, causing the evacuation of over 100,000 people. (AP Photo/Wally Santana)

contaminated with radiation was widely circulated in Japan, resulting in some illnesses, and a year after the incident, around 40 percent of the fish caught near the Fukushima region were deemed unfit for human consumption. Radioactive material was found in ocean water and sea creatures 186 miles (300 kilometers) from the coast in 2012.

In July 2012, a Japanese parliamentary committee investigation found negligence on behalf of Tokyo Electric Power Company (TEPCO), citing safety and training procedures. The committee held no individual responsible for the accident but blamed the organizational structure of TEPCO for not preparing better for extreme disasters. The committee also cited flaws in the country's emergency response procedures. For example, at the time of the incident, the regional nuclear emergency response team was supposed to act as an intermediary between the Japanese prime minister's office and the power plant. Instead, the prime minister's office communicated with TEPCO directly, which disrupted the proper channels of communication.

The central government was also found responsible for the poor evacuation plan. Approximately 150,000 people were evacuated from their homes, and some were relocated multiple times. Only 20 percent of residents in town were aware of the radiation leak when they were evacuated, and some people were evacuated to areas with higher radiation levels than where they came from due to lack of monitoring information. The Japanese parliamentary committee called for a complete overhaul of the corporate structure of TEPCO and the regulatory bodies that oversee it.

Three TEPCO employees were killed by the earthquake and tsunami while on duty at the plant, and over 1,000 deaths of nearby residents may have been caused by poorly implemented evacuation procedures. In May 2013, the UN Scientific Committee on the Effects of Atomic Radiation released a report finding no illnesses directly linked to the radiation exposure and minimal potential for increased cancer development in those exposed, except for children, who may be at higher risk for thyroid cancer as they age.

Mallory L. Daily

See Also: Chernobyl Incident; Nuclear Regulatory Commission; Nuclear Safety; Radiation, Ionizing and Nonionizing; Radiation Sickness; Three Mile Island Incident

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FULLER, BUCKMINSTER

R. Buckminster Fuller (1895–1983) was a man of many talents known as an inventor, architect, writer, teacher, and public speaker. He is perhaps best known for his development of the geodesic dome. He also created several inventions aimed at sustainability. These inventions include his *dymaxion* vehicle, house, and deployment units for troops. (The word "dymaxion" is a combination of the words "dynamic," "maximum," and "ion.") Fuller was also a prolific author. His writings, including *Operating Manual for Spaceship Earth* (1968) and *Critical Path* (1981), have been influential to the environmental movement and often focus on the relationship of humans to the earth's resources.

Buckminster Fuller, also known as "Bucky," was born on July 12, 1895, in Milton, Massachusetts. Fuller's birth date coincides with two other important events in his life: the death of his father in 1910 and his marriage to Anne Hewlett in 1917. While growing up, yearly family vacations to Bear Island in Maine fostered Fuller's appreciation of nature.

Fuller's academic and professional life began unconventionally. He attended Harvard but was expelled twice and never graduated. Following his second expulsion, Fuller served in the U.S. Navy during World War I, patrolling the Maine shoreline. He also worked for textile, meatpacking, and trucking companies. Fuller often found himself laid off and unsatisfied with his work in these positions, and he came to believe that the focus placed in life on earning a living rather than doing innovative work was detrimental to an individual's well-being. Following a self-imposed period of silence in 1927 spent in contemplation, Fuller began pursuing personal projects to address the needs of society.

Several of Fuller's early inventions focused on designing sustainable housing. His patented dymaxion house, bathroom, and deployment units exemplify this

Travel on Spaceship Earth

During Buckminster Fuller's time, travel in space was a popular topic of conversation. (The Apollo Space Program was making rapid achievements in space travel, and in 1969, Apollo 11 landed humans on the moon for the first time.) In response to questions about what space travel would be like, Fuller once commented, "The answer is very simple. What does it feel like? That's all we have ever experienced. We are all astronauts on a little spaceship called Earth." The concept of Spaceship Earth, popularized by Fuller in the 1960s, helped promote his vision for comprehensive planetary planning that would allow humans to live with freedom, comfort, and dignity without ruining the earth's ecosystems or regenerative ability.

aim. The modularity of the dymaxion inventions was their key strength. For example, because the parts could be easily mass-produced and repurposed, the dymaxion deployment units were seen as possible solutions to housing shortages for troops during World War II. And the dymaxion bathroom, which used vapor instead of running water for the shower, was notable for its preservation of natural resources. In addition to these inventions, Fuller served as the editor of the magazine *Shelter* from 1938 to 1940.

Fuller's most notable contributions are arguably his new methods of conceptualizing the world, as realized through his dymaxion map and construction of geodesic domes. A geodesic dome is a spherical structure composed of triangular framework components. Fuller developed his first geodesic dome while teaching at Black Mountain College in 1949. Today, more than 200,000 geodesic domes exist, including Disney's Epcot Center and the Montreal Biosphere. One goal of the geodesic dome was to help preserve the earth's limited resources by optimizing the use of space. Fuller called this idea of doing more with less "ephemeralization." Because geodesic domes focus on the harmonious use of the earth's resources, they can also be seen as the embodiment of the concept "spaceship earth." Both of these terms were popularized through Fuller's writings.

Meredith Hale

See Also: Biosphere, Environmental Threats to; Earth Charter; Earth Day; Human Ecology and Health; One Health; Sustainable Development and Health

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GENETIC ENGINEERING AND GMOs

The improvement of crops with desirable traits has occurred from the beginning agriculture, and as humans and civilizations have evolved, so have agricultural practices. For example, farmers learned to identify the best-looking plants with superior yield and pest resistance and to save the seeds from those plants for use in next year's plantings. Later on, plant breeders learned to combine desirable traits from two different plants of the same species, a type of genetic modification known as traditional plant breeding. This type of breeding has been followed for hundreds of years and is still practiced today. However, there are drawbacks to traditional plant breeding. For example, undesirable traits may be transferred along with the traits of interest, and breeding is not possible between two different species that cannot sexually mate with each other.

A new method of genetic modification, genetic engineering, has advantages over traditional breeding methods. Genetic engineering is the process of adding foreign genes with desirable traits to the genome of an organism, which allows transfer of genes from one organism to another of unrelated species. Several genetic engineering techniques are available, but the one most widely used is the recombinant DNA method. Plants can be genetically engineered to have properties benefiting both the farmer and consumer, for example, resistance against insects and disease and improved nutritional value.

Genetically modified organisms (GMOs) are plants, animals, and microorganisms where their genetic material (i.e., DNA) has been altered in a way that does not occur naturally by mating or natural recombination. Traditional plant breeding has created GMOs for hundreds of years, but today the term has come to represent the product of genetic engineering. Proponents of GMOs argue that their use is essential to addressing global hunger and the increase in pests and diseases expected in the wake of climate change. Additionally, GMOs can protect human health and the environment by reducing the need for pesticides and herbicides. Most GMO plants are used as ingredients in other food products, such as canola oil, corn syrup, and sugar beets. GMO varieties among crops include apples, corn, cotton, flax, papayas, potatoes, rice, soybeans, and squash. Also, tomatoes having a long shelf life and delayed maturity have been developed with this technology.

According to the U.S. Food and Drug Administration, "Credible evidence has demonstrated that foods from the GE [genetically engineered] plant varieties marketed to date are as safe as comparable, non-GE foods." And similarly, the World Health Organization has found that "GM foods currently available on the international market have passed safety assessments and are not likely to present risks for human health. In addition, no effects on human health have been shown as a result of the consumption of such foods by the general population in the countries where they have been approved." However, the safety of GMO remains a hot topic in American society today, with opponents arguing that GMO plants may affect the nutritional value of food or create allergens or toxins and that overuse of GMO crops have created herbicide-resistant "super weeds." Others are concerned about the uncertain ecological effects from introducing plants that have not followed a natural evolutionary pattern.

Damba Yahaya and Matthew W. Blair

See Also: Food Safety and Technology; Pesticides and Herbicides; World Health Organization

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GEOGRAPHICAL INFORMATION SYSTEM MAPPING

A geographical information system (GIS) is an integrated database management tool that is used to store, organize, retrieve, and analyze geographical and resource data for decision making. GIS mapping uses computer-assisted drafting and mapmaking to manage and analyze spatial information. A GIS map can help answer simple or complex questions about things on, near, or below the earth's surface or about other celestial bodies. Additionally, it can answer queries about selected things and their attributes and spatial relationships, such as adjacency, inclusion, direction, and distance. One important application of GIS mapping is to assess the extent of environmental pollution.

In the 1960s, GISs were primarily concerned with geoprocessing (i.e., manipulating spatial data), and by the 1980s, GIS was beginning to be used by spatial decision-support systems. Today, robust GISs with powerful graphics algorithms and high degrees of user friendliness have widespread applications, resulting from their strong analytical and modeling capabilities.

A GIS map can help (1) predict the attributes of a specific location, even if the location is not physically examined, for example, the types of poisonous plants found in a particular open meadow; (2) find locations that would fulfill certain specified parameters, such as finding poison-control centers within one mile (1.6 kilometers) of a major international airport; (3) answer trend questions by determining changes in the attributes of a place over time, such as the rate of a hazardous material spreading through a particular neighborhood bordering a toxic dump site (like Love Canal); (4) find routing solutions, for example, the fastest, shortest, or safest route from a hazardous waste disposal team's home station to an emergency toxic spill site; and (5) solve pattern queries so that managers or researchers can investigate the spatial distribution of a particular phenomenon for diagnostic or other purposes, such as exploring scientific hypotheses about whether certain disease incidences are higher than expected in low-income neighborhoods.

Overlay operation and data coverage lie at the core of most GIS software packages. Using the software, the phenomenon under study is regarded as a collection of superimposed elementary maps, each holding data pertaining to a specific attribute or aspect of the area being investigated (e.g., variables such as hydrology, land use, relief, roads, soils, and vegetation). The composite properties of any subject of interest can be deduced by combining the corresponding data of respective layers. Spatial data can be input from a variety of primary sources, including global positioning systems, radars, remote sensing scanners, and digitized images of traditional maps. The complex nature of spatial data used in constructing GIS maps necessitates consideration of numerous related issues, such as cartographic design, measurement, sampling, scale, uncertainty, visualization, and the very nature of geographical space itself.

GIS maps can aid in making decisions and policies whenever location is part of the problem that is under consideration. These maps can be very useful in tackling an array of environmental health problems because they can (1) readily present different options; (2) help facilitate a comparison of costs and benefits; (3) assist in examining the consequences of altering variables relevant to respective decision criteria; and (4) allow consideration of unanticipated alternatives, including those interjected by third parties. A particular power of GIS maps is their interactive and flexible nature, which allows the maps to be easily altered and manipulated as new data or questions arise. Their greatest utility, perhaps, is in their visualization of complex issues under consideration.

A National GIS Industry Certification, more commonly known as a Spatial Technology and Remote Sensing (STARS) Certification, is available. GIS technicians with this certification typically work under the supervision of cartographers, engineers, managers, surveyors, and other professionals. There is a growing need for such specialists to keep up with the rapid developments and emerging widespread implementations of GIS technology, particularly in areas related to environmental health.

Victor B. Stolberg

See Also: Biosphere, Environmental Threats to; Disaster Preparedness and Response; Hazardous Waste Disposal; Love Canal Incident

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GORE, ALBERT, JR.

Albert Gore Jr. (1948–), the 45th vice president of the United States and son of longtime U.S. senator, Albert Gore Sr., has been a leader and environmental activist in the worldwide struggle against global warming throughout his career. His efforts, which have raised worldwide awareness about the effects individual actions have on climate change, have been so widely recognized that he won the Nobel Peace Prize in 2007—a prize shared with the Intergovernmental Panel on Climate Change. In accepting this award, he warned that the world's largest carbon emission producers, the United States and China, needed to "make the boldest moves, or stand accountable before history for their failure to act."

Gore's interest in environmental issues began when he was a teenager growing up in Tennessee and his family discussed environmental concerns around the dinner table. Gore received a degree in government from Harvard in 1969 and then volunteered for the U.S. Army, serving as a reporter in Vietnam. His lifelong efforts to make a difference in the earth's well-being began in 1976 when he was a new congressman and raised the visibility of key issues through congressional hearings on toxic waste and global warming.

As vice president, he used his position to help advance his environmental agenda. Gore held meetings all over the world on the subject of global warming, and in 1990, he worked to support the Kyoto Protocol, which sought to establish international policies on global warming and reduce greenhouse gas emissions worldwide. In 1997, Gore launched an effort from the White House to produce a report card on the health of the nation's ecosystems.

In 2004, Gore cofounded Generation Investment Management, a company that creates environment-friendly portfolios. In 2010, two nonprofits founded by Gore, the Alliance for Climate Protection and the Climate Project, both aimed at educating the world on the potentially disastrous effects of global warming, were combined to create the Climate Reality Project.

In 2006, Gore produced the movie *An Inconvenient Truth*, which premiered at the Sundance Film Festival and won an Oscar. The film presents persuasive evidence that global warming exists and makes the point that if the earth's inhabitants don't make immediate changes by conserving energy, the planet's survival is

Albert Gore Jr., climate change activist and 45th vice president of the United States. Gore shared the 2007 Nobel Peace Prize with the Intergovernmental Panel on Climate Change, and his 2006 movie about climate change, *An Inconvenient Truth*, won an Oscar. (Randy Miramontez/ Dreamstime.com)

at stake. Gore donated 100 percent of the award's proceeds to the Alliance for Climate Protection.

Gore's efforts have not gone without criticism. Specifically, he has been criticized for (1) an alleged conflict of interest because he invests in green-technology companies; (2) his own personal consumption of energy (e.g., living in a big house); and (3) supposed inaccuracies in scientific claims (although a judge has ruled that his film is broadly accurate and its main findings are supported by research). Despite these criticisms, there is no question that Gore's work throughout his career has dramatically raised awareness and encouraged many effective actions to address global warming issues.

While Gore currently holds a number of significant positions, such as serving on the Apple Board of Directors, he spends the majority of his time as chairman of the Climate Reality Project, a nonprofit seeking to solve the worldwide climate crisis by urging action across every level of society. Gore, who was a keynote speaker at the COP 21 Climate Summit in Paris in December 2015, continues to speak widely, participate in events, and write on issues focusing on climate change.

Susan J. Montgomery

See Also: Climate Change and Human Health; Environmentalism; Intergovernmental Panel on Climate Change; United Nations Framework Convention on Climate Change

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GREAT LAKES POLLUTION

The Great Lakes form the world's largest surface freshwater system and are bordered by eight U.S. states and two Canadian provinces. With more than 30 million people living in the Great Lakes basin, environmental and human health has become closely linked with increased population pressures. In 1972, Canada and the United States signed the Great Lakes Water Quality Agreement to jointly mitigate threats to water quality and promote the "chemical, physical, and biological integrity" of the Great Lakes. The target areas of the amended 2012 version of this agreement include aquatic invasive species, habitat degradation, effects of climate change, and other threats to human health and the environment, such as harmful algae, toxic chemicals, and discharges from vessels.

The U.S. Environmental Protection Agency has identified several environmental issues to which the Great Lakes are particularly sensitive. Because outflows from each of the five lakes are relatively small, most pollutants that enter the water have high residence times (i.e., they remain a long time), slowly becoming more concentrated. Major sources of contamination include waste from shoreline cities, leachate from landfills, runoff from agricultural lands, discharges from industries, and atmospheric pollutants that fall with precipitation. Many toxicants can bioaccumulate in the food web, leaving people susceptible to greater toxicity when they eat freshwater fish. For example, the Michigan Department of Health and Human Services has warned that catfish and carp from the Great Lakes can contain high levels of chemical contamination, leading to adverse health effects, particularly for pregnant women and children who eat the fish. Contaminated sediments due to persistently elevated levels of pollutants have also resulted in low reproductive rates and greater birth defects among fish-eating birds like the eagle.

Increased levels of phosphorus, due to sewage treatment, agricultural runoff, and industrial processes, have also negatively impacted water quality in the Great Lakes. Although an essential nutrient, increased phosphorus concentrations can lead to overgrowth of algae and aquatic weeds, which can cause a decrease in dissolved oxygen levels and a die-off of other freshwater species. In Lake Erie, massive algae blooms have resulted in tap water bans in some Ohio cities due to the heightened risk of drinking water contamination. Toxins produced by these blooms have been known to cause neurological problems in humans, including paralysis and seizures. Warming waters caused by climate change may be exacerbating the extent of these blooms.

Humans have also extensively affected the Great Lakes ecosystem through the introduction of invasive species. Since the 1800s, more than 25 invasive species of fish and 7 invasive plants have been introduced into the Great Lakes. Often outcompeting native populations, invasive species throughout the Great Lakes can threaten human health and have cost billions of dollars in associated damage to infrastructure, fisheries, agriculture, and tourism.

Rachel L. Lamb

See Also: Bioaccumulation of Environmental Contaminants; Climate Change and Human Health; Drinking Water Quality and Regulation; Environmental Protection Agency; Fish Consumption Advisories; Groundwater Pollution and Depletion; Invasive Species and Human Health; Land Disposal of Waste Materials; Marine Vessels, Pollution from; Sewage Treatment and Disposal; Stormwater Runoff; Water Pollution

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GREEN PACKAGING

Green packaging, also known as sustainable packaging, refers to renewable, recyclable materials that are safe and healthy, both for people and for ecosystems. Compared with conventional packaging, green packaging is often sourced from biodegradable plant materials. In evaluating the sustainability of packaging, retailers examine the entire life cycle of the packaging material, from production to distribution to recycling or reuse.

Packaging is used by takeout restaurants, online shopping retailers, and shipping companies to protect and transport products. The types of packaging include bags, boxes, paper, tape, fillers, and cushions such as air pillows.

Green packaging may be made from postconsumer recycled content like shredded newsprint or from biodegradable components like plant fibers or starches. For instance, a green alternative to conventional food containers might use dairy-based proteins instead of a petroleum-based film to prevent oxygen from infiltrating the container. Some manufacturers have attempted to make plastic packaging more biodegradable by adding chemicals that stimulate microorganisms to break down the material. However, the Sustainable Packaging Coalition (SPC) argues that these additives are harmful because they do not actually make the plastic biodegrade or turn into compost. Instead, the plastic litter breaks into smaller pieces of plastic, called microplastic, that can harm the environment.

The ideal sustainable packaging is functional and cost-effective while reducing environmental impacts and pollution. According to the SPC, sustainable packaging should use (1) materials that are recyclable, reusable, biodegradable, or compostable; (2) manufacturing processes that conserve water and energy; and (3) logistics that optimize space in pallets and shipping containers for more efficient transportation. While many companies have started using sustainable packaging, vague labels such as "green" and "environmentally friendly" may be a form of "greenwashing" by some companies wanting their products to appear sustainable for marketing purposes.

In 1999, packaging made up one-third of solid waste by weight in the United States, according to the U.S. Environmental Protection Agency. Since then, however, many retailers have implemented green packaging practices due to municipal regulations and tightening industry standards. For example, as of 2016, Minneapolis, Portland, Seattle, San Francisco, and Washington, D.C., have all banned polystyrene foam, which is lightweight but takes thousands of years to break down in a landfill, leaches chemicals into groundwater, and contributes microplastics to the ocean.

The Walmart company is an example of a retailer that is pushing suppliers to use more sustainable packaging. In 2008, Walmart introduced its sustainable packaging scorecard, with the goal of reducing the use of packaging materials by 5 percent by 2013. In achieving this goal, Walmart stores helped reduce greenhouse gas emissions associated with packaging manufacturing and transportation. Under Walmart's 2016 sustainable packaging playbook, the company is focusing on optimizing package design, sourcing sustainable materials, and increasing recyclability. For instance, Walmart is asking its suppliers to maximize the recycled and renewable content of packaging material, such as by using postconsumer cardboard and paper certified by the Forest Stewardship Council. The company has also begun using a How2Recycle label that has instructions for consumers about how to recycle the product. Walmart has pledged to make 100 percent of its private label packaging recyclable by 2025.

Alisha K. Newton

See Also: Biodegradable Materials, Health Benefits of; Composting, Health Benefits of; Environmental Protection Agency; Recycling; Sustainable Development and Health; Three Rs of Waste Management

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GREEN SEAL PROGRAM

Green Seal is a brand and nonprofit organization that identifies products and services as meeting specific environmental standards. Since its founding in 1989 by environmental activist Rena Shulsky David, the Green Seal brand has helped consumers and companies identify which manufacturers are offering products that are not harmful to human health and the environment. This allows consumers to make sound ecological decisions and support businesses and companies that have sustainable environmental objectives.

Green Seal certification is a science-driven process that demonstrates compliance to specific standards in a wide variety of categories, including hotels and lodging, lighting, food service, vehicles, cleaning products, and construction materials. According to the Green Seal organization, there are 33 standards that cover 400 product and service categories. The organization has its headquarters in Washington, D.C., and its logo features a solid light-blue circle with a green check mark.

An impressive number of products and services have sought and received Green Seal certification, and many consumers make their buying choices on how environmentally friendly a product claims to be. As early as 1992, almost one-fifth of consumers made buying decisions based on how "green" they perceived a product or service to be, according to polling research conducted at the time. Today, some studies indicate this proportion may exceed 70 percent.

Charles Daniel

See Also: Consumer Product Safety Commission; Energy Star; Green Packaging; Life Cycle Assessment

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GREEN SPACE IN URBAN ENVIRONMENTS

The health and aesthetic benefits of urban green space have played an important role in American cities for many years. The parks designed by Frederick Law Olmstead and other early American landscape architects (e.g., Central Park in New York City and the Emerald Necklace in Boston) have become national landmarks and important city centers. Green space in cities, such as parks and other outdoor recreational areas, provides a refuge from the hustle-bustle of city life while helping to improve air and water quality and reduce the effects of climate change.

Green space is much more than planting trees in a concrete jungle. Rooftop gardens produce food and make use of vertical infrastructure, and green roofs (i.e., roofs planted with greenery such as shrubs and trees) help improve the albedo (i.e., the reflective properties) of a city, keeping it cooler in the summertime. Green roofs can also reduce energy used by a building by as much as 25 percent (with the added benefit of improving market value) and help with storm water management. Vines allowed to climb the face of a building can act as natural insulation and improve air quality in the vicinity. Trees, whether in parks or on rooftops, absorb carbon dioxide, thereby representing an important carbon sink in the fight against climate change.

A flower and vegetable garden on the roof of a city building. Urban green spaces, such as gardens, parks, and recreational areas, provide a refuge from city life while helping to improve air and water quality and reducing climate change. (Alisonh29/Dreamstime.com)

Two serious threats to human health associated with city living are poor air quality and the urban heat island effect, a phenomenon where cities are typically several degrees warmer than surrounding areas because of the ability of dense roadway and building materials (e.g., concrete, asphalt, steel, stone, and brick) to absorb heat. For example, in Atlanta, an area with heavy urban and suburban incursion (i.e., sprawl) into surrounding woodlands, the city temperature is typically 5–8°F (2.8–4.4°C) warmer than the surrounding countryside during the summer months. While helping to reduce urban temperature, green space also improves air quality because air pollutants are absorbed by trees and other plants and can be stored in the woody tissue. In fact, a single tree can remove the equivalent of 11,000 miles (17,700 kilometers) of automobile emissions every year. Even grass has the ability to absorb carbon dioxide and provide oxygen. Green space can also improve the mental health of city residents by providing a more pleasant environment, and green space used for exercise can improve physical health and reduce the risk of obesity.

Climate change will exacerbate the urban heat island effect, making cities even warmer. Perhaps the easiest way for cities to counter the effects of climate change is to incorporate greenery everywhere possible. Interestingly, the two U.S. cities with the highest percentage of green space are two cities with drastically different climates—Honolulu, Hawaii, and Anchorage, Alaska!

Aaron Dorman

See Also: Air Pollution; Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Greenhouse Effect and Global Warming; Heat Island Effect in Urban Areas; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Stormwater Runoff

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GREENHOUSE EFFECT AND GLOBAL WARMING

The terms "greenhouse effect" and "global warming" represent two scientific phenomena related to increased temperature conditions in the earth's lower atmosphere (known as the troposphere). To some extent, the greenhouse effect caused by certain gases in the atmosphere actually makes the earth habitable for human and animal life, and without this effect, the earth would be too cold to support complex life. However, if the atmosphere is overloaded with greenhouse gases, the greenhouse effect could cause global warming on a devastating level.

The greenhouse effect phenomenon is caused by energy transfer between the sun and Earth. When solar energy passes through the atmosphere, some is reflected into outer space by the earth and the atmosphere itself, while another portion is absorbed directly by greenhouse gas (GHG) molecules present in the atmosphere. Most incoming solar energy, however, is absorbed by the earth's surface and warms it. The energy absorbed by the earth is radiated back into the atmosphere, where it is also absorbed by GHG species. These molecules reemit the absorbed energy in all directions, which serves to warm the earth's troposphere. This is a positive aspect of the greenhouse effect, as this heating of the troposphere is critical for human and animal life.

The primary anthropogenic (human-generated) gases in the atmosphere responsible for absorbing and emitting the incoming and exiting radiation include the following compounds:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF_6)

Greenhouse gases result from a variety of activities and processes, such as the combustion of fossil fuels in transportation, as well as the production of electricity for domestic, commercial, and industrial operations. Other significant sources of GHG emissions include landfills, wastewater treatment operations, refrigeration, and certain industrial processes (see Table 7). The most prevalent GHG is CO_2.

Global warming as a phenomenon is attributable to the greenhouse effect working in our atmosphere. It represents a natural response to the accumulation of CO_2 and other GHG molecules in the atmosphere. This GHG overload is caused by a

Table 7. Typical sources of GHG emissions.

Greenhouse Gas	Sources
CO_2	Combustion of fossil fuels
CH_4	Landfills, wastewater treatment, oil/gas production, agriculture
N_2O	Combustion of fossil fuels, fertilizers, nitric and adipic acid plants
HFCs	Semiconductors, refrigeration, fire protection
PFCs	Semiconductors, refrigeration, fire protection
SF_6	Switchgears and gas-insulated substations

disruption to the natural carbon cycle in our environment. Carbon is an element that moves through the environment in a natural cycle, referred to as the carbon cycle. Anthropogenic emissions (as described earlier) and certain biological processes add carbon to the atmosphere. Large amounts of carbon are stored in the oceans, plants, and soil, as well as in deposits of coal, oil, and natural gas deep underground. When carbon is added to the atmosphere at a rate faster than natural processes can remove it, concentrations of GHG species in the atmosphere increase. The elevated GHG concentrations in the atmosphere create a global warming effect.

Greenhouse gas molecules differ in their capacity to produce a warming effect in the atmosphere. The global warming potential (GWP) is a relative measure that allows comparisons of the amount of heat trapped by different gases compared to CO_2. It relates how much energy the emissions of 1 ton (0.9 metric ton) of a gas will absorb over a given period of time, to the emissions of 1 ton (0.9 metric ton) of CO_2. Large GWP values signify that a given gas has more potential for warming the earth compared to CO_2 over that time period. The reference time period typically used for GWPs is 100 years. Using a common unit of measure like the GWP allows analysts to add up emissions estimates of different gases and compile a national GHG inventory, allowing policymakers to compare emissions reduction opportunities across sectors and gases.

Because it is the reference to which other gases are compared, CO_2, by definition, has a GWP of 1 regardless of the time frame. The increase in atmospheric concentrations of CO_2 will last thousands of years, as CO_2 remains in the climate system for a very long time. CH_4 (methane) has an estimated GWP of 28–36 over 100 years and stays in the climate system about a decade on average. However, methane also absorbs much more energy than carbon dioxide. Nitrous oxide has a GWP 265–298 times that of carbon dioxide over 100 years and stays in the atmosphere for more than 100 years on average. High-GWP gases, like HFCs, PFCs, and SF_6, trap substantially more heat than CO_2. Their GWPS are in the thousands, or even tens of thousands.

Richard F. Pandullo

See Also: Automobile and Truck Emissions and Controls; Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Electric Power Generation, Health Implications of; Landfill Gas Pollution; Sea Ice, Global Warming Implications for; Sewage Treatment and Disposal

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GROUNDWATER POLLUTION AND DEPLETION

Groundwater is a critical resource and an important feature of the water cycle. During rainfall, a portion of the runoff is absorbed by the ground, where it flows downward through the unsaturated portion of the soil profile. When the water reaches saturated soil, the water stops its primarily vertical movement. At this point, the groundwater forms an unconfined aquifer, and the water begins to flow horizontally in response to gravity. Where groundwater occurs, there may be multiple layers of unsaturated and saturated soil separated by relatively denser soil layers (aquitards), and a confined aquifer may be present. Depending on the specific geological conditions at a site, there may be less dense locations between two aquifers (aquitard gaps), which can allow water to flow downward by gravity or upward by pressure from one aquifer to another. Many aquifers eventually reach an open water body, such as a stream, lake, or ocean, and may provide a significant amount of flow in dry weather.

As groundwater can transport contaminants and pollutants from the soil it passes through to various bodies of water, it is important to monitor the water quality in these systems. The U.S. Environmental Protection Agency (EPA) sets nationwide standards designating the maximum level of a chemical or other material that can be present in water and other environmental media. In addition to variations by the type of media, there may be different standards for the same chemical based on the type of human exposure, environmental degradation, water usage, and many other factors. In EPA-delegated states, the state may adopt the EPA standards or develop their own, which are then approved by the EPA. When the amount of groundwater contamination exceeds the level established by a regulating jurisdiction, the groundwater is considered polluted.

Pollution of an unconfined aquifer can happen in many ways. Surface runoff can pick up chemicals and other contaminants and carry them with the water as it makes its way to the aquifer. Underground storage tank systems (piping, pumps, and tanks), pipelines, and aboveground storage tanks can also discharge chemicals into the environment. An accidental spill or work conducted at the surface can leave residues that may soak into the ground, such as paint, oil drips from vehicles, leaking liquid from waste receptacles, and wash water.

When these contaminants reach the soil, they travel through the soil in a complex manner similar to the way water travels through soil (i.e., generally downward by gravity). An impacted area called the contaminant plume is created, which may extend to the groundwater. Chemicals lighter than water will pool on top of the water, while those denser than water will sink (although most chemicals will dissolve in the groundwater to some extent). Due to variations in the conditions of release, each release results in a distinctive contaminant plume, and several plumes may often overlap. The plume of a denser chemical may extend through the unconfined aquifer to the aquitard and through several aquifers by way of aquitard gaps. The types of plumes that may be formed include plumes in the vadose zone (the soil between the surface and the groundwater table), along the surface of the groundwater, gaseous plumes, dissolved plumes within the groundwater, and product plumes. The amount and type of contaminant determine the extent of the impact by each material. Contaminated groundwater flowing into surface water bodies will transport these chemicals into the surface water.

Prior to identifying the contamination, people may be exposed to pollution from groundwater in many ways, such as by using polluted groundwater for drinking and irrigation. Once water is known to be polluted, the water can be cleaned up prior to use, but the process may cost more than finding an alternative water source. Note that a chemical may be present in groundwater without exceeding regulatory standards—in other words, the water may be impacted (have the material present) but not be polluted (exceeding a regulatory limit).

Groundwater is an important resource and is pumped to the surface for use throughout the country as municipal drinking water, as industrial process water, and for agricultural irrigation. Groundwater depletion occurs when the rate of extraction exceeds the rate of recharge. Groundwater depletion is a national concern, and the areas of greatest depletion include the Atlantic Coastal Plain from Long Island to northeast Florida, the Mississippi embayment (in the vicinity of Memphis, Tennessee), the High Plains (Ogallala) aquifer (stretching from west Texas to South Dakota), the southern Arizona alluvial basins, and the Central Valley of California. In areas of the western United States, large public works projects may be undertaken to save rainwater by developing infiltration basins that encourage runoff to soak into the ground and replenish the groundwater.

In addition to potentially running out of water, groundwater depletion can cause other complications. One problem is the reduction or elimination of the amount of water that enters adjacent lakes and streams during dry periods. This reduces the water available to local flora and fauna, some of which requires the base flow provided by groundwater infiltration to survive dry periods. Aquifer compaction (the rearrangement of soil particles in the aquifer into tighter formations after water extraction) leaves less space for water when the aquifer is recharged, with an ultimate loss in storage volume. In some circumstances, the loss of volume is visible on the surface as land subsidence (caving in or sinking of the land). In coastal areas, groundwater depletion can cause saltwater to enter the aquifer, causing a saltwater intrusion that makes the groundwater unusable without significant treatment. Groundwater depletion can affect groundwater pollution by providing new pathways for pollutants to enter the groundwater and by mobilizing pollutants in the water.

Thomas B. Lawrence

See Also: Construction Site Runoff; Drinking Water Quality and Regulation; Environmental Protection Agency; Stormwater Runoff; Underground Storage Tanks, Health Concerns with; Water Pollution

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GUINEA WORM DISEASE

Guinea worm disease, also termed "Dracunculiasis," comes from a parasitic worm (helminth) named *Dracunculus medinensis*, or the Guinea worm. The name is derived from the Latin for "affliction with little dragons," primarily because of the severe, debilitating burning sensation caused as the worm migrates through the body tissues, until it develops a sore in the skin to exit the body. This debilitating disease is on track to become the second human disease in history to be completely eliminated, as the incidence rate (number of afflicted people) has decreased from 3.5 million in 1986 to 25 cases worldwide in 2016.

Progress toward Eradicating Diseases

In 1986, there were an estimated 3.5 million cases of Guinea worm disease worldwide, and in 2015, there were only 22.

An Interview with Adam Weiss

Associate Director, Guinea Worm Eradication Program, The Carter Center

Adam Weiss is associate director of the Guinea Worm Eradication Program at the Carter Center, where he provides technical support to the center's programs in South Sudan, Mali, Chad, and Ethiopia. Previously, Weiss served as the center's technical advisor to the national guinea worm eradication programs in Ethiopia and Ghana. Additionally, he was a U.S. Peace Corps volunteer in Ghana, focusing on improving access to water and sanitation facilities, increasing awareness about HIV/AIDS, strengthening community-based health education, and assisting in the eradication of the Guinea worm disease.

The Carter Center is highly regarded throughout the world as a leader in the eradication and elimination of diseases, including waterborne diseases like Guinea worm and schistosomiasis. With so many environmental health issues in the world, how does The Carter Center decide which ones to go after?

A founding principle of The Carter Center is to tackle serious public health issues that are not being addressed by other organizations. In the case of the

Guinea worm, little was being done to stop the spread of the disease until we stepped in. In 1986 there were an estimated 3.5 million cases of Guinea worm disease worldwide, and in 2015 there were only 22. Guinea worm is now poised to be the second human disease ever eradicated. This shows how effective an intervention program can be when well-designed and implemented. Our approach included getting buy-in from governments and communities on the need to eradicate Guinea worm disease, implementing community-based interventions, providing communities access to information on stopping the spread of the disease, and making public health experts available for consultation and advice. Another important principle of The Carter Center is to *empower* governments and communities to address their own public health issues, with guidance and support from our experts in the field.

Clean water is crucial to addressing environmental health concerns and eradicating diseases. What are the greatest obstacles to providing a clean water supply in developing nations?

The problem in many areas is that it is not practical to pump up water from a water table that could be 100 meters deep or more. Areas prone to Guinea worm disease may also have limited or non-existent infrastructure to support advanced technologies. As a result, we rely on low-tech solutions that are less expensive and easy to use. For example, we distribute nylon-mesh filters for removing the water fleas that host Guinea worm, we coordinate the use of a larvicide, and we advocated for the provision of safe water among in-country organizations and the local government.

Climate change scientists predict that global warming will result in the spread of infectious diseases. For example, as temperatures increase and rainfall patterns change, mosquitoes capable of transmitting diseases can expand their territory and remain active for longer periods. Is this a concern of The Carter Center, and are you already seeing evidence of climate change spreading diseases?

Some diseases, for example, those spread by mosquitoes, are more vulnerable to climate change than others. We are not seeing Guinea worm disease spreading due to climate factors, but this may be because very effective interventions are already in place. The influence of climate on the spread of disease is a complex issue. If climate change brings more droughts, there would theoretically be less water for disease-carrying mosquitoes to breed in. On the other hand, under drought conditions, more people may be forced to rely on scarce water resources potentially infected with other diseases, such as Guinea worm. Overall, the theories about climate change helping spread diseases are very plausible and concerning.

The Carter Center works to promote both world peace and global health. Is there an interdependence between your peace and health programs, where the success of one program depends on the other?

World peace and global health are closely linked, and it is hard to have one without the other. For example, to address the Guinea worm problem, President Carter helped to negotiate a six-month cease-fire between Sudan and South Sudan that suspended fighting within the country. This unprecedented period of relative political stability in Sudan allowed for a mass public health effort to distribute medicine and supplies, including water filters to help prevent Guinea worm. In general, it is difficult to provide public health assistance to war-torn countries, and on the other hand, widespread public health issues can sometimes embolden warring factions. Thus, peace and public health programs often go hand in hand.

What is a good career path for a recent college or university graduate interested in eradicating disease and promoting peace?

More important than choosing a particular career path is to develop good analytical skills and to be a person who is thoughtful and has compassion for humanity. Being a good communicator is also very important. With these attributes, a variety of opportunities will open up for doing good work in the world.

The Guinea worm's larvae are commonly consumed by the water flea (*Cyclops copepod*), and individuals are typically infected when they drink the water fleas. The worm's larvae can survive three weeks outside of a host organism, and they can live up to four months inside the water flea. The larval life cycle is limited, and, with proper sanitation practices, the organism can be eradicated. However, inside the human host, the worm can grow, develop, and mature unharmed for up to one year. Due to its otherwise short life span, the Guinea worm must parasitize a human during its life cycle to persist within a community for greater than a year. Because the worm discharges many of its larvae as it exits the body, the human host can repopulate water supplies with this worm when they bathe with an open sore.

The World Health Organization, the Centers for Disease Control and Prevention, and the Carter Center track the Guinea worm's trends annually because there is no identified treatment. There is no medication or vaccine against this parasitic infection, and the only way to prevent disease transmission is to implement improved sanitation practices. Temefos is a chemical that is commonly used in attempts to kill the larvae in contaminated drinking water. Occasionally, antibiotics are required when the open skin sore develops a bacterial infection in combination with the worm exiting the body. Otherwise, caution is observed with antibiotics because the larvae can break off into the blood stream and go to internal organs.

The Guinea worm has a propensity to migrate to the lower extremities—like the leg, ankle, and feet—so it's important to not soak feet in drinking water sources. When trying to remove the Guinea worm, soak the extremity in a bucket of water for it to release its larvae. When a larva emerges, wrap the worm around a small stick, like a match stick, and slowly roll the stick to remove the worm from the body. The worms are usually about 0.05 to 0.1 inches (about 1 to 2 millimeters) in diameter and can range from about 0.5 to 1 inches (about 13 to 26 millimeters) in length for the males and from about 2 to 3 feet (about 60 to 90 centimeters) in length for the females. This removal process may take a few weeks, and the water used to start the process should be dumped onto the ground far from all community water sources.

Prevention of the disease is the primary method of treating and controlling the problem. This organism is nearly eradicated with improved sanitation practices and community awareness. Using fine mesh cloth filters or folded-over cotton filters to remove the Guinea worm larvae and water fleas (in combination with boiling water and decontaminating water sources) has proven effective in preventing the disease. Limitations to the eradication of this disease are due to a lack of funding and local governmental support for prevention.

Howard W. MacLennan Jr.

See Also: Carter Center; Centers for Disease Control and Prevention; Communicable Diseases; Drinking Water Quality and Regulation; Infectious Diseases; World Health Organization

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HAZARD RANKING SYSTEM

The hazard ranking system (HRS) is an important element of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as the Superfund Act), which was created to clean up hazardous waste sites. The HRS is the process the U.S. Environmental Protection Agency (EPA) uses to evaluate and prioritize sites, placing the most serious sites identified for long-term cleanup on the national priorities list (NPL).

The HRS is a screening tool used to assess the potential for release of uncontrolled hazardous substances that could damage human health or the environment. The sites presenting the greatest risk are placed on the NPL and cleaned up before sites posing a lesser risk. This screening process allows the EPA to apply a uniform assessment matrix to a wide variety of contaminated properties, determining which sites are likely to be the most hazardous. Sites must have a high probability of causing an environmental release that could threaten human health or the environment to be placed on the NPL. Once listed, the EPA begins to develop a cleanup plan for the contaminated property.

The HRS uses a numerical score ranging from 0 to 100, with sites scoring 28.5 or higher eligible to be placed on the NPL. There are currently over such 1,300 NPL sites, with a number of additional sites proposed. To evaluate a site for NPL listing, the EPA considers the potential release of hazardous substances to ground and surface water, soil, and air. The EPA begins by considering the quantity, toxicity, and concentration of chemicals and other hazardous constituents that are present in wastes, followed by an evaluation of the potential for environmental contamination. Finally, the EPA examines the degree of potential acute or chronic human health effects.

The process of identifying sites with the highest cleanup priority involves four steps:

- Site identification
- Preliminary assessment
- Site inspection
- HRS scoring

After a site is identified, the EPA conducts a preliminary assessment of the on-site hazardous substances, the potential release pathways (ground and surface water, soil, and air), the likelihood a release will occur, the populations likely to be impacted by a potential release, and whether the area is located in or could impact a sensitive environment. The preliminary assessment is an initial, low-cost review of reports and documents already existing to determine if further evaluation is warranted.

If the preliminary assessment warrants further investigation, a site inspection is performed, which typically involves sampling on-site waste to determine what hazardous substances are present and whether there is concern for their release to the environment. The site inspection is designed to understand the vertical and lateral extent of the problem, to screen out sites that do not justify NPL listing, and to obtain data necessary to calculate an HRS score. The HRS is strictly a scoring system, and it does not specify cleanup priorities or methods or the amount of cleanup required. These decisions are made by the EPA considering a number of assessment outcomes as well as state priorities for cleanup.

One of the top U.S. environmental disasters took place in the Love Canal community in upstate New York, where about 22,000 tons (19,960 metric tons) of industrial hazardous waste had been buried. In the 1970s, wastes began rising to the surface of the ground, invading backyards and cellars, and residents reported a variety of illnesses. The Love Canal incident is recognized as a seminal event leading to creation of CERCLA.

Elizabeth Ann Glass Geltman

See Also: Environmental Impact Assessment; Environmental Protection Agency; Hazardous Waste Disposal; Love Canal Incident; Superfund Act

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HAZARDOUS AIR POLLUTANTS

Hazardous air pollutants (HAPs) cause serious adverse health effects that are often debilitating and even life-threatening. (HAPs are also known as toxic air pollutants, or simply, air toxics.)

Examples of HAPs include benzene in gasoline, perchloroethylene from dry cleaning facilities, methylene chloride used as a solvent and paint stripper, and mercury found in emissions from coal-burning electric power plants. HAPs are also emitted indoors (e.g., from building materials, cleaning product, and pesticides) and from natural sources like volcanoes and forest fires.

A variety of adverse health effects are associated with exposure to HAPs, including cancer, damage to the immune system, and various neurological, reproductive, developmental, and respiratory problems. Additionally, HAPs can cause environmental damage. For example, mercury can be deposited onto soils or bodies of water, taken up by plants, ingested by animals, and magnified through the food chain. Also, animals exposed to HAPs can experience adverse health effects similar to those seen in humans.

Some examples of common HAPs are arsenic, asbestos, benzene, beryllium, cadmium, chromium, dioxin, lead, mercury, methylene chloride, perchloroethylene, toluene, and vinyl chloride. Exposure to these and other HAPs usually occurs by breathing contaminated air. However, exposure can also happen by eating foods and drinking water that have come into contact with contaminated air, and young children can be exposed through ingestion or skin contact when playing in contaminated soil, dust, or water. Because some HAPs will bioaccumulate in the body, animals at the top of the food chain often have much higher concentrations of HAPs than found in the air, water, and soil.

The Clean Air Act requires the U.S. Environmental Protection Agency (EPA) to develop regulations to limit HAPs emitted from industrial and commercial facilities. There are 187 HAPs specified in the act (the original list had 189, but the EPA has since modified the list), and the EPA has developed regulations covering industries emitting many of these HAPs. Most of the regulations are called maximum achievable control technology (MACT) standards, and they limit HAP emissions from large industrial facilities, which are known as major sources. These standards are based on the emission levels already being achieved by well-controlled and low-emitting sources within the industry.

Within eight years after a MACT standard is set, the act requires the EPA to assess any remaining health risks and to determine whether the standard was set at a level low enough to protect public health with an ample margin of safety and to prevent any adverse environmental effects. Whereas MACT standards are first set using a technology-based approach (i.e., based on the technology employed at well-controlled and low-emitting sources), the eight-year review involves a risk-based assessment to identify whether a significant risk of adverse health effects remains even with the MACT standard in place. The act refers to any remaining risk as residual risk. If residual risk is found, the EPA must consider revising the MACT standard to be more health-protective. While performing a residual risk review, the EPA must also determine if there have been improvements to air pollution controls or other preventive strategies that would warrant revising the standard.

In addition to the MACT standard program for major sources, the act also requires the EPA to develop standards for smaller HAP facilities known as area sources. These are small facilities, such as dry cleaners, auto body paint shops, and gas stations, which individually may not emit much pollution. However, when all of the area sources in a city are considered together, the air pollution can be quite substantial. The EPA also has a number of programs to reduce HAP emissions from mobile and indoor sources. (See the entries on Automobile and Truck Emissions and Controls and Indoor Environment for more information.)

To learn about HAP emissions in your community, you can visit the National Air Toxics Assessment website for information on the 33 HAPs that present the greatest risk to public health in the largest number of urban areas. Additionally, visit the Toxics Release Inventory Program website to learn about toxic chemical releases through the air, water, and land for your zip code. The EPA MyEnvironment website also provides useful community information.

Richard Crume

See Also: Asbestos; Automobile and Truck Emissions and Controls; Cancer Clusters; Cancer Risk from Environmental Exposure; Clean Air Act; Dioxin Pollution; Electric Power Generation, Health Implications of; Environmental Protection Agency; Hexavalent Chromium; Indoor Environment; Integrated Risk Information System; Lead Poisoning Prevention; Mercury Pollution; Persistent, Bioaccumulating, and Toxic Chemicals; Toxics Release Inventory

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HAZARDOUS WASTE DISPOSAL

The importance of proper disposal of hazardous waste came to light in the 1970s when residents of the working class upstate New York neighborhood of Love Canal noticed odd odors and nasty liquids leaching into basements of some homes, and there was an unusually high rate of miscarriages, birth defects, and cancer among local residents. Heavy rains had caused chemicals to surface after leaking out of drums that were lawfully buried on the site in the 1940s.

Hooker Chemicals and Plastics Corporation had a permit from the state of New York to dispose of over 21,000 tons (19,050 metric tons) of toxic chemicals into

Love Canal between 1942 and 1953. In 1953, Hooker Chemical ceased using the site for disposal of hazardous waste, and the site was covered and leased to the Niagara Falls Board of Education to build an elementary school. Subsequently, homes were built nearby, and a community developed in the vicinity. President Carter declared a state of emergency at Love Canal in 1978 and again in 1980, requiring residents to leave their homes so the site could be properly cleaned up.

News of the Love Canal disaster gave impetus for the U.S. Congress to pass the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) of 1980, commonly called the Superfund Act. CERCLA allowed the federal government to take charge of Love Canal and other abandoned hazardous waste sites for the purpose of cleanup.

CERCLA is one of two pillars of hazardous waste regulation in the United States. The other is the Resource Conservation and Recovery Act (RCRA), Subtitle C, which regulates active sites containing hazardous waste by implementing a system that tracks the hazardous waste from the time the waste is created until disposal. The U.S. Environmental Protection Agency (EPA) describes RCRA as "cradle to grave" management of hazardous waste, from generation to transportation to recycling, treatment, or disposal.

Under RCRA, anyone handling chemicals must determine if the associated wastes are considered hazardous and thus potentially harmful to health. Those handling such chemicals are considered "generators" because use of the chemical may generate hazardous waste. Generators must ensure the waste is disposed of in a manner that is safe and complies with the law.

To ensure safe handling of hazardous waste, RCRA mandates that all generators (1) obtain an EPA identification number; (2) document the amount hazardous waste produced; and (3) identify the waste as hazardous. The purpose of labeling the waste as hazardous is to notify any workers and members of the public who come in contact with the substance that it could be hazardous to human health or the environment if not handled properly. Generators must also manage and treat the waste so that it can be safely handled until treatment, recycling, or disposal. The specific responsibilities of the generator depend on how much waste is created.

To remove hazardous waste from their properties, generators often use transporters to move the waste to a facility that will treat, recycle, or dispose of it. Hazardous waste transporters must follow rules established by both the EPA and the U.S. Department of Transportation when moving these substances on public roads, highways, rails, and waterways. All transported hazardous waste must have a hazardous waste manifest that explains the type and amount of waste being carried. The purpose of the manifest is to inform first responders about the type of waste in case of an accident.

There are a limited number of ways to dispose of hazardous waste. Burning hazardous waste can cause toxic air pollution, and burying hazardous waste can lead to the types of problems found at Love Canal. Federal law sets strict standards for both burning and landfill disposal of hazardous waste. Most generators transport hazardous waste to a facility that recycles the waste or treats it so that it is safe to dispose of in a landfill. Facilities that treat hazardous waste, called treatment storage and disposal facilities, are subject to strict standards to ensure the waste is disposed of in an appropriate manner. The EPA has separate guidelines for the disposal of electronic and pharmaceutical wastes and used oil.

Elizabeth Ann Glass Geltman

See Also: Environmental Protection Agency; Land Disposal of Waste Materials; Love Canal Incident; Resource Conservation and Recovery Act; Superfund Act; Waste Incineration

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HEALTHCARE-ASSOCIATED INFECTIONS

Healthcare-associated infections (HAIs) are infections that patients acquire while being treated for another condition at a healthcare facility, including a hospital, outpatient clinic, nursing home, and rehabilitation center. (HAIs are also known as hospital-acquired infections and nosocomial infections.) HAIs are caused by infectious agents, such as viruses, bacteria, and fungi, that the patient is exposed to.

According to the U.S. Office of Disease Prevention and Health Promotion, about 1 in every 25 inpatients acquires an infection related to hospital care, costing the U.S. healthcare system billions of dollars each year and leading to the loss of tens of thousands of lives. Additionally, HAIs are sometimes acquired by physicians and other staff members working in a healthcare facility.

The most common HAIs are urinary tract, surgical site, and bloodstream infections and pneumonia. Reducing HAIs has been a priority of healthcare professionals for a number of years, and although the infection rate has been declining, HAI remains a serious problem. The ultimate goal among healthcare workers is to reduce the number of HAIs to the lowest possible level, eventually eliminating these infections altogether.

The factors that promote infections among patients include decreased immunity, an increasing variety of invasive medical procedures that provide routes of infection, and the transmission of drug-resistant bacteria. Infection rates tend to be higher among patients who are older, have underlying diseases, or are undergoing diagnostic and therapeutic interventions.

Most HAIs today are caused by microorganisms that are common in the general population, where they typically cause mild symptoms or no symptoms at all. But in a healthcare setting, where the patient is undergoing treatment and the immune system may be compromised, exposure to these common microorganisms can be much more serious, sometimes resulting in complications and a prolonged hospital stay.

If you are a patient in a healthcare facility, what can you do to reduce the risk of acquiring an HAI? There are no guarantees, but the following steps can be helpful:

- Talk with your doctor about your HAI concerns, and ask what measures are being taken to protect you.
- Insist everyone wash their hands before touching you.
- Ask what types of tests will be performed to be sure you are receiving the right antibiotic.
- Become familiar with the signs and symptoms of infection, such as redness, pain, drainage, or fever.
- Notify your doctor immediately if you are having a problem with diarrhea (e.g., three or more episodes over 24 hours).
- Avoid complications by getting vaccinated against the flu and other infections.

By following procedures such as these and keeping your doctor informed about unusual symptoms, you can often prevent HAI or minimize its severity. Of course, lifestyle and diet are also important in staying healthy and avoiding lengthy hospital visits, where infections can occur.

Richard Crume

See Also: Infectious Diseases; Norovirus Infection; Sick Building Syndrome

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HEAT ISLAND EFFECT IN URBAN AREAS

As cities have developed over time, the open land and vegetation have been replaced with roads and buildings that contain dense materials, such as asphalt, concrete, steel, brick, and stone. These dense materials are particularly effective in absorbing and retaining heat from the sun. (In scientific terms, these materials are said to have high thermal mass and heat capacity.) Furthermore, soils and grassy areas, which tend to dry out and become impermeable in the urban environment, can quickly absorb heat from sunlight. The result is that cities heat up more than rural areas during the day and hold their heat longer during the evening hours. This is the heat island effect.

What You Can Do to Reduce the Heat Island Effect

There are steps you personally can take to help reduce the heat island effect in your city. For example, if you live in a house with a yard, you can increase the shading by planting trees and other vegetation. The vegetation will block direct sunlight and provide cooling through the process of evapotranspiration. Next, if you have a flat roof that will support the additional weight, create a green roof by installing a rooftop garden, which could include some combination of ground cover, shrubbery, small trees, and even a vegetable plot. Green roofs provide shade and reduce heat from the roof and surrounding air through evapotranspiration while insulating your home. (Be sure to have an engineer evaluate whether your house can support the extra weight of a green roof.) If creating a green roof is not feasible, install reflective roofing material that directs sunlight and heat away from your house. This can be as simple as installing lightly colored shingles or painting the roof a light color. Finally, by using energy-efficient appliances that require less electric power, you can help reduce carbon dioxide and other greenhouse gases emitted from power plants that burn fossil fuels, and this will help reduce the heating associated with climate change. (Always look for the Energy Star label when buying new appliances.)

The heat island effect is important because people exposed to higher summertime temperatures are at greater risk for:

- Heat cramps (muscle spasms that affect the arms, legs, or stomach)
- Heat exhaustion (stress on the body's cooling system, resulting in symptoms such as headache, heavy sweating, intense thirst, dizziness, fatigue, loss of coordination, nausea, impaired judgment, hyperventilation, and weak and rapid pulse)
- Heat stroke (depletion of the body's supply of water and salt, causing body temperature to rise to dangerous, life-threatening levels)

Additionally, higher temperatures lead to higher energy bills due to the increased need for air-conditioning in buildings, which in turn, increases air pollution and

Preventing Heat-Related Illnesses

Do you spend significant time outside for work or recreation, particularly in an urban environment where the heat island effect may increase temperatures? If so, you should take the following precautions to prevent heat-related illnesses, such as heat cramps, heat exhaustion, and heat stroke:

- Condition yourself to the hot weather by starting slowly and building up to more physical exercise, allowing your body to adjust over a few days.
- Drink a lot of liquids, including electrolyte drinks, which are good at replacing both water and minerals that are lost through sweating. Do not wait until you are thirsty because by then you may already be dehydrated. Avoid alcohol and caffeinated beverages.
- If you feel overheated, have a headache, or otherwise are not feeling well, stop what you are doing and take a break. Go inside an air-conditioned building or sit in the shade.
- Wear lightweight and light-colored clothing that will reflect the sunlight and help you feel cooler.
- Watch the weather forecast and stay inside an air-conditioned building whenever the National Weather Service issues a heat advisory, an excessive heat watch, or an excessive heat warning. Excessive heat outlooks are also issued for potential excessive heat events in the next three to seven days.
- Sleep well at night. (Adults need seven to nine hours of sleep to function well, and children and teenagers need even more.)

By preparing for warm weather, drinking lots of fluids, and taking it easy on hot days, you can avoid heat-related illnesses while still enjoying an active lifestyle. And do not forget to check on your family and friends when the weather is hot, especially those who are young, old, or sick, who are particularly susceptible to heat-related illnesses.

greenhouse gases emitted from electric power plants that burn fossil fuels. Warmer temperatures can also increase the amount of ground-level ozone, an air pollutant common in many metropolitan areas.

In large cities with populations of 1 million or more, the heat island effect can be quite pronounced, resulting in temperatures 1.8 to 5.4°F (1 to 3°C) warmer than surrounding areas. And during the evening hours, temperatures can be as much as 22°F (12°C) higher. This is because air temperatures away from cities tend to cool off quickly in the evening, whereas the dense materials cities are made of retain their heat into the evening hours, releasing it slowly and keeping air temperatures warm. Because the electricity required for air-conditioning a building typically increases 1.5 to 2.0 percent for every 1°F (0.6°C) increase in outside air temperature, it follows that as much as 5 to 10 percent of a city's summertime use of electricity can be attributed to offsetting the heat island effect.

Many American communities have implemented strategies to reduce the heat island effect. One common approach is to increase trees and other vegetative cover in urban areas, which can lower temperatures by providing shade and through evapotranspiration. Ponds, fountains, and parks can also create cooler areas in a city. Another approach is to install green roofs (rooftops covered with a vegetative layer of plants, shrubs, ground covers, or trees) that reduce temperatures by providing shade and through evapotranspiration.

Communities are also reducing the heat island effect by installing cool roofs (roofing made of light-colored, reflective materials), which reduce rooftop temperatures by reflecting the sunlight away from buildings. Cool pavements made of materials that reflect sunlight and enhance water evaporation are also becoming popular, as are smart growth practices that embody a variety of development and conservation practices aimed at protecting the environment while making neighborhoods more livable.

Urban heat islands are usually largest during the summer months, when solar intensity is greatest. However, heat islands can also occur in the wintertime, and some communities may actually benefit from the extra heat, for example, in helping to melt snow and ice on roads. On the other hand, cool roofing materials may make buildings harder to heat when the weather is cold. In any case, the energy benefits from implementing heat island mitigation techniques for summertime heating far outweigh any energy penalties during the winter.

During daylight hours, downtown metropolitan areas can absorb twice as much heat as surrounding rural areas. The key to success in countering the urban heating phenomenon is for communities to implement heat reduction programs, such as community-wide tree planting initiatives, that also provide environmental benefits while making urban areas more attractive and comfortable places to live.

Richard Crume

See Also: Climate Change and Human Health; Electric Power Generation, Health Implications of; Energy Star; Green Space in Urban Environments; Greenhouse Effect and Global Warming; Ozone and Smog in the Urban Environment

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HEAT WAVES

Climate change is associated with extreme climatic conditions, such as heat waves and severe precipitation events. Small changes in global average temperatures can result in relatively large changes in the frequency of extreme temperatures, and these phenomena are associated with increased mortality and morbidity rates. The relationship between temperature and mortality and morbidity is J-shaped curve, with a steeper slope at higher temperatures. In the United States, heat waves are deadlier than hurricanes, floods, and tornados combined. On average, nearly 200 Americans die every summer due to high temperatures.

One of the most significant heat wave episodes took place in Chicago, Illinois, from July 12 to July 16, 1995, resulting in temperatures as high as 106°F (41°C) with heat index values (a measure of discomfort when relative humidity is taken into account) soaring to 119°F (48°C) at O'Hare Airport and 125°F (52°C) at Midway Airport. This heat wave resulted in 465 deaths that were certified as heat-related and over 700 deaths that were attributable to the heat wave. In Chicago, this mortality was concentrated in the elderly with preexisting conditions. Another significant heat wave occurred in Europe in August 2003. France experienced the highest toll, with an estimated 14,802 deaths. However, more than 2,000 people died in each of the United Kingdom, Portugal, and Italy. In most estimates of heat wave deaths, very few are attributed to heat stroke. Instead, the immediate cause of death for most victims is cardiovascular or respiratory failure.

The extent of temperature-related mortality has been shown to vary according to geography, and the threshold temperature above which mortality increases is location-specific. Additionally, the risk of death increases after several consecutive days and nights of high temperatures. This suggests that there may be a critical load of heat stress, after which coping mechanisms are insufficient, and that this varies based on adaptation to heat that may be location-dependent. Vulnerability to heat waves is also driven by socioeconomic factors, such as poor housing quality.

The impact of heat waves has been primarily studied in urban areas, which experience the urban "heat island" effect. This effect occurs when urban areas generate and retain heat as a result of human and industrial activities. For example, black asphalt surfaces in cities are dense and heat-retaining. In addition, because urban areas generally lack tree cover, they experience less cooling by the process of evapotranspiration. It is expected that climate change will increase both heat and humidity, potentially worsening the effect of urban heat islands. Average surface temperatures may also increase due to urban sprawl and land-use changes, which will compound the heat island effect for urban areas.

Jyotsna S. Jagai

See Also: Climate Change and Human Health; Greenhouse Effect and Global Warming; Heat Island Effect in Urban Areas; Socioeconomic Status and Health

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HEAVY METAL POLLUTION

Metals occur naturally throughout the world. The term "heavy metals" as related to environmental pollution and health has no standard definition but generally refers to elements that are several times denser than water. Heavy metal pollution can occur in many ways, such as air pollution from industrial activities, stormwater runoff from industrial and mining solid waste, degradation of products containing metals, liquid waste discharged into water bodies or soaking into the ground, discharges from sewer systems, leachate from dumps, and particles and liquids from vehicle operation (e.g., copper from brake pads). Some human activities may unwittingly cause heavy metal pollution, such as irrigation with water containing dissolved metals. (When the irrigation water evaporates or is used by plants, it may leave behind the metals, leading to increasing concentrations in the soil over time.) Exposure to some heavy metals is associated with serious adverse health effects in humans.

While some metals are required for proper bodily function, specific metals may have adverse health effects when safe levels are exceeded. These metals include arsenic, chromium, copper, lead, mercury, silver, and zinc. The Environmental Protection Agency (EPA) and state agencies have regulatory standards for specific metals, and a single metal may be subject to several standards, depending on the situation where the metal is found. Because naturally occurring levels of metals, particularly in soils, may exceed regulatory standards, additional investigation may be needed in specific situations to determine the concentration level, form and availability of the metal, location (e.g., on or near the ground surface or farther underground), and potential for human exposure.

Heavy metals can have many different forms and be present in different compounds in the environment. The form of the metal in the environment is an important factor in the metal's toxicity. For example, chromium can exist in several forms, primarily chromium-3 (trivalent chromium) and chromium-6 (hexavalent chromium). While chromium-6 is the more toxic form, the metal can change forms, depending on environmental conditions and other factors. The EPA reports that health effects from continued exposure to chromium-6 can include allergic dermatitis, and studies suggest that chromium-6 may be a human carcinogen if ingested.

One of the better known heavy metal pollutants is lead. Because of health concerns, leaded gasoline containing tetraethyl lead was phased out in the United States beginning in the 1970s, and lead in paint used in homes was phased out about the same time. In 2016, a federal state of emergency was declared in Flint, Michigan, due to lead contamination in drinking water from lead pipes. Health effects from lead include behavior and learning problems in children (even at low levels of lead in the blood), reduced growth of the fetus, premature birth, and cardiovascular effects in adults. As far back as the ancient Romans, lead in drinking water may have affected health.

Thomas B. Lawrence

See Also: Ambient Air Quality; Arsenic Pollution; Drinking Water Quality and Regulation; Environmental Protection Agency; Hazardous Air Pollutants; Hexavalent Chromium; Lead Poisoning Prevention; Mercury Pollution; Stormwater Runoff

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HEXAVALENT CHROMIUM

Chromium is an odorless and tasteless metal that is found naturally in rocks, plants, soil, volcanic dust, and animals. However, the hexavalent form of chromium, Cr(VI), is rarely found in nature. Cr(VI) is a manufactured chemical used for many industrial purposes, including as pigment in dyes, paints, inks, and plastics and as an anticorrosive agent in paints, primers, and surface coatings. Cr(VI) is also used to increase the hardness and corrosion resistance of steel.

The Occupational Safety and Health Administration (OSHA) estimates that about 558,000 workers are exposed to Cr(VI) annually in the United States. This includes workers engaged in welding stainless steel and other alloy steels containing chromium metal and workers using electroplating technology. OSHA specifies worker protections to reduce Cr(VI) exposure in the general industry, at shipyards, and in the construction industry. Inhalation is the main route of exposure, but Cr(VI) can also enter the body through ingestion and skin contact.

The general population can be exposed to health risks from Cr(VI) if it leaches into water sources. The popular movie *Erin Brocovich* chronicled the story of a community in Hinkley, California, exposed to Cr(VI) through contaminated drinking water that leached into the ground water supply from a nearby industry. In response, the California Department of Public Health began monitoring Cr(VI) in drinking water in 2001 and later established statewide limits on the amount of Cr(VI) permissible in drinking water. Few people live in Hinkley today, but numerous communities in California still have drinking water sources with elevated Cr(VI) concentrations. In addition to drinking contaminated water, people can be exposed to Cr(VI) when using the water for other purposes, for example, while bathing.

Industries involved with chrome plating and the production of chromium-containing dye and paint pigments and wood preservatives can create waste streams containing Cr(VI). As such, communities located near these facilities are at greater risk for Cr(VI) exposure, particularly if the facilities do not adhere to state and federal environmental standards. U.S. Environmental Protection Agency (EPA) rules prohibit the use of chromium-based treatment chemicals in cooling towers at major industrial facilities, such as petroleum refineries, chemical manufacturing plants, and primary metal producers, thereby eliminating Cr(VI) emissions from these cooling tower operations.

Exposures to hexavalent chromium can lead to both short- and long-term health issues that include eye and respiratory irritation, asthma attacks, nasal ulcers, dermal burns, anemia, acute gastroenteritis, vertigo, gastrointestinal hemorrhage, convulsions, ulcers, and damage to the liver and kidneys. Additionally, Cr(VI) is considered a reproductive toxicant, and epidemiology studies have found it can increase the risk of lung cancer. The health effects associated with Cr(VI) exposure are described in various publications, including the EPA's Integrated Risk Information System database.

A 2010 study commissioned by Environmental Working Group found Cr(VI) in the drinking water of 31 of 35 cities tested. Although the EPA is evaluating Cr(VI) and has issued proposed regulations and guidance under the Safe Drinking Water Act, the EPA does not require water utilities to test for Cr(VI) and has not established exposure limits for the chemical. Only California law specifically requires testing for Cr(VI).

Elizabeth Ann Glass Geltman

See Also: Cancer Risk from Environmental Exposure; Drinking Water Quality and Regulation; Environmental Protection Agency; Heavy Metal Pollution; Occupational Safety and Health; Occupational Safety and Health Administration; Safe Drinking Water Act

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HUMAN ECOLOGY AND HEALTH

The concept of human ecology finds its earliest roots in the discipline of ecology and has since developed diffusely into a transdisciplinary and integral scientific study of humans and their natural environment. Throughout the eighteenth and nineteenth centuries, ecological principles developed in conjunction with other biological disciplines. When ecology first emerged as a distinct discipline early in the 20th century, it sought to clarify the relationship between an organism's morphology and physiology and the abiotic factors defining its natural environment. In 1935, British ecologist, Arthur Tansley (1871–1955), expanded the practice of ecology to the science of ecosystems: interactive systems established between living organisms and the full environment within which they live (e.g., biogeochemical cycles, flora, fauna, and minerals). Although humans were not considered the focal organisms of ecological study, anthropogenic systems increasingly became of interest to ecologists due to the unique influence of humans on nature.

The rise of the urban environment led social scientists in the 1920s to offer human ecology as an adaptation of traditional ecological analysis and a means of articulating everyday human-nature interactions. The initial focus on cities meant that much of this early framing focused on human modification of nature, treating society as an organism living either in tension or harmony with it. At the crux of this work are questions about the degree to which humans are a part of or separate from the rest of the natural world. On the one hand, people clearly rely on nature for their survival, can be classified biologically as mammals and, as conservationist Aldo Leopold once put it, are plain members and citizens of the larger biotic community. On the other hand, humans, and their impacts on the world, are unlike that of any other creature. The global human population, through its cultural, political, and economic systems, has dominated the earth's ecosystems and altered its biogeochemical cycles over a comparatively short period of evolutionary time.

As the debate over human influence and relationship with nature developed, human ecology moved beyond the fields of ecology, biology, and sociology to include anthropology, geography, economics, theology, philosophy, and psychology. Rather than becoming its own discipline, human ecology has led to an advancement of theory and science about the relationship between humans and nature across a range of disciplines, forming ecological anthropology, integrative geography, urban ecology, ecological economics, and environmental sociology. The multifaceted development of the concept has led many scholars to seek a larger bridging framework, coupled with human-natural systems, to span the total, transdisciplinary, and complex landscape of human-environment interactions.

Connections between human ecology and public health became established in the medical literature in the mid-20th century, particularly through epidemiology. The central premise of this work is that patterns of disease are not solely influenced by individual behavior and biological traits but are dependent on a person's social and physical environment. The interest in using an ecological frame to understand public health problems was likely in response to increasing dissatisfaction with linear explanations of causality, emerging links between social and health inequalities, and a greater emphasis on studying human behavior within natural environments instead of through controlled experiments. For example, environmental epidemiology emerged as a discipline focused on understanding how biological, chemical, physical factors, as well as social and economic factors, all influence people's health. Changes to an individual's and community's surrounding environment are known to have a coinciding impact on disease exposure.

Concepts in human ecology have also been used to advance more sophisticated health intervention techniques. In 1988, health promotion was defined in the context of broader social-ecological models that highlight the various and interrelated systems of human development, where the factors that produce and maintain human health are best understood in the context of one's physical environment and culture. Full consideration of all relevant factors means assessing health determinants along a continuum of concentric circles featuring intrapersonal, interpersonal, organizational, community, and policy levels. By adopting a holistic social-ecological framework for public health, the U.S. National Institutes of Health and other similar research institutions have better articulated how health issues and social problems are connected and advanced across a given system.

Health problems have become increasingly complex as global environmental change alters life-supporting systems. For example, natural disasters, such as floods and hurricanes, can exacerbate epidemics due to the spread of biological pathogens. Globalization, urbanization, and climate change have also resulted in demographic shifts that impact adverse health outcomes, including infectious disease. There are still many uncertainties about the threat that global environmental change poses to human health due to its scale and nonlocalized character. However, many resulting health effects from global warming, land-use changes, freshwater degradation, and biodiversity loss can already be empirically observed in some populations.

Rachel L. Lamb

See Also: Biosphere, Environmental Threats to; Climate Change and Human Health; Ecosystems, Importance of; Environmental Epidemiology; Greenhouse Effect and Global

Warming; Infectious Diseases; Natural Disasters; Population Trends, Health Implications of; Socioeconomic Status and Health

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HUMAN EXPOSURE ASSESSMENT

Human exposure assessment can be used when the actual dose of a chemical, toxicant, or stressor is absent by measuring contaminant concentrations in the air, water, food, and soil with which humans come into contact. This approach has historically been easier than measuring dose directly. Validated methods of sampling and analysis as well as knowledge of the relationship between exposure and health effects must be established for exposure assessment to be a reliable and useful method. (These conditions are addressed by the fields of industrial hygiene and epidemiology, respectively.) The ultimate goal of human exposure assessment is to keep contaminant levels low enough to prevent disease and death.

Childhood Lead Exposure at Home

Exposure assessment plays an important role in assessing childhood exposure to lead, which is present in many older homes. There are several sources of childhood lead exposure at home (e.g., toys, kids' cosmetics, and lead in drinking water pipes), but the most significant exposures are typically associated with lead dust from lead-based paint that is deteriorating and from lead-contaminated soil that is tracked inside as people come and go. Lead dust from paint can particularly be a concern during renovation activities, such as sanding or cutting into walls and woodwork or demolishing an area of the house. Young children can ingest high lead dust concentrations as they play or eat due to normal hand-to-mouth actions, potentially affecting brain and nervous system development and causing reduced IQ, learning disabilities, and behavioral problems.

Year Home Was Built	Percentage of Homes Believed to Have Lead-Based Paint
Before 1940	87
1940–1959	69
1960–1977	24

Source: U.S. EPA.

The three main pathways, or routes, of exposures through which chemicals enter the human body are inhalation (through the air we breathe), ingestion (through the food or water we consume), and absorption (through contact with the skin). A fourth route by which chemicals enter the body is injection, an important pathway for drug delivery but usually less important in environmental exposures. The rate at which a chemical can enter the body, the absorption rate, is dependent on the route of exposure, concentration, and type of contaminant. In general, it is easiest for chemicals to gain access to the body's internal environment when they are inhaled, but each chemical is different.

Exposure to an airborne contaminant depends on the total volume of air inhaled during an identified time period, the concentration of the contaminant in the air, where the contaminant lands in the lungs, and how quickly the contaminant is absorbed. The amount of air that humans breathe depends on the number of breaths and the volume of air inhaled, both of which change with the age, body size, and activity level of the individual. For example, children inhale a smaller volume of air than adults but breathe at a significantly higher rate, and people who are working or exercising take larger and more frequent breaths. Both of these circumstances result in higher exposures.

Exposure to ingested contaminants depends on the concentration of the contaminant in liquids or solids, the amount of contaminated liquids or solids ingested, and the rate at which the contaminant is absorbed by the digestive tract. Children may react differently than adults to the same exposure because their digestive systems have not fully matured. Ingestion of a contaminant may also occur when particulate matter is inhaled and trapped in the mucus of the nose and upper respiratory system and then swallowed. This can be a significant exposure pathway for particulate contaminants like lead.

Human skin is a protective barrier, but many contaminants can penetrate the skin and contribute significantly to dose. For example, organic solvents (e.g., benzene and trichloroethylene) and petroleum-based liquids can enter the body through the skin, whereas skin absorption may not be as much a factor for other types of chemicals. Note that the mucus membranes of the eyes and mouth can also be significant exposure pathways.

Biological exposure assessment evaluates levels of contaminants or their metabolites in urine, feces, blood, nails, and hair. Based on the amount of contaminant or its metabolite found, the internal dose and exposure can be calculated. The National Health and Nutrition Survey has documented hundreds of chemicals found in the blood of Americans. One approach to assess such broad exposure is for a person to wear a silicone bracelet that can absorb many of the contaminants the wearer is exposed to, allowing qualitative characterization of the exposure. (Although these bracelets do not currently provide data on *how much* of each contaminant the wearer has been exposed to, scientists are working on methods to do this.)

Much effort has gone into establishing the exposure level of specific chemicals in air, water, food, and soil that is generally considered safe for most humans, and a number of organizations have contributed to this effort. For example, the American Conference of Governmental Industrial Hygienists (ACGIH) began to derive acceptable levels for contaminants in the workplace in the late 1930s, and in the early 1970s, the U.S. Occupational Safety and Health Administration enacted into law exposure limits proposed by the ACGIH. The U.S. Environmental Protection Agency first developed acceptable exposure limits for the general population in the 1980s. At about the same time, the Agency for Toxic Substances and Disease Registry, which conducts human health assessments in response to environmental exposures, was established in response to toxic chemical dumping.

Acceptable exposure limits are usually higher (i.e., not as stringent) for workers than the general public for two reasons. First, workers typically work for 8 hours and then have 16 hours away from occupational exposures for their bodies to recover. And second, most workers are generally healthy, whereas the general public includes people who suffer from illness, the very young, the very old, immunocompromised people, and people with other conditions that may increase their risk of an adverse effect from chemical exposure.

Although chemicals are typically the first image that comes to mind when people think about exposure assessment, several external stressors, in addition to chemicals, can affect the internal environmental of the body. These include noise, radiation, molds, pollen, and physical variables such as heat, cold, vibration, and musculoskeletal stressors (e.g., awkward posture, force, and repetition). Stress caused by adverse social and economic factors as well as hostile work or living environments can also result in internal body changes, such as cardiovascular variations, altered hormone levels, increased risk of disease, and altered sleep patterns.

Exposure assessment science is continuously evolving. Unresolved challenges include assessing the health effects of multiple simultaneous exposures, the effect of each individual's unique microbiome on health outcomes, and the individual and collective effects of psychosocial stressors.

Mary V. O'Reilly

See Also: Biomonitoring and Biomarkers; Children's Environmental Health; Dose-Response Assessment; Environmental Epidemiology; Environmental Protection Agency; Industrial Hygiene; Lead Poisoning Prevention; Noise Pollution; Occupational Safety and Health; Occupational Safety and Health Administration; Soil Contamination and Remediation; Toxic Substances and Disease Registry, Agency for

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HYBRID AND ELECTRIC AUTOMOBILES, HEALTH BENEFITS FROM

According to the U.S. Environmental Protection Agency (EPA), driving a conventional car is probably an individual's most polluting daily activity. By driving cleaner hybrid and electric automobiles, tailpipe emissions are reduced, which results in lower levels of air pollution. Although there are still air pollution emissions associated with the power plants that provide electricity for charging electric vehicles, driving electric vehicles is still generally less polluting.

The transportation sector in the United States contributes to smog in our large cities and to poor air quality throughout large regions of the country. Vehicles powered by gasoline or diesel fuel are responsible for over 50 percent of the nation's

Gasoline versus Diesel Fuel

Compared with gasoline, diesel fuel is denser and contains more energy per gallon or liter. For this reason, it generally results in higher fuel economy, and it is the fuel of choice for heavy vehicles, such as trucks and buses. However, diesel fuel also contains more carbon than gasoline, which generally results in higher carbon dioxide emissions per gallon or liter, and diesel vehicles also emit more particulate matter. Nevertheless, today's high-tech gasoline- and diesel-fueled vehicles are much cleaner than earlier models, which is important because these vehicles will continue to make up the majority of new vehicles purchased for years to come.

nitrogen oxide emissions, 30 percent of volatile organic compound emissions, and over 20 percent of particulate matter emissions. The health effects associated with this pollution include asthma and heart attacks, stroke, cancer, and even premature death. In contrast to industrial pollutants that are often emitted from tall smokestacks, vehicle emissions are released at ground level, where it is easier to breathe the pollutants, whether we drive, walk, or ride a bicycle.

In contrast to gasoline and diesel vehicles, hybrid vehicles produce fewer emissions because they rely on both a conventional gasoline engine and a battery-powered motor. (The battery may be charged during vehicle operation, for example, when slowing down and applying the brakes, or for plug-in hybrid electric vehicles, by plugging the battery into an electricity source.) Electric vehicles produce no tailpipe emissions because they have only a battery-powered motor. (The battery is charged by plugging the battery into an electricity source.) Although energy from an electric power plant is required to charge the electric vehicle batteries, the power plant air pollution is typically less than if the electric cars were powered with conventional fuels, according to the EPA. This is particularly true on the East and West Coasts, where the energy grid is more diversified, deriving its power from renewable energy sources and nuclear power plants as well as fossil fuel-burning electric plants.

In assessing pollution from vehicles, there is more to consider than tailpipe and power plant emissions. The manufacturing process for new vehicles also produces pollution, although the efficiency and environmental impact of vehicle manufacturing have improved over the years. Cradle-to-grave comparisons of new vehicles, which include an assessment of pollution from mining and extraction of raw materials through the entire manufacturing process, have found that electric vehicles generate more pollution than conventional vehicles during manufacturing (possibly due to pollution associated with the battery-manufacturing process), but these electric vehicles more than compensate for the extra pollution during actual use on the road.

If nationwide use of electric and plug-in hybrid electric vehicles greatly expanded, would this require the construction of new power plants, including some potentially powered with fossil fuels? Probably not. It is estimated that the most energy-efficient electric vehicle models would increase a homeowner's electricity consumption by about 33 percent. However, because vehicle battery charging will usually take place at home in the evening and overnight, when electric demand is at its lowest, the grid capacity is not expected to become overloaded. In fact, electric vehicles might even be able to store excess power plant energy that might otherwise be wasted.

Aaron Dorman

See Also: Air Pollution; Automobile and Truck Emissions and Controls; Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Electric Power Generation, Health Implications of; Environmental Protection Agency; Greenhouse Effect and Global Warming; Nuclear Safety; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Respiratory Disease and Air Pollution

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HYDRAULIC FRACTURING

Gas drilling has been conducted for many years. Hydraulic fracturing, also known as "fracking," however, is a newer process for gas extraction. Since the early 1940s, vertical fracking has been conducted in the United States, a process by which gas trapped in rock below the earth's surface is broken and blasted apart by pressurized water pumps. In the early 1990s, a process known as horizontal fracking became possible in shales that are less porous. Although the fracking boom began in Texas (half of all U.S. fracking wells are still located there), large shale deposits of gas are prevalent throughout the country. For example, the Marcellus Shale formation extends from southern New York all the way to West Virginia. The U.S. Environmental Protection Agency (EPA) estimates that up to 30,000 new fracking wells were drilled in at least 25 states between 2012 and 2014.

The process of modern horizontal fracking works as follows: An initial drill hole is bored vertically, sometime going as deep as 3 to 5 miles (4.8 to 8.0 kilometers) below the surface. Once the drill reaches the depth of the gas-rich bedrock, the hole is turned 90 degrees and drilling continues. Next, a fluid mixture is pumped at extremely high pressure through the entire well to expand the rocks and create cracks, allowing the trapped gas to flow back through the well. The fracking fluid is mostly sand and water, but the remaining chemical composition is proprietary information. The purpose of these chemicals is mainly to dissolve minerals in the bedrock and to kill any bacteria and other growths. Additionally, gel-like substances are used to help convey the sand through the well.

There are three main ways in which hydraulic fracturing can negatively impact health and the environment: water contamination, gas leakage, and increased earthquake risk. A fourth problematic issue is that of the drill installation itself and the infrastructure involved with maintaining a fracking site.

Water contamination occurs when the toxic fracking fluid enters local aquifers and watersheds. Horizontal drilling goes well below the water table, and often special precautions must be taken at the depth of any fresh water, such as an extra layer of well casing (e.g., cement). Considering that this high-pressure process is meant to create fractures in hard substances, it should not be surprising that the well casing is vulnerable as well. Also, acid in the fracking fluid can corrode the cement layer meant to serve as a barrier between the well and water table. How significant water contamination is and how frequently it occurs as a result of fracking operations is open to debate. Without information from fracking companies on their proprietary fracking fluid composition, it is difficult to link fracking operations with nearby water contamination. (The Sundance award-winning documentary film, *Gasland*, includes a famous scene where a Pennsylvania homeowner near a fracking site turns on their tap water and lights the water on fire, a problem attributed to gas entering the groundwater supply due to fracking operations.)

A demonstration of how well water ignites when contaminated with methane. Many environmental activists blame well water contamination like this on nearby hydraulic fracturing operations. (AP Photo/L. M. Otero)

The EPA reports that 9.4 million people in the United States live within one mile (1.6 kilometer) of a fracking site, and 6,800 drinking water sources are located within that same radius. The agency found no widespread, systemic impacts on drinking water but noted specific incidences where water was proven to be contaminated by fracking. Some studies have attempted to link fracking with adverse health effects from contaminated drinking water. For example, a Colorado School of Public Health retrospective cohort study of 125,000 births within a 10-mile radius of maternal residence found a positive association between the density and proximity of natural gas wells and the prevalence of congenital heart defects and possibly neural tube defects.

Gas leakage from wastewater handling, condensation tanks, and the drilling process itself is a second major consequence of fracking. Additionally, diesel emissions are released from trucks and machinery operating at fracking sites. A study of sites in Pennsylvania found elevated levels of hydrogen sulfide in the air, and sites in West Virginia were found to have elevated levels of benzene, toluene, ethylbenzene, and xylenes. Tiny particles of silica, originating from the sand in fracking fluids, may also be present. Methane, a global warming gas much more potent than carbon dioxide, is also released from fracking operations. Currently, there are no air pollution regulations specifically related to industrial fracking.

The third major risk to public health from fracking is earthquakes. However, the fracking operation itself is not believed to be causing most of the earthquake activity detected in states having a large concentration of fracking wells. Instead, most earthquakes are caused by the disposal of wastewater by injection back into the rock layers, according to the U.S. Geological Survey. Whether an injection well can cause an earthquake depends on the injection rate and volume, the existence of faults and stresses large enough to cause earthquakes, and the presence of a pathway for the fluid under pressure to travel from the injection point to a fault. Most injection wells do not cause earthquakes that can be felt.

Finally, secondary environmental impacts can occur related to construction of the site and the transportation of materials to and away from the site.

Aaron Dorman

See Also: Air Pollution; Climate Change and Human Health; Drinking Water Quality and Regulation; Environmental Protection Agency; Greenhouse Effect and Global Warming; Groundwater Pollution and Depletion; Respiratory Disease and Air Pollution; Water Pollution; Watershed Management, Health Implications of

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HYDROLOGIC CYCLE AND CLIMATE

It is difficult to overstate the importance of water to the various species that inhabit the earth, indeed to the very existence of life. Trees and vegetation are about 50 percent or more water; some organisms are 90 percent water, and even humans, once described by imaginary hostile aliens on the popular TV program *Star Trek* as "giant bags of mostly water," are approximately 60 percent water. (Our brains and hearts are almost 75 percent water.) We absolutely could not survive without water!

Water is the primary building block of cells and is a vital nutrient to the life of every living cell. It regulates body temperature through perspiration and respiration, helps metabolize proteins and carbohydrates, moves nutrients in our bloodstream, forms saliva needed to digest food and aid swallowing, lubricates joints and serves as a shock absorber for the brain and spinal cord, and flushes waste and toxins from the body via urination. Externally, water is used in irrigating crops and growing food, generating electricity, and operating industrial and manufacturing equipment, and it is responsible for remarkable advances in medicine, sanitation, and life expectancy. Fortunately, water is almost everywhere, and approximately two-thirds of the earth's surface is covered in water—in the oceans, ice caps and glaciers, lakes, rivers, and streams. Water is even in the air that surrounds us, as humidity.

Water is constantly on the move in what we call the hydrologic cycle. Human consumption, crop irrigation, uptake by trees, the rain, the rivers, and even the humidity in the air are all components of the hydrologic cycle. The amount of water in the lithosphere and atmosphere is essentially fixed, with some estimates of the quantity of water on the earth at approximately 370 quintillion (18 zeros) gallons (1,400 quintillion liters). The water cycles through various forms and phases, including solid, liquid, gas, and biological water. There is a relatively recent theory that new water does, in fact, enter the earth's atmosphere through "snowball" comets approximately every three seconds or so. However, the quantity of such extraterrestrial water is very small, adding approximately 1 inch (2.5 centimeters) of water across the earth's surface every 20,000 years. For all practical purposes, it is useful to consider the volume of water on the earth as a fixed volume.

Of the total volume of water on the earth, approximately 97.5 percent exists as salt or brackish water in the oceans, seas, and bays—too saline for human and most other uses. That leaves just 2.5 percent of all water in the more useful freshwater state. But almost all of the freshwater is locked up in ice and in the ground, some so deep that it is essentially unavailable. Thus, the water that can be used to sustain life is only about 1.2 percent of the total freshwater available.

Of the shrinking fraction of available freshwater, 69 percent is bound in the ice caps, glaciers, and permafrost. Water vapor in the atmosphere accounts for 3 percent, and living organisms take up another 0.26 percent. Rivers (0.49 percent), swamps and marshes (2.6 percent), soil moisture (3.8 percent), and lakes (20.9 percent) account for the balance, with some error allowed for rounding. That leaves 26 quadrillion gallons (98 quadrillion liters) to share between drinking, bathing, industry uses, irrigation, and whatever other uses the 7.5 billion inhabitants of the earth have for water on an ongoing basis.

Space travel has given us the ability to view Earth from an incredible vantage point: images of the "blue planet" by NASA from 2002 give the illusion of a limitless supply of water. But a more sobering understanding of the limited available freshwater is provided by a U.S. Geological Survey illustration of the tiny volume of freshwater available compared with the size of the earth (water.usgs.gov/edu/earthwherewater.html).

As alluded to earlier, water is always on the move in some phase of the hydrologic cycle. The hydrologic cycle is the mechanism whereby water continuously changes states between liquid, vapor, and ice—sometimes very quickly and other times over millions of years. The hydrologic cycle is nature's water purification system. Solar energy heats and evaporates water, which condenses into clouds. The clouds cool and precipitation falls back to the ground, to be absorbed into the ground, percolate into groundwater, or flow along the surface into streams and back to the ocean. During that hydrologic journey, the water may be intercepted by the vegetative canopy, captured by the roots of the vegetation, diverted to industrial or irrigation uses, consumed by organisms and humans, or used by humans for any number of purposes. Eventually, the water will evaporate, leaving behind impurities and going through the entire process again and again. If the water falls as snow or ends up in the Antarctic, it may have a very slow journey through the hydrologic cycle, and the same is true of water that percolates into deep aquifers.

The predictability and stability of the global hydrologic cycle are important to human existence. Typically, people use available water in their area and compensate for any shortfall through storage, by finding alternate sources or by bringing in water from outside areas. The complexities and uncertainties of interactions between atmospheric moisture content, ocean currents, air and water temperatures, soil aridity, and land use make predicting changes in the hydrologic cycle tenuous at best. And as the earth's population continues to increase, impoundment and storage of water, along with withdrawals for irrigation and consumption, will only further complicate the cycle.

Climate change will likely influence atmospheric water concentrations, cloud cover distribution, and precipitation patterns. Some current mathematical models predict increasing intensity and occurrence of precipitation in northern latitudes with corresponding reductions near the equator, along with increasing temperatures. Precipitation, evapotranspiration, and runoff are all expected to increase globally, and hydrologic extremes (floods and droughts) will become more common and intense. More work remains to be done to understand and mitigate the impacts of climate change on the hydrologic water cycle. This is especially important given the world's increasing population and growing demands for freshwater.

John K. Borén

See Also: Climate Change and Human Health; Deforestation; Drought and Desertification, Health Consequences of; Greenhouse Effect and Global Warming; Heat Waves

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HYGIENE HYPOTHESIS AND HORMESIS

The hygiene hypothesis is a theory accounting for why certain neonatal and possibly perinatal environmental exposures, especially infections, result in some individuals being less likely to develop allergies, asthma, and autoimmune diseases.

The suggestion has been that mild early immune stimulation helps the developing immune system adapt to later exposures that might induce immune-mediated pathologies. In other words, extreme cleanliness early on in life may not be as beneficial as exposure to low doses of environmental contaminants or stressors that may induce protection to subsequent exposures.

Under this hypothesis, it is posited that if cell-mediated immunity occurs in the newborn, it helps to establish the proper helper T-lymphocyte (Th cell) balance, which under normal circumstances, is skewed toward Th2 cells at birth. Newborns have predominantly Th2 cells of the $CD4^+$ T cell population because of the activities of the maternal hormones, cytokines, and other immunoregulators that lower Th1 cell-mediated immunity during pregnancy to prevent spontaneous abortions. However, Th1 cell stimulation is needed early in life to improve the T cell balance and establish immunomodulator capacity to protect against later exaggerated induction of inflammation. Additionally, Th1 cells are needed for host defenses against viruses and intracellular bacteria.

Under normal, healthy circumstances, the immune system naturally regulates itself by differential activation of the T cell subsets at appropriate times, which helps to control innate and adaptive immune responses. For example, upon infection, innate immune cells, mainly natural killer lymphocytes (NK cells), macrophages, and neutrophils slow pathogen propagation and spread until adaptive Th1 cell-mediated immunity and B-lymphocyte antibody production (humoral immunity) become activated. However, if Th1 cells remain active too long, the host will develop systemic inflammatory response syndrome (SIRS), which can lead to septic shock, with organ failure and death. Therefore, when SIRS begins to peak and most of the initiating pathogen has been killed, a compensatory anti-inflammatory response syndrome (CARS) is initiated. Both innate and adaptive (antigen-specific) immune cells are responsible for the SIRS and CARS.

Prior to understanding the mechanisms of the immune modulations affecting later immune-related pathophysiological outcomes, hypotheses abounded suggesting general hygiene had influences on dental caries, mental illnesses, and cancers. Certainly, good general hygiene will reduce exposures to environmental pollutants and pathogens and thus will lessen the likelihood of illnesses. However, the current description of the hygiene hypothesis is somewhat counter to cleanliness being beneficial.

As often mentioned in toxicology, “the dose makes the poison,” and the immune stimulatory dose affecting the developing T- and B-cell memory pool of neonates is critical. Low exposures to certain immune stimulators may be beneficial, but high doses could be harmful. This suggestion brings into play the theory of hormesis. Hormesis suggests that a toxic compound or stressor at a low dose induces less risk and greater benefit in that it enhances a response that provides protection to a subsequent harmful stressor without causing harm. In theory, the protection comes from the immune cells developing an adaptive phenotype that is more balanced for a controlled immune response and more resistant to inflammation-induced tissue damage.

A more appropriate terminology for the hygiene hypothesis has been suggested to be the microbiota hypothesis, which more accurately addresses the involved participants. The microbiota are the composites of different microbes that colonize various parts of the body, such as GI tract, lungs, and skin. It is estimated that there are more microbes in the average GI tract than cells of a person. Microbiota are passed from mother to offspring through vaginal birth and nursing. Vaginal secretions and milk contain maternal cells, antibodies, and microbes. Children born by cesarean section and bottle-fed develop a more deficient microbiota and are more susceptible to allergies and inflammatory diseases later in life.

A recent study demonstrates how readily microbiota transfer to coinhabitants and affect immunity. Laboratory mice are usually housed with specified pathogen-free conditions and thus have a small immune repertoire (a low immune transcriptome with modest number of antigen-specific receptors), which is equivalent to a newborn human. Besides the antigen-specific repertoire being small, the numbers of activated and memory B and T cells are low, and the numbers of $CD4^+$ and $CD8^+$ T cells and immunoglobulins of all isotypes (IgA, IgG, IgM, and IgE) are lower in laboratory mice than in pet-store mice. Pet-store mice have an immune repertoire similar to a healthy adult human, with expanded expression of B and T cell receptors for different antigen specificities because of the diversity of environmental exposures. Within two weeks of cohousing specific pathogen free (SPF) laboratory mice with pet-store mice, the laboratory mice possessed similar numbers of activated T cells and B cells and produced immunoglobulins of all isotypes with expanded specificities. Furthermore, after the cohousing, the SPF laboratory mice were as protected from a listeria infection as laboratory mice preimmunized to listeria. The enhanced protection documents the disadvantage of developing in an environment that is too clean.

Individuals who live on a farm and are exposed to farm animals are more likely to develop a fuller immune transcriptome and have more diverse microbiota, and such people have lower prevalence of allergies. Newborns with older siblings also tend to develop fewer allergies, which has been suggested to relate to increasing the diversity of immune specificities and the microbiota. Similar to the pet-store mouse effects on laboratory mice, older siblings would bring more microbial exposures into the household. The beneficial effects of the maternal and sibling exposures would be dependent on the types of microbes and the socioeconomic conditions of the household, which includes adequate housing and diet. Early worm infections appear to lessen prevalence of allergies, and interestingly, the pet-store mice gave pinworm to the laboratory mice. In general, the hormetic effects of the mechanistic processes associated with the hygiene or microbiota hypothesis appear to relate mainly to westernized cultures having good health care and diet.

David A. Lawrence

See Also: Asthma; Children's Environmental Health; Environmental Toxicology; Reproductive Health and Environmental Exposure

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HYPOXIA, GULF OF MEXICO

Seventy-one percent of the earth is covered by water, and these bodies of water are home to a diversity of rich ecosystems. As in any other ecosystem, the organisms populating these areas have certain nutritional requirements. Most rely on oxygen to some extent, and oxygen deprivation, otherwise known as hypoxia, can be devastating. Hypoxic areas, commonly known as dead zones, have been identified near inhabited areas since the 1970s. As humanity depends on marine life and biodiversity, these dead zones represent a continuous and major water quality issue.

The Gulf of Mexico hypoxic area is a dead zone located at the northern Gulf of Mexico, adjacent to the Mississippi River. Scientists have discovered that this dead zone is caused by runoff from agricultural operations and other human activities that discharge sediment and nutrient loads into watersheds feeding the Mississippi River. As the Mississippi is a primary source of nutrients and fresh water to the Gulf of Mexico, this uptick in nutrient load and sediment stimulates excessive algae growth in the Gulf that consumes the oxygen in this body of water. This dead zone was first recorded in the 1970s and has become an issue of increasing concern since the late 1990s.

Nutrient pollution in the Mississippi River comes from both point and non-point sources. Any single identifiable source of pollution, such as pipes, ditches, ships, or factory smokestacks, is known as a point source of pollution. Mills, factories, and treatment plants are common point sources of pollution. In contrast, nonpoint source pollution comes from many diffuse sources and is caused by runoff from various types of landscapes. Agricultural operations have been considered the leading source of water quality impairment to surveyed rivers and lakes and the second largest impairment to wetlands.

An additional contributor to the Gulf hypoxic zone is the excessive sediment load that empties into the watershed. Sediment originates from upstream erosion in the form of gully, sheet, and rill erosion. This sediment is first suspended in water, reducing the amount of light available for organisms in that watercourse, and then blankets the watercourse bed, ultimately smothering its aquatic inhabitants.

Deoxygenated water, coupled with excess sediment, creates near-uninhabitable water conditions for almost all marine life. These degraded conditions are only conducive for the growth of anaerobic bacteria, and organisms that are unable to escape the deoxygenated area die. Fish kills (the death of a large number of fish) are a common result of Gulf hypoxia. A deoxygenated environment created by decomposing algae suffocates the fish and other aquatic life in the area. The dead fish then decompose and litter fishing waters, further contributing to the dead zone. Fish kills can completely wipe out a species of fish or other marine life in the zone. This results in the elimination of marine diversity and severely damages aquaculture in the area. If not for hurricanes and tropical storms in late August and September, which break up the hypoxic area, the dead zone would last all year.

Numerous federal, state, and independent organizations and agencies spend millions of dollars and resources to reduce nutrient and sediment loads within the Mississippi River Basin. These organizations have combined their efforts and formed the Hypoxia Task Force, which was established in 1997, chartered in May 1998, and released its first action plan in 2001. The task force was established to understand the causes and effects of eutrophication in the Gulf of Mexico, to coordinate activities to reduce the size, severity, and duration of the hypoxic zone, and to improve the effects of hypoxia. Through the task force's efforts, measures are being taken to reduce the hypoxic zone's expansion and protect the countless resources in the Gulf of Mexico.

Leon D. Tillman Jr.

See Also: Deepwater Horizon Incident; Water Pollution; Wetlands and Healthy Waterways

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I

INDOOR ENVIRONMENT

The indoor environment has a direct and lasting effect on human health. In an effort to identify key variables and correlations, environmental health scientists have primarily focused on discrete indoor pollutant sources and exposures relevant to specific disease processes. However, as this field evolves with advancing science and emerging technology, current research includes the complex social interactions between the health of people and the interior space in which they inhabit.

The indoor environment is wide ranging and includes interior space such as the home, workplace, and car. According to the Environmental Protection Agency (EPA), people spend most of their time indoors. This leads to sustained exposure from both chemicals and building conditions. A variety of chemicals, such as household cleaners, soaps, and air fresheners, are present indoors. Building conditions, including ventilation, lighting, building design, and location, all define how people interact with their environment.

According to the EPA, the quality of indoor air has decreased over the previous two decades. The reductions in air quality, and consequently, in the health of inhabitants, have been directly attributed to the changing designs by builders seeking energy efficiency, driven by the market demand to have more energy-efficient homes. In an effort to moderate external influences on the indoor environment, builders are creating, in essence, airtight homes. While this may reduce heating and electric bills, the end result is the continued redistribution of the same air. In homes where chemicals are frequently used, this can lead to an increased level of exposure to these chemicals for the inhabitants.

Compounding this exposure is the increased use of synthetic materials in building supplies and indoor products. To produce a comfortable and affordable indoor space that also complies with local building codes, designers and builders often choose synthetic materials, in some instances trading quality for a cheaper price. However, this practice has sometimes led to corrupted indoor environments, where occupants were exposed to indoor contaminants that surpassed recommended levels, leading to reduced air quality within the building. Studies indicate that individuals within these environments experienced greater health problems, supporting the connection between a person's health and the indoor environment.

It has been more than 30 years since the First International Indoor Climate Symposium, where 10 researchers from the United States, Slovakia, Sweden, and Denmark described the key health impacts from indoor exposure to combustion products resulting from heating, cooking, and the smoking of tobacco. These variables continue to remain relevant today as scientists study connections

Air duct cleaning inside a home. Because people spend up to 90 percent of their time indoors, maintaining a healthy indoor environment can help prevent illness. (Bill Oxford/iStockphoto .com)

between the indoor environment and human health. As people heat their homes, cook, and smoke tobacco inside, these combustibles and their by-products become embedded into the environment. Compounding this are pollutants emitted from building materials, including volatile organic compounds emerging from sources such as paints, varnishes, solvents, wallboard, and flooring material. Over a period of time, these pollutants begin having a negative effect on a person's health.

The health effects of a compromised indoor environment can also emerge from structural deterioration of older building materials, such as asbestos. Asbestos exposure can lead to health issues associated with chronic respiratory diseases, and during the past 30 years, there has been a continual increase in reported cases of mesothelioma. The health effects resulting from inhaled biological particles within a controlled indoor environment can also be significant, particularly when a large variety of biological materials are present. Their role in inducing illness by attacking immune mechanisms, supporting the infectious process, and leading to direct toxicity highlight the challenges associated with controlled indoor environments. Additional sources of toxicity, which can be transferred from outdoor sources, can compromise indoor environments and elevate concentrations of pollutants. These include contaminants such as radon, a radioactive gas that can arise from the ground and concentrate indoors.

The presence of contaminants in buildings has led to a condition known as sick building syndrome. Occupants of particular buildings with this condition are affected by a series of complex, vague, and subjective health complaints. The presence of sick building syndrome can often be attributed to poor air quality associated with a number of factors, including insufficient ventilation, sources of air pollutants and molds, and habitual smoking.

As world health experts seek to understand the connections between health and environment, it is clear that a significant problem is ventilation. An optimal exchange of fresh air being continually introduced into an environment promotes good health and healthy interactions. But in buildings designed and built to be tightly sealed to increase energy efficiency, emissions can build up from a variety of sources, including furniture, cleaning products, and building materials. These emissions, along with indoor conditions such as increased humidity, can lead to increased levels of air pollutants, microorganisms, insects, and allergens. In a domino-like effect, the buildup of emissions challenges the immune system of the habitant.

While building enhancements and performance should be continued and encouraged, there is an equal need to provide healthy and secure indoor environments. As innovative materials are constantly being developed, chemicals not fully tested can be introduced into the building process. Thus, the possibility remains for another future catastrophic epidemic, similar in nature to the identification of the harmful effects of asbestos. Government agencies have been called upon to actively research and evaluate the emissions from new building materials that will eventually affect controlled spaces and environments. This type of forward thinking is driven by the belief that upfront investment into research will prevent future problems, potentially saving billions of dollars associated with medical care, litigation, remediation, and lost productivity by the designers, builders, and occupants. Indoor exposure problems affect several layers of society, which suggests a collaborative approach in their resolution.

Recently researchers have begun examining the effects of climate change on the indoor environment. As climate change takes hold, buildings designed and constructed under previous climatic conditions may not function optimally. As a result, global warming may adversely affect the health of the individuals who live, work, study, and play indoors. As climate change worsens, the indoor effects will become more obvious and solutions more urgent.

Charles Daniel

See Also: Air Pollution; Asbestos; Climate Change and Human Health; Environmental Protection Agency; Greenhouse Effect and Global Warming; Hazardous Air Pollutants; Particulate Matter and Bioaerosols Pollution; Personal Care Products, Health Issues with; Radon; Respiratory Disease and Air Pollution; Sick Building Syndrome; Tobacco Smoke, Secondhand and Thirdhand; Volatile Organic Compound Pollution; Woodstove Air Pollution

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INDUSTRIAL EFFLUENTS

Industries in communities served by publicly owned treatment works (POTWs) often discharge effluents (i.e., wastewater) into the same sewer systems that collect domestic wastewater. However, wastewater generated by industrial sources is often quite different from the domestic wastewater that POTWs were designed to treat. Industrial wastewater can vary tremendously from facility to facility, depending on what products, processes, and raw materials are used, and there can even be great variability within a facility. Some wastewaters can have very high organic strength, often many times stronger than sanitary effluent, and other wastewaters may contain heavy metals, other inorganic compounds, and constituents that are toxic to treatment microorganisms and to receiving stream biota. And some wastewater may even manifest inhibitory characteristics that make it unsuitable for biological treatment at the POTW.

A discharge of pollutants directly into a receiving water body is termed a "direct discharge." POTWs are required to have National Pollutant Discharge Elimination System (NPDES) permits for direct discharges of their treated effluent to receiving water bodies. Facilities that discharge wastewater to a POTW are termed "indirect dischargers." Federal regulations require POTWs to establish a local pretreatment program to control discharges from nondomestic sources (i.e., indirect dischargers) and to prevent pass-through and interference at the POTW. Pollution control authorities develop pretreatment programs that establish limits and conditions for indirect discharges, often by issuing pretreatment permits under which industrial users can discharge wastewater to the POTW. Discharges must comply with federal, state, and local pretreatment standards and requirements.

To meet the requirements of indirect discharge permits, it may be necessary to treat the industrial wastewater before discharge (i.e., pretreatment). To determine the type of pretreatment required, it is necessary and standard practice in industrial wastewater engineering to develop a wastewater characterization through survey methods and treatability studies. Variability in the wastewater should be included in the characterization so that treatment systems are sufficiently robust and adaptable to treat an expected variation of wastewater. The amenability to aerobic degradation must be assessed as well as organic loading estimated so that adequately sized treatment units can be designed. It may be necessary to conduct investigations to determine the source of toxicity or other undesirable/inhibitory characteristic so that appropriate treatment can be employed.

While pretreatment of industrial wastewater may include a biological system similar to a POTW (i.e., an aerobic-activated sludge system), additional or different treatments may be prescribed by the treatability study. High strength waste, defined by biochemical or chemical oxygen demand, may be better treated by anaerobic means. (For example, with less sludge production and generation of methane instead of CO_2, biological degradation by anaerobes and methanogens may be a more economical alternative.) Attached growth media may be required to lengthen sludge retention times to adequately treat such high-strength wastes. Heavy metals may have to be removed through a program of pH adjustment, coagulation, flocculation, and settling. Free oils may be removed by dissolved air flotation units. Toxic organics may necessitate passage through an activated carbon column or addition of powdered activated carbon to adsorb the toxic constituents. The treatability study may show that air stripping of volatile organic compounds is required, or perhaps membrane polishing can be used to provide final treatment. A treatment train (i.e., a series of treatment technologies) may be required, and source reduction of pollutants before they are mixed into the plant wastewater system may also be necessary. The combinations are endless, and the treatability study can be a complex task and test of investigative skills.

Effluent discharge limitations for indirect dischargers may be established by federal categorical pretreatment standards for some 58 different categories of industries. In many cases, if an industry has multiple waste streams, the limits may apply at the process level, further complicating treatment and management of wastewater. Dilution or mixing effluents with wastewater may have the effect of reducing pollutant concentrations but is typically not allowed for meeting permit limits. If the POTW has limited capacity or is itself discharge-limited, permit limits for indirect dischargers may be correspondingly tightened. It may be the case that the organic content of the wastewater cannot be reduced by pretreatment to an acceptable level, shifting the burden of treatment to the POTW. In these situations, the POTW, while designed to remove organics, may incur additional costs from additional aeration and sludge disposal due to the added organics. In many cases, local control authorities may not consider excess conventional pollutants as a permit violation up to a point, but they will levy a surcharge for providing the additional treatment. Establishing permit limits and surcharge levels is often a matter of negotiation, and pretreatment users are advised to understand and participate in the limit-establishing process.

Sometimes an industry is located in a community that does not have a pretreatment program, or the industry is unable to discharge to a POTW because of location or other physical limitations. In those cases, the industrial facility may be considered a direct discharger with its own NPDES permit. Permit limits attached to a direct discharger are established based on the more stringent of categorical effluent limitations, whole effluent toxicity, or water quality criteria of the receiving stream. Water quality criteria of the receiving stream are often the most stringent because the use of the stream (e.g., potable water supply) may require very low levels of contaminants. Without the benefit of dilution from domestic sources of wastewater throughout the POTW sewer collection system, it is likely that these direct discharge permits will have very stringent limits that may be difficult to achieve.

John K. Borén

See Also: Clean Water Act; Heavy Metal Pollution; Pollution Prevention; Sewage Treatment and Disposal; Toxics Release Inventory; Water Reuse and Recycling

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INDUSTRIAL HYGIENE

The field of industrial hygiene is concerned with protecting the health and safety of people from hazardous conditions in the workplace caused by a wide range of chemicals, physical agents, and biological materials. The workplace environment and the manner in which jobs are carried out can also be unsafe and unhealthy for workers. Industrial hygiene addresses all factors that may compromise worker health and safety. Terms such as "occupational health," "occupational hygiene," and "health and safety" are sometimes used interchangeably with industrial hygiene.

Industrial hygienists are professionals with training and experience in recognizing, evaluating, and correcting hazardous conditions in the workplace. At a minimum, an industrial hygienist must have a bachelor's degree in an area such as engineering, chemistry, physics, biology, or environmental sciences and several years of practical experience. A certified industrial hygienist is an individual who has passed a certification examination offered by the American Industrial Hygiene Association and completed four years of work experience. This is an important recognition of professional competence in the field. Today, industrial hygienists work in a variety of capacities, including regulators and inspectors for the Occupational Safety and Health Administration (OSHA) and its state and local counterparts, staff members and managers of industrial hygiene programs in both public- and private-sector workplaces, researchers at universities, and designers and developers of exposure evaluation methods and protective equipment.

The history of industrial hygiene traces back to the 4th century BCE, when Hippocrates (c. 460–c. 375 BCE) observed health problems in lead mines. A few hundred years later, a Roman scholar named Pliny the Elder (c. 23–c. 79 CE) was credited with devising with the first respirator, a face mask made from an animal bladder, to protect workers from inhaling dust and lead fumes in mines. However, for the most part, society paid little attention to the hazardous conditions in many workplaces. Early on, some people actually believed it was demons inhabiting the mines that made workers sick.

The first major shift in societal attitudes came in 1700, when Bernardino Ramazzini (1633–1714), an Italian physician, described silicosis in his book *De Morbis Artificum Diatribia (Diseases of Workers)* as an occupational disease among miners. The work of Percival Pott (1714–1788), who recognized soot as a cause of scrotal cancers among chimney sweeps, is often cited as the inspiration behind passage of the Chimney Sweepers Act of 1788 in England.

In the United States, no major developments in industrial hygiene occurred until the early 1900s. The New York Department of Labor and the Ohio Department of Health established the first state industrial hygiene programs in 1913. This was followed by the first Master of Industrial Hygiene degree program at Harvard University in 1922, established to provide professional education and training for industrial hygienists in the United States. Alice Hamilton, an American physician, has been credited as a leading force in establishing the field of occupational medicine and in raising American awareness about health and safety issues in the workplace. Her work as the chief investigator for a 1910 survey of occupational health problems in Illinois, commissioned by the Illinois Occupational Disease Commission, was the nation's first industrial survey of hygiene and occupational health.

The concept of a worker's right to a healthy and safe workplace was first established at the federal level in the Coal Mine Health and Safety Act of 1969. The act comprehensively addressed the protection of health and safety for coal miners by requiring adequate dust control, ventilation, respiratory protection, and periodic medical examinations. One year later, similar protections were extended to workers in other industries with the enactment of the Occupational Safety and Health Act of 1970. Under the act, the newly created OSHA in the U.S. Department of Labor was authorized to develop and set mandatory occupational safety and health standards and to fine employers who violate them. A typical health standard is defined by a limit on the concentration of a toxic substance a worker may be exposed to without experiencing adverse health effects, expressed as a time-weighted average over an eight-hour work shift. This limit is referred to as a permissible exposure limit (PEL). In addition, highly toxic substances are often assigned short-term exposure limits (STELs), which apply to exposure over a 15-minute period.

The primary responsibility of industrial hygienists is to ensure that the workplace under their charge meets applicable OSHA standards by identifying, assessing, and controlling worker exposure to hazardous substances. For example, the workers in the curing area of a tire plant are likely to be exposed to fumes from the curing process, which often contain highly carcinogenic substances such as benzene. In this situation, an industrial hygienist is likely to conduct personal sampling (i.e., measurements of contaminant levels in a worker's breathing zone) to determine whether the exposure to benzene exceeds the OSHA PEL of 1 part per million (ppm) and STEL of 5 ppm. (Before applying these limits, be sure to check the OSHA website for any revisions or updates.)

If worker exposure to benzene, for example, exceeds the PEL, the industrial hygienist would develop a plan to protect the workers by lowering their exposure to benzene below the PEL. Typically, this is done by providing appropriate personal protective equipment, such as a respirator. Other types of protective equipment include gloves, goggles, hard hats, and Tyvek suits, depending on the nature of exposure. Training workers on the proper use and maintenance of protective equipment is an important part of an industrial hygienist's responsibilities. Occasionally, industrial hygienists work with engineers to modify the production process or equipment to lower or eliminate exposure risks in the workplace.

Throughout recent history, workers have been exposed to an increasing number of chemicals in liquid, dust, fume, mist, vapor, and gaseous forms. Furthermore, in some workplaces, exposures to ionizing and nonionizing radiation and blood-borne pathogens pose serious risks to worker health, and ergonomic problems and the adverse health effects of a stressful work environment have become more evident in recent years. Additionally, industrial hygienists are often concerned with job safety and indoor air quality because these issues are frequently inseparable from other industrial hygiene issues in the workplace. In view of all of these concerns, the responsibilities of industrial hygienists can be highly complex and enormously challenging.

Yoko S. Crume

See Also: Indoor Environment; National Institute for Occupational Safety and Health; Occupational Safety and Health; Occupational Safety and Health Administration; Radiation, Ionizing and Nonionizing; Radon

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INFECTIOUS DISEASES

Infectious diseases are caused by pathogenic microorganisms, including certain types of bacteria, viruses, parasites, fungi, and algae. Cholera, Ebola, Guinea worm disease, hepatitis, HIV/AIDS, influenza, malaria, measles, meningitis, pertussis, rabies, sexually transmitted diseases, shigellosis, tuberculosis, West Nile virus, Zika virus, and tropical diseases such as dengue fever, lymphatic filariasis, river blindness, schistosomiasis, and trachoma are all examples of infectious diseases.

An infectious disease that can spread directly from person to person or indirectly by way of a vector, such as a tick or mosquito, is called a communicable disease. We can contract a communicable disease in various ways, including contacting blood and other bodily fluids of an infected person, being bitten by an insect, touching a contaminated surface, or inhaling an airborne organism. All communicable diseases are infectious, but not all infectious diseases are communicable. For example, noncommunicable infections can be caused by toxins found naturally in the environment (e.g., tetanus infection) and by toxins associated with food poisoning.

Infectious diseases contracted through foods, including beverages, are very common. Every year in the United States, one in six Americans becomes ill from eating foods contaminated with bacteria, viruses, or parasites, and about 3,000 die each year from foodborne diseases. Some diseases are caused by the organism itself, while other diseases are caused by the human body's reaction to the organism or the pathogenic toxin it creates. Examples of foodborne diseases are botulism, hepatitis A, norovirus infection, salmonellosis, and shigellosis.

Zoonotic diseases are infectious diseases of animals that can be transmitted to humans, and surprisingly, as much as 60 percent of all infectious diseases in humans are zoonotic in origin. Several examples are Lyme disease and Rocky Mountain spotted fever (transmitted by ticks), malaria and West Nile virus (transmitted by mosquitoes), and *E. coli* and salmonella infections (from handling infected animals or eating contaminated animal food products). Anthrax, another type of zoonotic disease, can be contracted by touching infected animals and contaminated animal products, although anthrax outbreaks affecting humans are rare in the United States.

Infectious diseases in developing countries often proliferate where people have little or no access to safe drinking water and basic sanitation. For example, the World Health Organization estimates that the drinking water used by at least 1.8 billion people is contaminated with feces and that contaminated drinking water causes a half-million diarrheal deaths per year. Additionally, annual deaths from schistosomiasis number between 20,000 and 200,000, and trachoma is responsible for blindness or visual impairment in about 1.9 million people.

Hospitals, clinics, nursing homes, and rehabilitation centers in the United States and other developed nations are often plagued by healthcare-associated infections (HAIs), which are infections that patients acquire while being treated for another condition. Urinary tract, surgical site, and the bloodstream infections, along with pneumonia, are the most common types of HAIs at these facilities. It is estimated that about 1 in every 25 hospital patients acquires an HAI, costing the U.S. healthcare system billions of dollars each year and leading to the loss of tens of thousands of lives.

In the 19th century, many Americans and Europeans moved from the countryside to large cities for manufacturing jobs, and there they encountered poor housing conditions, including overcrowding and inadequate drinking water and waste disposal systems. As a consequence, outbreaks of cholera, dysentery, tuberculosis, typhoid fever, influenza, yellow fever, malaria, and other infectious diseases were common. But in the 20th century, deaths from infectious diseases declined precipitously, largely due to:

- Improved sanitation and hygiene
- The discovery of antibiotics
- Universal vaccination programs for children

The decline in infectious diseases in the United States was aided by the creation of many health departments at the state and local levels of government. These health departments implemented vaccination programs as well as a number of crucial disease prevention initiatives aimed at improving water quality, sewage disposal, pest control, food handling, and other sanitation and hygiene practices. Penicillin and other antibiotics for bacterial infections have achieved near-miraculous results, and drugs for treating viral, fungal, and parasitic diseases have also been effective. Unfortunately, the emergence of drug resistance among many microorganisms has required the development of new drugs and other tactics to treat infectious diseases, including a greater emphasis on disease prevention.

Richard Crume

See Also: Bubonic Plague; Communicable Diseases; Drinking Water Quality and Regulation; Ebola Virus; *Escherichia coli* (*E. coli*) Infection; Food Safety and Technology; Foodborne Diseases; Guinea Worm Disease; Healthcare-Associated Infections; Infectious Diseases; Insect-Borne Diseases; Legionnaires' Disease; Lyme Disease; Lymphatic Filariasis; Norovirus Infection; Public Health Service; River Blindness; Rocky Mountain Spotted Fever; Schistosomiasis; Sewage Treatment and Disposal; Sick Building Syndrome; Tetanus Infection; Trachoma; Waterborne Diseases; World Health Organization; Zika Virus; Zoonotic Diseases

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INSECT-BORNE DISEASES

Thousands of people throughout the world are bitten by ticks and mosquitoes on a daily basis. While these arthropods are viewed primarily as a disgusting nuisance, they can also carry a variety of diseases and pose a risk of illness. When you view the number of individuals exposed to insects in comparison to the prevalence of disease, it may be difficult to see the importance of preventing these types of diseases. Historically, however, insect-borne diseases have had a devastating toll on humankind, and disease prevention can save hundreds of thousands of lives every year.

Insect-borne diseases are illnesses carried by an insect vector. A vector is an organism that transports pathogens, like bacteria or viruses, from one location to another. Insects become infected when feeding on the blood of an animal that contains a microorganism. The bacteria or virus replicates within the insect, where it ultimately infects the salivary glands. Finally, when that insect takes a blood meal from a new host animal, it transmits the pathogen to the new host via the saliva in the infected salivary glands.

The two most common insect vectors are mosquitos and ticks. Various species of these arthropods, which can bite both humans and animals, exist in every country. The different organisms and illnesses have certain regional predilections due to their dependence on certain climates and environments to survive. The majority of insect-borne illnesses carried by mosquitos are viruses, with a few exceptions. Viral illnesses include diseases like yellow fever, dengue, equine encephalitis, chikungunya, Zika, and the West Nile fever. Many mosquito-transmitted infections are found in less developed countries.

Encephalitide diseases all cause encephalitis (inflammation of the brain), and they have similar neurological symptoms even though the organisms that infect the cerebrospinal fluid are different. These viral organisms do not cause disease in the insects that carry them—they only affect the animals and humans that are bit by the insect. Viruses that cause encephalitis are typically members of the *Flavovirus, Togavirus, Bunyavirus*, or *Reovirus* genera. The three forms of insect-borne encephalitis that present the largest threat in North America are termed the St.

Louis, LaCrosse, and the West Nile fevers. Various forms of equine encephalitis are most commonly found in Central and South America.

Some mosquitoes carry parasitic helminthes that cause filariasis, a disease in which roundworms infest various parts of the body. These helminths include *Wuchereria bancrofti* from Africa and India, *Brugia malayi* from China and Malaysia, and *Brugia timori* from Indonesia. Mosquitos can also carry the parasites that cause malaria. Malaria parasites can infect many animals, where they first grow in the liver and then infect the red blood cells, leading to red blood cell rupture and anemia. The five strains that typically infect humans are *Plasmodium falciparum, Plasmodium ovale, Plasmodium vivax, Plasmodium malariae*, and *Plasmodium knowlesi*. This disease can be fatal in many individuals, particularly young children. The vast majority of deaths attributed to malaria are children under the age of five in sub-Saharan Africa, where the disease is endemic.

While more viruses are transmitted within the tick family, the bacterial pathogens are more well known, and they clinically present with a variety of disease patterns. Tick-borne illnesses depend on the tick vector within which the microorganisms reside as well as the country where they reside. Ticks can cause diseases like Rocky Mountain spotted fever, Lyme disease, Q fever, and a red meat allergy.

The majority of tick-borne illnesses present with flu-like symptoms, such as nausea, headache, and malaise (feeling tired), along with symptoms like rash and nonspecific joint pains. The initial rash can appear as a bull's-eye rash, which may change after the organism has been within the new host for a long time. In severe cases, the bacteria can cause meningitis shortly after inoculation, and after prolonged exposure, the bacteria can also cause severe disease, such as blood cell rupture (granulocytosis), neurodegenerative disorders, and organ failure. On some occasions, individuals can acquire tick-paralysis, often confused with Guillain-Barré syndrome, but the paralysis resolves with removal of the tick.

A red meat allergy is uncommon but can be very severe. It is due to an immune response to a sugar, galactose-alpha-1, 3-galactose ("alpha-gal"), that is regurgitated into the host during a bite from certain species of tick. This sugar is also found in red meat (e.g., beef, pork, venison, or rabbit) and some dairy products. The alpha-gal allergy can cause symptoms ranging from urticaria (rash) to angioedema (lips and mucosal swelling) and sometimes anaphylaxis (severe allergic reaction leading to shock) after a person ingests red meat. Treatment typically involves avoiding the ingestion of mammalian meat.

Outside of the United States, there are some unique insects that carry various insect-borne illnesses. These illnesses possess special characteristics that are rarely seen within the United States, except among international travelers. Each of these microorganisms is transmitted by a particular insect vector and presents with symptoms based on their life cycle, characteristics, and geographic region. One example is leishmaniasis, a disease caused by a protozoan parasite named *Leishmania donovani*. This parasite is carried by the sandfly, which is prevalent in many countries. Leishmaniasis can present with a cutaneous (skin) infection or more severely with destruction of internal organs like the spleen, liver, and bone marrow.

In Central and South America, one well-known insect-borne illness is Chagas disease, which is caused by *Trypanosoma cruzi*. This is a protozoan parasite, carried by the "kissing bug" or "assassin bug," that can cause heart failure through chronic fibrosing myocarditis (scarring of the heart), leading to an enlarged, poorly functioning heart muscle (cardiomyopathy). *Loa Loa*, which causes loiasis, is a helminth (parasitic worm) carried by deer flies. This parasite works its way through the body's lymph system or under the skin to other body regions, and it can sometimes be visibly seen moving around within the eye.

Unique insect-borne illnesses in Africa also include trypanosomiasis, or sleeping sickness. This is caused by the bacterial organism *Trypanosoma brucei gambiens*, which is carried by the infamous tsetse fly. River blindness is another illness caused by the parasitic helminth *Onchocerca volvulus*, transmitted by the African black fly. Behind trachoma, river blindness is the second most common cause of infectious blindness in the world. Africa also hosts a number of insect-borne illnesses that affect animals in Africa, including Bluetongue disease, which affects sheep and cattle, and African horse sickness, which plagues the equine species (horses, asses, and zebras).

Some illnesses can also be transmitted by common household insects. Fleas can carry the plague (*Yersinia pestis)*, which caused one of the greatest pandemics in human history. The human louse can carry some rickettsial pathogens similar to those found in ticks, causing conditions such as epidemic typhus (*Rickettsia prowazeki*) and trench fever (*Rickettsia quintana*).

New insect-borne illnesses are discovered every year, and prevention is fundamental to protecting oneself from insect-borne illnesses. DEET (N, N-diethyl-3-methylbenzamide) and permethrin are neurotoxic chemicals that can deter fleas, flies, mosquitoes, and ticks from acquiring a blood meal, which subsequently decreases transmission of insect-borne illnesses. Using these insect repellants in combination with barrier methods (like clothing and mosquito nets) is a highly effective strategy for preventing insect-borne illnesses.

Howard W. MacLennan Jr.

See Also: Communicable Diseases; Infectious Diseases; Pesticides and Herbicides; Waterborne Diseases

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INTEGRATED RISK INFORMATION SYSTEM

The integrated risk information system (IRIS) is a database of human health assessments for chemicals found in the environment. The IRIS was initially created by the U.S. Environmental Protection Agency (EPA) in 1985 for internal use to encourage consistency in conducting chemical toxicity evaluations. However, the database quickly grew into an important public resource that is widely used today by regulators, researchers, international health organizations, and the public for the latest information on health hazards associated with chemical contaminants in the environment.

The IRIS database consists of high-quality, evidence-based human health assessments of specific chemicals, groups of related chemicals, or complex chemical mixtures. The database is the main source of human toxicity information used by the EPA for setting standards to protect the public against exposure to harmful chemicals. (Both carcinogenic and noncarcinogenic health effects are evaluated.) Many other agencies, both in the United States and abroad, also use the IRIS to develop standards to protect public health.

IRIS assessments typically provide two types of toxicity values for chronic exposure to chemicals:

- Oral Reference Dose: the amount of a chemical that can be ingested daily over a lifetime without causing harmful noncarcinogenic health effects.
- Inhalation Reference Concentration—the concentration of a chemical that can be continuously inhaled over a lifetime without causing harmful noncarcinogenic health effects.

Additionally, the IRIS database addresses the risk of cancer by providing the following cancer descriptors:

- Carcinogenic to humans
- Likely to be carcinogenic to humans
- Suggestive evidence of carcinogenic potential
- Inadequate information to assess carcinogenic potential
- Not likely to be carcinogenic to humans

Cancer risk is characterized using (1) an oral slope factor, which is an upper-bound estimate of the increased cancer risk from a lifetime oral exposure and (2) an inhalation unit risk, which is an upper-bound estimate of the increased cancer risk from a lifetime inhalation exposure.

Table 8. IRIS assessment development process.

Assessment Steps	Description
Scoping and problem formulation	Identify needs of the EPA's program and regional offices, and frame scientific questions specific to the assessment
Draft development	Apply principles of systematic review to identify pertinent studies, evaluate study methods and quality, integrate evidence for each health outcome, select studies for deriving toxicity values, and derive toxicity values
Agency review	Review by health scientists in the EPA's program and regional offices
Interagency science consultation	Review by other federal agencies and executive office of the president
Public comment	Release for public review and comment
External peer review	Release for independent external peer review
Revised assessment	Address peer review and public comments
Final agency review and interagency science discussion	Discuss with EPA health scientists and with other federal agencies and executive office of the president
Post final assessment	Post to IRIS website

To ensure that the IRIS database contains the most accurate and reliable information, the EPA conducts an exhaustive review of information while seeking input from experts and the public. This assessment development process is summarized in Table 8.

This process is designed to provide the highest level of scientific integrity by ensuring that interested parties have the opportunity to participate in the assessment development process and review critical development milestones.

Richard Crume

See Also: Cancer Risk from Environmental Exposure; Environmental Protection Agency; Environmental Risk, Communication of; Environmental Toxicology; Toxic Substances and Disease Registry, Agency for

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INTENSIVE FARMING PRACTICES AND HEALTH

Simply put, intensive farming involves producing more in a smaller space while using fewer resources. Two examples are maintaining a large number of livestock in a confined indoor area, where they can be more closely controlled, and farming a small acreage while increasing the use of chemical pesticides and fertilizers. While there are a few benefits to farmers practicing this method of farming, the risks to human health and the environment are numerous.

Soil Depletion and Agriculture*

Only by working with nature's systems that have evolved over time can we reverse the soil depletion that is rampant throughout the United States and much of the world.

An Interview with the Land Institute

The Land Institute is an agricultural research organization in Salina, Kansas, dedicated to advancing perennial grain crops and polyculture farming as alternatives to the current destructive agricultural practices. The institute researches and develops sustainable food production methods, based on the concept that food must be grown in partnership with nature by planting perennial grains in mixtures that can help build and protect soil. According to the institute, "We are dependent on our soil. It is everyone's future."

The Land Institute was founded on the belief that food must be grown in partnership with nature, including the inherent wisdom of planting mixtures of perennial grains that can help build and protect soil. Aside from building soil and preventing soil erosion, why are more natural farming practices good for the health of Americans?

To avoid health problems and ecological damage, we need to stop using chemical fertilizers, herbicides, and pesticides that human tissues have no evolutionary experience with. The manufacture of these agribusiness chemicals pollutes the environment and contributes to climate change. Only by working with nature's systems that have evolved over time can we reverse the soil depletion that is rampant throughout the United States and much of the world while protecting human health and the environment.

Land use, including agriculture, is second only to electric power generation in greenhouse gas emissions. How can improved agricultural practices, such as reducing the amount of tillage, cutting back on chemical fertilizers, and

developing perennial plants grown in mixtures, help in the fight against climate change?

When nitrogen-based fertilizers are used on annual crops, only about half is taken up by the plants, with the remainder ending up in streams and other bodies of water, including the Gulf of Mexico, killing off native plants and fish and creating dead zones where almost nothing can survive. [The Gulf of Mexico dead zone often exceeds 6,000 square miles, or 15,500 square kilometers.] Additionally, cities are forced to treat their drinking water to remove the nitrogen, soil chemistry is altered, and greenhouse gases increase. There is also pollution associated with the manufacture of these fertilizers, including carbon emissions from fossil fuel-burning electric power plants. A better approach is to plant perennials, which reduce soil erosion and the pollution that comes with today's agribusiness chemicals, and which help fight climate change by increasing carbon sequestration.

Like oil, soil accumulates on a geologic timescale, and as such, is a nonrenewable resource. But unlike oil, it has no substitute, and it has always been central to human survival. What does the current rate of soil depletion tell you about the future of agriculture and its ability to feed the world's growing population?

Soil depletion is a big problem. Last year, 30 million acres were lost to land degradation, including erosion, worldwide. Part of the problem is that there are just too many people on the earth, and economic growth is happening too rapidly. Unfortunately, limiting population and economic growth are rarely discussed as viable options for protecting our lands. No-till farming (growing annual crops without disturbing the soil through tillage) is not the solution to soil depletion because this method is herbicide-dependent. I believe only a perennial crop approach can address soil depletion in the long term without damaging the environment and exposing humans to harmful chemical herbicides.

What is a good career path for a recent college or university graduate concerned about both environmental health and the state of American agriculture?

There are many opportunities in a variety of fields for young people who are serious and intellectually aggressive about taking on these issues. Regardless of their field of study, understanding and working with politics is often necessary, and social justice is commonly an underlying problem.

There is no arguing that intensive farming practices help to keep down the costs of producing food while maximizing the profits available to the farmer. Because farmers can maximize every square inch of farmable space, it allows them to keep up with larger farms having more acreage. These practices also produce *a lot* of products, and it makes it easier for farmers to watch over their livestock to ensure it remains healthy and protected from possible predators. Making more food with less land is appealing as well because it allows farmers to meet increasing food demand for growing communities.

Nevertheless, there are many pitfalls in intensive farming practices. One of the largest risks to human health is the overreliance on antibiotics. Having many animals in a small, enclosed area means that illness can spread quickly. As a result, farmers use antibiotic treatments regularly to prevent and treat illnesses, and a fraction of these antibiotics end up in our foods. The prevalence of antibiotics in our food supply has been shown to lead to the development of treatment-resistant bacteria.

In addition to concerns about the welfare of so many animals in a confined place, intensive farming practices can cause a reduction in biodiversity on the farm and in the surrounding areas. The pesticides used on crops do not discriminate between helpful and harmful insects, and there is a loss of both when sprays are used. This impacts species dependent on insects as a food source, with potential implications for the food chain. Furthermore, when high levels of chemical pesticides and fertilizers are used to produce high crop yields quickly in a small area, these chemicals can leave a residue on the crops. Testing has found that many of the fruits and vegetables grown with intensive practices retain significant residue even after being washed.

Intensive farming practices can also create a rainwater runoff problem because the water carries with it the chemical pesticides and fertilizers, antibiotics present in manure, and other farm chemicals that leach back into the surrounding environment. This can affect the health of streams and surrounding wildlife, particularly because some chemicals are known to bioaccumulate, building up to higher concentrations in the food chain. Also, people living nearby may find these chemicals in their well water. Opponents of intensive farming believe that exposure to farm chemicals has caused an increase in cancer and other serious health problems in some surrounding communities.

Intensive farming is a controversial topic with many opinions about the right way to do it and whether it should even be allowed. As an alternative to intensive farming practices, researchers are searching for ways to use organic methods of farming to produce more varieties of foods while keeping the costs down.

Ronda Bowen

See Also: Endangered Species and Human Health; Food Supply, Environmental Threats to; Organic Agriculture; Persistent, Bioaccumulating, and Toxic Chemicals; Pesticides and Herbicides

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INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

Although several national and international organizations concern themselves with the causes and effects of climate change, no organization does so with greater scientific authority than the Intergovernmental Panel on Climate Change (IPCC). The IPCC's mission is to make comprehensive, objective, and transparent assessments of scientific, technical, economic, and social information relevant to understanding climate change. It performs this mission chiefly through its publication of assessment reports and through synthesis reports that summarize the contents of assessment reports for policymakers. It also issues methodology reports that provide practical instructions for preparing greenhouse gas inventories (tallies of greenhouse gas emissions). The IPCC's reports have provided a baseline for discussions at the national and international levels about the nature of climate change, about the risks it poses to public health, the environment, and the global economy, and about ways to respond to these risks.

The IPCC was established in 1988 by the World Meteorological Organization and the United Nations Environment Programme. The UN General Assembly Resolution 43/53 assigned the IPCC its first task: to prepare a comprehensive review of knowledge of climate change and its impacts as well as recommendations of possible response strategies and other elements to include in an international climate agreement. In keeping with that instruction, IPCC's First Assessment Report, published in 1989, laid the groundwork for the UN Framework Convention on Climate Change, which was ratified in 1992 and entered into force in 1994. Since 1998, the IPCC has operated under a set of governing principles, which spell out its role, organization, and procedures. The IPCC's membership now includes 195 countries, and it has issued five assessment reports, the most recent released in four parts between September 2013 and November 2014.

The IPCC publishes assessment reports on three areas: the scientific basis of climate change; climate change impacts, adaptation, and vulnerability; and the mitigation of climate change. These areas correspond to IPCC Working Groups I, II, and III, and each report is divided into chapters. For example, the Fifth Assessment

Report on the scientific basis of climate change contains 14 chapters, such as Observations: Atmosphere and Surface, and Evaluation of Climate Models. The IPCC also publishes methodology reports that instruct national governments and others on best practices for tallying greenhouse gas emissions. This effort is conducted not by a working group but by the Task Force on National Greenhouse Gas Inventories.

The working groups and task force are each supported by a bureau, whose cochairs are elected by a vote among member states. The IPCC's governing principles call for the cochairs' countries of origin to reflect a balance among regions and member state economic status (i.e., developed, developing, and least developed). The governing principles also prescribe the process for selecting the scientists and experts who coordinate, draft, and review all of the materials that inform IPCC reports. That process begins when the cochairs of each bureau solicit nominations from IPCC member governments and observer organizations. That solicitation generates suggestions for coordinating lead authors, lead authors, review editors, and contributing authors. Coordinating lead authors and lead authors are responsible for coordinating all contributions and reviews, and they also have input into the process of selecting contributing authors. Review editors provide critical feedback on drafts. Contributing authors supply research and draft material based on their particular expertise. All told, hundreds of scientists and other experts participate in the process that yields final assessment and methodology reports.

Justin M. Gundlach

See Also: Climate Change and Human Health; Greenhouse Effect and Global Warming; International Environmental Law and Policy; Sea Ice, Global Warming Implications for; United Nations Framework Convention on Climate Change

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INTERNATIONAL ENVIRONMENTAL LAW AND POLICY

As with the origination of many environmental laws in the United States, human health concerns have provided the impetus for much of international environmental law. However, unlike the binding effect of environmental laws in the United States, international environmental law is comprised of various conventions, treaties, and agreements that typically depend on commitments that are often unenforceable and on the specific laws of the ratifying nation. As time progresses and environmental concerns take more of an international character, more nations have demonstrated a willingness and devotion to solving international environmental problems.

The history of international environmental law is a rather brief one, relatively speaking, but one that is expanding exponentially and gaining momentum. Historians have identified three significant periods of international law: the traditional era (pre-1972), the modern era (1972–1992), and the postmodern era (1992–present).

The traditional era takes place prior to the 1972 United Nations Stockholm Conference on the Human Environment. Most of the international environmental law during this period was focused between two nations dealing with a specific transboundary disputes, particularly over pollution and natural resources. For example, the International Conventions for the Regulation of Whaling in 1931, 1937, and 1946 were directed toward regulating and managing the commercial use rather than the conservation of whales. It was not until the middle of the 20th century, with the establishment of organizations like the International Union for Conservation of Nature, that international environmental conservation and protection efforts began to develop on a global scale.

The 1972 UN Stockholm Conference on the Human Environment (UNCHE) marks the transition from the traditional era to the modern era. In the 1970s, awareness of global environmental degradation rose among both developed and developing nations due to disasters such as the *Torrey Canyon* oil spill in 1967 and the Minamata incident in the 1950s. As a consequence, the international community gathered together in Stockholm, Sweden, in 1972 to address global environmental problems from a political and economic point of view, with the main objectives to balance the responsibilities of people with their rights and to exhort the global community to protect and improve the environment for present and future generations. One important consequence of the UNCHE was the creation of the UN Environment Programme (UNEP). While the focus of the UNCHE and UNEP was not on human health, these developments marked a shift in international cooperation in protecting the environment and laid the foundation for more comprehensive international environmental instruments.

From 1972 until the 1990s, the number of multilateral environmental agreements (treaties concerning the environment agreed upon by multiple nations) more than doubled, and many of these treaties directly responded to health concerns posed by pollution. For example, after the Chernobyl Nuclear Power Plant disaster in Ukraine in April 1986, the International Atomic Energy Agency oversaw the adoption and ratification of the Convention on Early Notification of a Nuclear Accident in October that year. The treaty establishes an early notification system that alerts other nations of the incident to help safeguard populations and communities at risk. Furthermore, the International Convention for the Prevention of Pollution from Ships (also known as MARPOL) was adopted in 1973 (and amended each decade since) in the wake of a number of oil spill disasters. MARPOL sets forth regulations concerning the disposal of oil from ships as well as reporting and emergency procedures in the event an oil spill does occur.

In addition to oil spills and nuclear radiation, there was also a growing concern for hazardous wastes and chemicals. In 1989, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal was adopted in response to the large volumes of hazardous toxic waste being disposed of in developing nations by developed countries. One of the principal objectives of the Basel Convention is to protect human health and the environment from hazardous waste. To achieve this objective, the Basel Convention promotes the reduction of hazardous wastes and establishes a regulatory system based on prior informed consent, meaning that the importing nation must give its consent to receive the hazardous waste from the exporting nation. The Basel Convention laid the groundwork for a number of future conventions dealing with hazardous wastes.

Other important agreements created during this period were the Vienna Convention for the Protection of the Ozone Layer and the subsequent Montreal Protocol on Substances that Deplete the Ozone Layer. To address the depletion of the ozone layer and control the chlorofluorocarbons that cause that depletion, 24 nations signed the protocol in 1987. Over the next few decades, the protocol resulted in over 99 percent of all chemicals regulated by the protocol being phased out of production and consumption by developed nations. Furthermore, developing nations have achieved a reduction of approximately 75 percent. By 2009, the Vienna Convention and the Montreal Protocol had received universal ratification by the entire international community. These agreements are often cited as international environmental law success stories because of the extent of participation and the results achieved.

Following the modern era, the postmodern era began with the 1992 UN Conference on Environment and Development (UNCED). While nations became more aware of international environmental law during the modern era, the sheer number of treaties and agreements that were created in only a couple of decades seemed to have a paralyzing effect, despite being made with good intentions. There was concern that the international instruments designed to handle these complex environmental issues were not effective because of the lack of coordination among the various agreements and governing bodies. In addition, environmental degradation continued, and unprecedented environmental challenges, such as climate change, began to emerge. All of these issues required an important discussion with the international community in developing strategies to address them.

Thus, in 1992, the international community convened in Rio de Janeiro, Brazil, for another UNCED, which came to be known as the Earth Summit. The Earth Summit brought the importance of sustainable development to the global forum in an unprecedented way, emphasizing the interlinkages among the environment, national and international economies, urbanization, poverty eradication, social justice, and human health. Five important developments came from the Earth Summit: (1) Agenda 21; (2) Rio Declaration on Environment and Development; (3) Statement of Forest Principles; (4) UN Convention on Biological Diversity (CBD); and (5) UN Framework Convention on Climate Change (UNFCCC). Agenda 21 and the Rio Declaration established that human health is an integral part of achieving the goals of the Earth Summit. Specifically, Chapter 6 of Agenda 21 set forth objectives, goals, and activities that achieve health for all by 2000. Such activities include strengthening primary healthcare systems, creating financing mechanisms to ensure the development of health systems, and providing access to health care in rural areas. While Agenda 21, the Rio Declaration, and the Statement of Forest Principles were not binding agreements, they set the tone and provided a roadmap for moving forward.

Two conventions, the CBD and the UNFCCC, were also adopted at the Earth Summit. The CBD focuses on the conservation of species, recognizing that biological diversity is necessary to ensure healthy communities and stable food sources. The UNFCCC provided a landmark foundation for dealing with the global issue of climate change. Realizing that coming to an international agreement and binding targets for curbing greenhouse gases was not possible, the nations developed a "framework" convention whereby they would continue negotiations at future meetings with the goal of coming to an ultimate agreement. Since 1992, there have been a number of protocols and agreements, such as Kyoto Protocol in 1997 and the Cancun Agreements in 2010, that have brought the international community closer to establishing an agreement to reduce greenhouse gas emissions to mitigate climate change.

Finally, on December 12, 2015, at the 21st Conference of the Parties in Paris, France, an agreement was reached by the international community to reduce greenhouse gas emissions to prevent more than a 2°C increase in global temperature. At least 185 countries have submitted "intended nationally determined contributions" (INDCs) that set forth their commitments to reducing greenhouse gases and their plans for accomplishing these commitments. These INDCs will be reviewed every five years to assess their effectiveness and progress. This milestone marks an important moment in protecting human health from the effects of climate change, including intense weather events, desertification, droughts, floods, and food scarcity. The conference language affirms everyone's "right to health" and the importance of safeguarding that right in the context of combating climate change. (The agreement requires ratification by 55 countries to enter into force.)

In addition to the UNFCCC, two other important conventions are (1) the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and (2) the Stockholm Convention on Persistent Organic Pollutants. As an addition to the Basel Convention, the Rotterdam Convention, adopted in 1998 and entered into force in 2004, regulates the transportation and trade of hazardous chemicals, such as pesticides, and industrial chemicals to protect human health and the environment. The Stockholm Convention, adopted in 2001 and entered into force in 2004, protects human health from persistent organic pollutants (POPs), which are chemicals that can cause serious birth defects, cancers, immunological disorders, and increased susceptibility to diseases. Similar to the Basel and Rotterdam Conventions, the Stockholm Convention seeks to reduce and eliminate exposure to humans and the environment by establishing a regulatory mechanism by which nations (1) share information; (2) reduce the production, importation, and exportation of POPs; and (3) promote best practices to ensure the proper handling of POPs.

In less than a century, the international community went from having a few bilateral environmental agreements between nations to a complex, comprehensive web of interlinking and overlapping multilateral environmental agreements that protect the environment and safeguard people from harmful effects of environmental pollution.

Anthony G. Papetti

See Also: Chernobyl Incident; Chemical Weapons Elimination; Chlorofluorocarbons; Minamata Disease; Persistent, Bioaccumulating, and Toxic Chemicals; Stratospheric Ozone Depletion; *Torrey Canyon* Incident; United Nations Environmental Programme; United Nations Framework Convention on Climate Change; World Health Organization

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INVASIVE SPECIES AND HUMAN HEALTH

Invasive species are plants, animals, and microorganisms that are introduced into new regions where they cause significant harm to native species, ecosystems, and sometimes human health. Invasive species have traits that help them (1) establish, reproduce, and spread rapidly; (2) outcompete native species for resources; and (3) otherwise thrive in the absence of conditions that impose natural limits in their native range. Invasive species are one of the top threats to the health and survival of native plants and animals around the world, and they also can directly threaten human health by spreading diseases.

Invasive Pathogens and Human Diseases

Some experts consider infectious, nonnative pathogens, such as the avian influenza, West Nile virus, and severe acute respiratory syndrome, to be among the most harmful invasive agents to human health and the economy in the United States. As climate change worsens and habitat loss continues, the spread of invasive agents may become a serious concern worldwide.

Invasive species are a subset of all nonnative species. (Nonnative species are also known as introduced, exotic, nonindigenous, or alien species.) Nonnative species are commonly spread by humans during the transportation of food, wood products, ornamental plants, and exotic pets and through the ballast water of ships. There are more than 50,000 nonnative species in the United States, and between 4,000 and 6,500 of these are considered invasive. According to the U.S. Geological Survey, the yearly environmental, economic, and human health–related costs of nonnative and invasive species are greater than those of all other natural disasters combined.

Because of their competitive advantages, invasive species often cause a loss of biodiversity and sometimes result in local extinctions of native species. In the United States, between 30 and 42 percent of all threatened and endangered species are at risk of extinction because of competition with or predation by nonnative species. The impacts of invasive species often multiply as the ecosystems they invade become less structurally and biologically diverse. Less diverse ecosystems are often more at risk from human and natural disturbances and are less able to provide ecosystem services, many of which are important to humans.

Ecosystem services impacted by invasive species may include (1) providing clean air and water and products such as food and timber; (2) regulating natural hazards like fires and floods; (3) controlling pests and diseases; and (4) offering opportunities for recreation, tourism, and other cultural values. Some scientists believe that nonnative species in the United States cause billions of dollars of environmental damage and economic loss each year, including the costs of controlling these species. The greatest economic damages come from the weeds, pests, and pathogens that impact agricultural crops.

Some invasive species also directly impact human health. Nonnative rodents, birds, and insects can carry disease. For example, the invasive Asian tiger mosquito (*Aedes albopictus*) is known to transmit West Nile virus. Invasive animals, such as the African honeybee (*Apis mellifera scutellata*) and red imported fire ant (*Solenopsis invicta*), inflict painful injuries, sometimes resulting in hospitalization and, rarely, death. Invasive species can also be poisonous to humans. For example, according to the U.S. Fish and Wildlife Service, approximately half of all poisonous plants in the eastern United States (excluding those found in agricultural areas) are nonnative or invasive.

Overall, global environmental threats, such as habitat loss and climate change, are exacerbating the spread of invasive species as these species are able to survive in previously unsuitable habitats. For example, deforestation opens disturbed areas that allow the establishment of some invasive plants, and increasing temperatures enable the spread of tropical species farther northward. Many expect that the threats that invasive species pose to the environment, the economy, and human health will increase as the pathways for their spread (e.g., global trade, human travel, and environmental change) become more prevalent.

Melisa L. Holman

See Also: Biodiversity and Health; Biosphere, Environmental Threats to; Climate Change and Human Health; Deforestation; Ecosystems, Importance of; Endangered Species and Human Health; Insect-Borne Diseases

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ITAI-ITAI DISEASE

Itai-Itai disease refers to a painful kidney and bone disease caused by chronic exposure to excessive levels of cadmium in the environment. The symptoms of Itai-Itai disease were first observed among residents living in areas along Jinzu River and its tributaries in Toyama, Japan, in 1911. A local doctor named the condition Itai-Itai Byo ("it hurts, it hurts" disease in Japanese) from the agonizing refrains uttered by his patients afflicted with this disease.

In Toyama, the history of mining for gold and other metals dates back to the 1590s, but serious cadmium pollution did not occur until the Mitsui Mining and Smelting Company expanded zinc production at its Kamioka mines in the early 1900s. Cadmium is a heavy metal and occurs naturally in small quantities, often in zinc ore. At the Kamioka mines, cadmium had been removed from zinc ore and discarded as waste. This practice continued until mid-1940s, when the company found a lucrative market for cadmium as a versatile industrial metal and stopped discarding it as waste.

It had taken almost 50 years since the beginning of the zinc production operation before a causative relationship was established between environmental exposure to cadmium and Itai-Itai disease. The first breakthrough came in 1957 when Noboru Ogino (1915–1990), a local physician, presented a hypothesis at a regional medical conference, linking the disease with heavy metal pollution in Jinzu River. By 1961, two scientists, Kinichi Yoshioka (1902–1986) and Jun Kobayashi (1909–2001), proposed cadmium as the causative agent. However, it took seven more years before the Japanese government finally recognized in 1968 that Itai-Itai disease was caused by environmental exposure to cadmium.

Dietary intake through consumption of contaminated food, such as rice and fish, was the major route of cadmium exposure among Itai-Itai disease victims, many of whom were postmenopausal women with a long history of cadmium exposure. The ingested cadmium initially accumulates in kidney and induces renal damage, and later the condition leads to changes in calcium metabolism, resulting in bone diseases such as osteoporosis and osteomalacia. The characteristic symptoms include severe joint pain and spontaneous bone fractures. In advanced stages of the disease, the victims suffer from excruciating pain and become incapacitated. There is no cure for Itai-Itai disease.

To date, 196 people have been officially recognized as victims of Itai-Itai disease, and most of them are now deceased. Additionally, 336 people are considered at risk of developing Itai-Itai disease due to their past history of excessive exposure to cadmium, and they are being monitored for symptoms. Besides the Jinzu River region, high levels of cadmium contamination have been detected in several other areas in Japan, and a special monitoring program is in place in these areas to prevent another outbreak of Itai-Itai disease. Cases of environmental diseases caused by cadmium exposure are also suspected in Korea and China.

Yoko S. Crume

See Also: Exposure Pathways; Fish Consumption Advisories; Foodborne Diseases; Heavy Metal Pollution; Water Pollution

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K

KUWAITI OIL FIRES

The Kuwaiti oil fires occurred at the end of the Gulf War in the early 1990s. In August 1990, Iraq invaded neighboring Kuwait, which caused the United States to begin Operation Desert Storm, a coalition of 39 countries with the goal of liberating Kuwait. Iraqi troops were pushed out of Kuwait in early 1991, and the country was liberated on February 28 that year. But before the Iraqi forces left, around 11 million barrels of crude oil were spilled into the Arabian Gulf, and at least 650 wells were set on fire. (One barrel of oil is equal to 42 gallons and about 159 liters.) Reports say Kuwait lost around 600 million barrels of crude oil and $12 billion as a result, equal to about three months of global oil usage. A survey of U.S. soldiers indicated that the fires caused eye irritation, breathing complications, rashes, and fatigue.

The fires in the oil fields produced gases containing hydrocarbons and metals as well as soot and smoke composed of benzene and polycyclic aromatic hydrocarbons that drifted over nearby lands. The oil field area, known as the Greater Burgan oilfield, is the largest in the state and located just 10 miles (16 kilometers) south of Kuwait City, which also experienced occasional soot and smoke during the fires.

The Kuwaiti Oil Company operates these oil fields. Initial estimates from company officials indicated it could take around two years to put out the fires, but the last fire was actually capped in just eight months. Roughly 85 percent of Kuwaiti Oil Company's wells were blown up by Iraqi forces, which not only caused the oil to ignite but also to leak into surrounding areas. Pools of oil gathered around each well, and after the fires were put out, more than 300 of these "oil lakes" remained, holding an estimated 19 square miles (50 square kilometers) of oil. The pools of oil made subsequent inspection and repair of the wells difficult.

The wells released roughly 6 million barrels of oil per day before they were capped, resulting in approximately 1.0 to 1.5 billion barrels released into the environment. Most of the oil released was burned, but more than 10 million barrels contaminated the Persian Gulf, and 25 to 40 million barrels were spread across surrounding lands.

The oil well repairs took approximately 10,000 workers from more than 30 countries. Seven men were killed during the cleanup, and five were seriously burned. To stop the fires, workers had to drill holes into the sides of damaged wells and then pump in fire retardants, such as mud, liquid nitrogen, and steam. This operation took as long as 45 days per well, and the working conditions were almost unbearable due to the soot and smoke. Stopping the fires and the oil spillage

Oil wells burning out of control in Kuwait in 1991. The fires were set by retreating Iraqi forces during Operation Desert Storm, when the United States and its allies liberated Kuwait from the invading Iraqis. (U.S. Department of Defense)

cost around $2 to $10 million per well. By the time the last fire was extinguished, 5 percent of Kuwait's landscape was covered in a mixture of soot and oil. Before the fires, the country produced 1.5 million barrels of oil each day, but in November 1991, after the last fire had been extinguished, Kuwait was producing just 320,000 barrels per day.

Significant environmental damage was reported to Kuwait's coral reefs. Additionally, increased cases of heart disease, cancer, allergies, and breathing complications were reported, although a direct link to the oil fires has not been established. At least 21 million barrels of oil were removed from the surrounding lands.

Mallory L. Daily

See Also: Air Pollution; Coral Reefs and Food Supply; Deepwater Horizon Incident; Hazardous Air Pollutants; Polycyclic Aromatic Hydrocarbons; Respiratory Disease and Air Pollution

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Environmental Health in the 21st Century

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Environmental Health in the 21st Century

From Air Pollution to Zoonotic Diseases

Volume 2: L–Z

RICHARD CRUME, EDITOR

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Contents

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Alphabetical List of Entries

Topical List of Entries

Environmental Pollution

Health Sciences

Energy and Climate

Waste Management

Built Environment

L

LABORATORY QUALITY ASSURANCE

Analyses of environmental pollutants are usually conducted in laboratories, where trained scientists and technicians apply standard operating procedures to achieve consistent and reproducible results. To ensure that the correct processes and procedures are followed, including appropriate instrumentation and calibration protocols, a quality assurance (QA) evaluation is often performed by someone independent of the laboratory. QA is important to establish that environmental contaminants are correctly identified so that appropriate measures can be taken to protect public health.

To be confident that a laboratory provides accurate results, a QA plan is created that (1) describes their polices, objectives, principles, organizational authority, responsibilities, accountability, and implementation plans and (2) provides the framework for planning, implementing, and assessing their work. QA plans are often required by organizations like the federal government before the organization will do business with the laboratory. Independent auditors ordinarily carry out QA evaluations to ensure that the QA results are unbiased.

Often a QA plan is developed that is specific to a particular project, for example, analyzing a large quantity of samples from a contaminated stream or industrial smokestack. This plan is commonly referred to as a quality assurance project plan (QAPP). QAPPs integrate all technical and quality aspects of the project, including planning, implementation, and assessment. The purpose of the QAPP is to document the analytical approach and to provide a project-specific "blueprint" for obtaining the type and quality of environmental data needed for a specific purpose.

Once the QAPP is finalized and approved, each person associated with requirements of the QAPP must be provided a copy, and system must be in place to track revisions and document distributions. Additionally, training is required for anyone

What Are Standard Operating Procedures?

An important laboratory QA requirement is that all routine processes and procedures used in the laboratory must be documented as standard operating procedures (SOPs). These SOPs must be detailed enough to ensure that a scientist or technician knows exactly how to follow the processes and procedures to achieve accurate and reproducible results. Well-written SOPs are essential for an effective QA program.

implementing any part of the QAPP, and this training must be documented. Any controls or standards used to perform and validate the analyses, including equipment calibrations, must be checked and verified to ensure they meet any certification requirements.

Before beginning any measurement and data collection activity, it is imperative to understand the monitoring objectives and to document them in the QAPP. All collected data inherently have some degree of uncertainty, and it is important to establish the acceptable level of uncertainty before beginning the measurement and data collection activity. A systematic approach to establishing the acceptable degree of uncertainty involves developing data quality objectives (DQOs). These can be viewed as quantitative and qualitative objectives for measuring data in terms of precision, accuracy, representativeness, comparability, and completeness, and they are frequently cited as the level of uncertainty acceptable to a decision maker. Ideally, the DQO process leads to efficient and effective expenditure of resources; consensus on the type, quality, and quantity of data needed to meet the project goals; and the full documentation of actions taken during the development of the project.

Joe Elkins and Richard Crume

See Also: Ames Test; Environmental Auditing

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LAND DISPOSAL OF WASTE MATERIALS

What are waste materials? Garbage is so pervasive in our society that we know what it is intuitively, but often the exact definition eludes us. The U.S. Environmental Protection Agency (EPA) considers solid waste as "any garbage or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, resulting from industrial, commercial, mining, and agricultural operations, and from community activities." Just about everything we do leaves behind some type of waste material. Note that the definition of solid waste includes wastes that are liquid, semisolid, or contained gases. In the United States, wastes amount to about 260 million tons (236 million metric tons) per year, or around 4.4 pounds (2.0 kilograms) per person per day.

The four most common components of municipal solid waste in the United States are paper, food, yard trimmings, and plastics (see Table 9). Additionally, there

Table 9. Municipal solid waste components in the United States.

Municipal Solid Waste Material	Percentage of Total Solid Waste (By Weight, before Recycling)
Paper	26.6
Food	14.9
Yard trimmings	13.3
Plastics	12.9
Rubber, leather, textiles	9.5
Metals	9.0
Wood	6.2
Glass	4.4
Other	3.2

are other types of wastes that are sometimes more difficult to account for, including sewage, radioactive and other hazardous waste materials, petroleum refining by-products, and electronic wastes.

Efforts over the past few decades by the EPA and other government agencies to deal with waste and its associated problems, including public health issues and environmental degradation, have yielded mixed results. Recycling rates have risen, but so has the total amount of solid waste generated, such that the quantity of waste being disposed of today is still slightly more than it was in 1980. Recycling rates in the United States lag behind many other developed nations. For example, some northern European countries (e.g., Sweden and the Netherlands) recycle over half of their wastes and incinerate the remainder. Relying on recycling and incineration, Germany landfills are less than 1 percent of overall waste, and Japan has a very extensive recycling program where very little goes to waste.

There are three main paths for waste materials once they are ready for disposal: they can be recycled, incinerated, or placed in a landfill. In the past, some wastes were simply left out to rot in open dumps, often at sites near waterways. This practice created a number of environmental hazards, including water contamination, toxic gas releases, fire hazards, and infestations. At the turn of the 20th century, the United States imported incinerator technology from England, and around the time of World War II, the concept of landfilling became attractive for large American cities.

Today, waste materials that are landfilled must be disposed of in a capped and carefully controlled landfill environment. Between 1984 and 1988, new regulations and enforcement of the Resource Conservation and Recovery Act required safety standards at disposal sites, including rejecting certain hazardous materials, which required processing in special facilities. Beginning in 1991, federal regulations began requiring landfills to have waterproof plastic liners to keep liquefied garbage (leachate) from leaking into the surrounding soil. Landfills must now also

Large piles of garbage at a landfill. Many municipal landfills are reaching full capacity, causing cities to find alternatives to the land disposal of wastes, including waste reuse, reduction, and recycling programs. (PhotoDisc, Inc.)

monitor leachate and methane gas collection. At many modern landfills, the controlled release of gases through pipes is allowed, or the gases are captured and burned to produce energy.

Landfill space is becoming a major issue in the United States as older sites become filled and citizens reject new sites in close proximity to their communities. In 1970, there were over 16,000 authorized waste disposal landfill sites in the United States, but that number had fallen to 1,200 by 2011 (although many of the remaining sites are far larger than their predecessors). As new landfills are created farther away from the cities where the wastes originate, this creates secondary impacts on the environment, such as air pollution emissions from garbage trucks. Although many landfills have closed over the past few decades, there is still plenty of space available for new landfills outside of urban areas. As of 2015, 22 states reported having landfill space available into the next decade, and it has been estimated that current landfills can meet U.S. trash disposal needs for years to come.

Modern landfills are often considered preferable to waste incinerators from a public health perspective because incineration creates toxic air pollution emissions, including dioxin compounds, that are hazardous to health and may be carcinogenic. Incinerators also cause gaseous and particulate matter pollution, although emission controls today are effective in reducing (but not eliminating) these pollutants.

Incinerator technology, which is now used mainly for waste-to-energy purposes (i.e., incinerators that produce useful heat or electricity), can be less expensive than a comprehensive recycling program when energy recovery is taken into account.

Aaron Dorman

See Also: Bioremediation for Waste Treatment; Dioxin Pollution; Electronic Waste Disposal; Environmental Protection Agency; Landfill Gas Pollution; Municipal Solid Waste Management; Ocean Dumping and the Pacific Garbage Patch; Particulate Matter and Bioaerosols Pollution; Recycling; Resource Conservation and Recovery Act; Three Rs of Waste Management; Waste Incineration

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LANDFILL GAS POLLUTION

In the United States and many other nations, much of the municipal garbage is deposited in landfills (also called sanitary landfills), which are specially designed facilities for burying wastes (e.g., kitchen garbage, yard wastes, used packing materials, and sometimes commercial wastes and other nonhazardous waste materials). Landfills may also be designed to receive construction and demolition debris and hazardous wastes. Over time, microorganisms begin to break down and decompose landfill wastes, resulting in the release of gases, including methane, a highly flammable and potent greenhouse gas. These gases can be harmful to human health and contribute to climate change.

Fighting Climate Change by Recycling

How much trash does the average American create every day? Would you believe over 4 pounds (1.8 kilograms)? For all Americans, that adds up to over 250 million tons (227 million metric tons) of trash each year! About 35 percent of these waste materials are recycled or composted, which has prevented the release of over 200 million tons (181 million metric tons) of carbon dioxide (CO_2) per year from landfills and incinerators, the equivalent of taking nearly 40 million cars of the road. Reducing CO_2 emissions is important because the increasing concentrations of CO_2 in the atmosphere, mainly due to human activities beginning with the industrial revolution, are the primary cause of climate change.

Kitchen garbage and other wastes contain many organic compounds that microorganisms feed on, forming methane and other gases. These gases migrate upward through the landfill, eventually being released to the surrounding air. Typically, about half of landfill gases consists of methane, and most of the remainder is carbon dioxide. While both methane and carbon dioxide contribute to global warming, methane is a much more potent greenhouse gas. (In the United States, nearly 20 percent of methane associated with human activities comes from landfills.) The remaining landfill gases are composed of hundreds of different compounds, including complex organic molecules and hydrogen sulfide. The makeup of landfill gases varies greatly from site to site, depending on factors such as the type of waste and the climate.

Landfill gases often contain certain organic compounds that are considered hazardous air pollutants (also called air toxics) and are known or suspected to cause cancer and other adverse health effects in humans. Toluene, benzene, xylenes, vinyl chloride, and ethyl benzene are examples of these types of air pollutants. Although typically present at very low concentrations relative to methane and carbon dioxide, these toxic pollutants can still represent a significant health risk to the surrounding population.

Another problem with landfill gases is odor. Well-designed and well-operated facilities typically do not have odor problems. But under certain weather conditions (e.g., during an atmospheric inversion when pollutants tend to be trapped near the ground), nearby residents may be able to smell the landfill. One common component of landfill gases, hydrogen sulfide, smells like rotten eggs and can easily be detected by the human nose, even at concentrations as low as 0.5 to 1 part per billion. The ammonia present in landfill gases also has a distinctively pungent odor. When exposed to landfill gas odors, some people may experience headaches or nausea, although medical attention is seldom required. Families living close to landfills may find the odors disruptive to their daily lives.

Landfill gases can be collected using a system of wells, trenches, piping, and fans (or other gas-moving equipment). After being collected, the gases may enter a combustion device (e.g., a boiler, engine, turbine, or flare), which destroys the methane and many of the organic and odorous compounds. Because methane can be used as a fuel, combusting it in a boiler, engine, or turbine to generate power (e.g., electricity or heat) is an attractive benefit of collecting landfill gases. (Roughly a quarter of U.S. landfills collect gases for power production, mostly electricity.) Landfill gas emissions can also be reduced by producing less waste to begin with, by recycling waste materials instead of sending them to the landfill, and by finding other uses for wastes, such as composting.

Due to concern about landfill gases, the U.S. Environmental Protection Agency has issued rules requiring owners of large landfills to capture and control gases emitted from their facilities. Owners have the option of burning the gas in a combustion device (e.g., a boiler, engine, or turbine) to generate energy, collecting and treating the gas for sale or other beneficial use, or destroying it in a flare. These rules are part of the nation's climate strategy to reduce methane emissions. Additionally, the rules reduce emissions of other organic compounds, including some hazardous air pollutants, and pollutants causing odors.

Richard Crume

See Also: Bioremediation for Waste Treatment; Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Environmental Protection Agency; Hazardous Air Pollutants; Hazardous Waste Disposal; Land Disposal of Waste Materials; Municipal Solid Waste Management; Odor Pollution; Open Burning of Waste; Recycling; Three Rs of Waste Management; Waste Incineration

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LAPPÉ, FRANCES MOORE

Frances Moore Lappé (1944–), author of the 1971 best seller *Diet for a Small Planet*, which has sold 3 million copies worldwide, grew up in a Fort Worth, Texas, household where meat and white bread were the centerpieces of what was then considered to be a healthy family meal. But her life led her on a path to redefining what healthy eating should be and exploring how individuals can make a difference in their own lives and the lives of others by changing their eating habits. The impact Lappé has had on world hunger and health is extensive and multifaceted. She has written 18 books, is a world-renowned spokesperson on the topic of solving world hunger, and has founded and contributed to a wide variety of organizations focusing on food, hunger, and the environment.

Solving Our Biggest Global Challenges

Thinking like an ecosystem, we see that, since we are all connected, we are all implicated in every social outcome.

An Interview with Frances Moore Lappé

Best-selling author, public speaker, and activist

Frances Moore Lappé is the author or coauthor of 18 books, including the groundbreaking best seller Diet for a Small Planet, *which began a revolution over 30 years ago in how America and the world think about food and hunger. (J. M. Hirsch of the Associated Press calls* Diet for a Small Planet *"the blueprint for eating with a small carbon footprint since long before the term was coined.") She has received 18 honorary doctorates and a large number of awards, including the James Beard Foundation Humanitarian of the Year Award for her lifelong impact on the way people all over the world think about food, nutrition, and agriculture. She is also a member of the World Future Council and the International Commission on the Future of Food and Agriculture. With her daughter, Anna Lappé, Frances Moore Lappé cofounded the Small Planet Institute. Her most recent work is* World Hunger: 10 Myths *(coauthored with Joseph Collins).*

Recently you have written that to address our biggest global challenges, whether hunger, environmental pollution, or climate change, we need to rid ourselves of what you term the scarcity-mind. Can you elaborate on this concept and why it is important to you?

Much of humanity is now trapped in a truly dangerous mental map, a worldview that fails to protect life because it is perversely aligned with nature, including with human nature. I say perversely because its assumptions elicit the worst in us while stifling the best, and they defy the laws of wider nature as well, thus bringing both human and environmental destruction. From this profound malalignment, humans end up creating together a world that few, if any, of us would individually choose. I believe the core assumptions of this deadly mental map are *separateness* (we each exist apart from one another and from nature), *stasis* (reality is best understood as fixed and finished), and *scarcity* (there is not enough of anything). These assumptions make up what I call *scarcity-mind*. Through it, we see ourselves in perpetual competition with other selfish creatures over scarce goods. The conditions flowing from scarcity-mind—concentrated power, lack of transparency, and a culture of blame—are precisely those proven repeatedly to bring forth the worst in our species. The Holocaust, after all, was not the work of only a few mad men. And extreme chronic undernourishment harms 795 million people today, even as food production per person has increased over 65 percent since the 1960s, now supplying nearly 2,900 calories for each of us daily.

Let me now introduce another concept: *eco-mind*. This evidence-based way of seeing is emerging worldwide and draws on ancient wisdom and disciplines from anthropology to neuroscience, and I believe it can free us from the self-reinforcing destructiveness of scarcity-mind. For some time, science has confirmed what great seers have told us for eons, that the true nature of reality is *connection* (all exists in relationship with all else), *continuous change* (change is the one constant we can count on), and *co-creation* (if connection and change are both givens, then all is both shaped by and shaping all that emerges in ongoing co-creation). This evidence-based view of reality, the eco-mind, suggests thinking like an ecosystem. Its most obvious and helpful lesson is that we humans are like every other organism in the ecosystem: what we express is largely shaped by our context and the stimuli around us. With this realization, we can form a hypothesis about human nature—identifying what useful human traits are there to be tapped by our social environment for meeting the goal of planetary transition to life-serving cultures, and what tendencies need to be minimized by social rules and conditions, if we are to thrive.

And finally, there is the concept of *living democracy*. Through this lens, we can envision a more functional social ecology—rules and norms we create that are positively aligned both with our nature and the laws of wider nature. I mean that we can perceive mechanisms for making choices together—governance, formal and informal—that align positively with our nature, and we can understand why they are essential to wider, ecological health. In other words, we are thinking like an ecosystem and applying it to our social reality. The term living democracy suggests democracy as both a lived experience and an evolving, organic reality itself, "easily lost but never finally won," in the words of the first African-American federal appellate judge, William Hastie.

Thinking like an ecosystem, we see that because we are all connected, we are all implicated in every social outcome. We can, therefore, forego preaching and pleading, as we realize that much of the terrible dysfunction evident today—from random violence to environmental destruction to persistent, massive hunger—is the result of social systems created by us and perversely aligned with our nature.

Lappé's consciousness about world hunger was raised during the 1960s at the University of California, Berkeley, where she first started to realize that a plant-centered diet was best for everyone. She also began researching why there was such a huge hunger problem in a world with an abundance of food available. She has demonstrated that the world's food availability is economically driven by the extreme inequalities around the globe, pointing out in her many publications and presentations that millions of people are too poor to buy food at marketplace prices. As a result, grain that could feed hungry people instead feeds meat sources (e.g., beef cattle), which are unnecessary for a healthy diet. She emphasizes that if only diets around the world would focus on plant-based foods, our worldwide hunger problems would disappear.

In 1975, she and Joseph Collins founded the Institute for Food and Development Policy (also known as Food First), which focuses on educating Americans about the political and economic causes of and solutions to the global hunger problem. The institute's first book, *Food First: Beyond the Myth of Scarcity*, coauthored by Lappé and Collins, explains that scarcity and overpopulation are not the causes of world hunger and describes how grassroots organizations can help the poor improve their health through democratic processes.

Frances Moore Lappé, author and world hunger activist. Lappé's 1971 best seller *Diet for a Small Planet* demonstrated how people can make a difference in their own lives and the lives of others by changing their eating habits. (AP Photo/Diane Bondareff)

Lappé calls her solution to the world's hunger crisis "living democracy," meaning that by making wise food choices on a day-to-day basis, individuals are not only contributing to their own well-being but to the good health of the entire world as well. In 1990, Lappé and her husband, Paul Martin Du Bois, founded the Center for Living Democracy. Their 1994 book, *The Quickening of America: Rebuilding Our Nation, Remaking Our Lives*, shows how ordinary people can solve the world's hunger problems by participating in this living democracy. In 2002, Lappé and her daughter, Anna Lappé, created the Small Planet Institute, a collaborative network that promotes the living democracy tenets through education and research. She and her daughter also founded the Small Planet Fund to connect resources to global efforts supporting the living democracy concept.

Lappé has received countless awards and 17 honorary degrees from universities all over the world. In 1987, she was only the fourth American to ever receive the Right Livelihood Award in Sweden, and in 2003, she was honored by the National Nutritional Foods Association with the prestigious Rachel Carson Award. In 2008, Lappé received the James Beard Foundation's Humanitarian of the Year Award.

Susan J. Montgomery

See Also: Environmentalism; Food Supply, Environmental Threats to; Organic Agriculture; Pesticides and Herbicides

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LEAD POISONING PREVENTION

Lead, one of the earth's natural elements, is a bluish-white, lustrous metal that is extracted from various underground ore deposits. Lead is extremely dense, corrosion resistant, and malleable, and it has a low melting point, making it an important component in batteries, X-ray shields, ammunition, electronics, and industrial paints. Historical records indicate humans began mining lead over 6,000 years ago due to its unique properties, and the toxic effects of lead exposure have been known for 2,500 years. In ancient times, the Romans used lead to glaze pottery, construct water pipes and aqueducts, make cosmetics, and sweeten wine as a flavoring additive. Due to its prolific use, many individuals were exposed to lead, and lead poisoning symptoms were described throughout ancient history as lead colic, paralysis, palsy, and lead madness.

Lead Exposure: A Problem of the Past?

Lead poisoning has been perceived by some as a problem of the past, given that lead paint is no longer used and lead gasoline is no longer sold at the gas pumps. In addition, blood lead levels in children have dropped significantly since the late 1970s due to various laws and programs that eliminate the use of lead in certain products, thereby preventing future exposures. Nevertheless, lead exposure, especially for children, remains a concern, a problem highlighted by research showing that there is no safe level of lead in the bloodstream.

Recently, public water supplies have come under investigation for lead contamination. For example, the water supply of Flint, Michigan, became contaminated with lead in 2014 after the city tapped into the Flint River as a backup water source while constructing a new pipeline to Lake Huron. The corrosive Flint River water, which had not been treated with an anticorrosion agent (in violation of federal law), caused lead in aging water service lines to leach into the residential water supply, resulting in unacceptably high lead concentrations. Various complaints, criminal charges, and lawsuits were filed, including felony charges against four officials for mishandling funds. President Barack Obama visited Flint in 2016 to meet with residents and discuss federal assistance.

Lead in Drinking Water

While exposure to lead in paint and soil is well understood, less is known about lead in drinking water, especially at low concentrations.

An Interview with Jennifer Chavez

Staff Attorney, Earthjustice

Jennifer Chavez is a staff attorney with Earthjustice, a nonprofit environmental law advocacy organization, where she is involved with a number of cases related to protecting water resources in the Washington, D.C., and Chesapeake Bay regions and to stopping mountaintop removal mining in the Appalachian coalfields. Chavez previously worked for a Chicago-area law firm representing municipal governments.

We have known about the hazards of lead exposure for a long time, but problems with lead in drinking water continue to surface. Why hasn't more been done to address an obviously serious problem?

Lead in drinking water is invisible to the ordinary person, and the factors that cause lead contamination of water are outside of the ordinary person's control, so most of the public has remained in the dark and powerless to do anything about the problem. The U.S. Environmental Protection Agency (EPA) has been regulating lead in drinking water for a long time, but the permissible levels are not low enough to prevent lead exposure problems. Furthermore, the EPA rules have too many loopholes that allow drinking water utilities to comply with the law while still exposing water consumers to dangerous levels of lead in water.

It was recently discovered that the drinking water supply of Flint, Michigan, has high levels of lead contamination. Yet, little was done to address this problem until outspoken residents and environmental activists got involved. Is this an example of an environmental justice situation, where low income and minority people often bear the brunt of environmental contamination and exposure? (Flint is 56 percent African American, and the median household income is below $30,000 per year.)

In a sense, environmental justice is embedded in the nation's drinking water supply system in that lead and other contaminants often occur in older homes and inner city locations where low income and minority people tend to live. Thus, it is reasonable to ask whether the response to the Flint crisis would have been different if a community with a different composition were involved. Ultimately, as long as there are some cities and neighborhoods that get their water through drinking water pipes and fixtures that contain lead, even in wealthy neighborhoods, people will be at risk of drinking lead. The only way to fully remediate the problem is to remove all of the lead from our drinking water systems.

Evidence is building that even low doses of lead can be harmful, especially in children. Is there a safe level below which we need not be concerned?

I am an attorney, not a health scientist, but there is a consensus building that low levels of lead contamination in drinking water can be harmful and that there may not be a threshold level below which adverse health effects will not appear.

For most people lead in drinking water is not their main source of exposure, but it can be a significant source in addition to paint and air pollution. For some people, including pregnant women and fetuses, lead in water can be the primary source of lead exposure at a time when they are highly susceptible to lifelong harm. While public health departments know a lot about lead in paint and soil, they are less knowledgeable about lead in water. If lead paint is discovered in an old home and the children show symptoms of exposure, the drinking water should also be tested, but this is seldom done.

What is a good career path for a recent college or university graduate who is interested in addressing urban environmental problems such as lead exposure among inner city children?

There is a disconnect between scientists and advocacy groups, and closer coordination between these groups is needed. Whatever career recent graduates select, they should look for opportunities to merge science and advocacy so that clear and unambiguous messages about environmental pollution are conveyed to the public.

In the modern era, three major uses for lead resulted in millions of people, primarily children, getting lead poisoned. Beginning in the late 1800s, lead was used as a performance additive in household paint and gasoline. In paint, lead provided durability, flexibility, and a glossy appearance, and it repelled mold and mildew. Tetraethyl lead was added in gasoline to improve performance and curb engine knocking. Lead was also used to make water pipes and as a solder to seal pipe joints. Due to these long-standing uses, lead poisoning often occurred from ingesting or inhaling lead paint chips and dust, inhaling automobile exhaust, and drinking contaminated water. The risks of exposure were higher in children due to their smaller stature and greater likelihood of touching contaminated surfaces, licking fingers, and inhaling contaminated air collecting closer to the ground.

Exposure to lead causes a variety of adverse health effects. Lead poisoning can impact nearly all organs in the body but primarily affects the blood system, brain, and central nervous system, leading to anemia, behavioral and learning problems, reduced IQ, delayed growth, kidney problems, and even death. These health effects are more pronounced in children, who have a faster metabolism, higher absorption and lower excretion rate, and greater risk of toxic effects on developing organs and the central nervous system.

Throughout the nineteenth and twentieth centuries, physicians and scientists documented illnesses and deaths in children and workers associated with lead exposure, and the Centers for Disease Control and Prevention (CDC) established blood lead health standards. These concerns resulted in two major U.S. laws that banned lead in residential paint in 1978 and phased out lead in gasoline through 1986. These two regulatory actions resulted in significant reductions in lead exposure, preventing millions of future lead poisoning cases.

The primary cause of lead poisoning today is from older homes (built before 1978) that were painted with lead paint. The CDC estimates there are 24 million homes in the United States that have deteriorating lead paint and high levels of lead dust, with approximately 4 million of these homes inhabited by children. State public health programs report blood lead results to the CDC, and based on this information, it is estimated that over a half-million U.S. children ages 1 to 5 have blood lead levels of 5 microgram/deciliter or greater, with significant disparities between African American and Caucasian children. When a child's blood lead level exceeds this reference level, family lead prevention education, removing the sources of lead exposure, and medical case management are recommended.

Preventing lead poisoning is the primary goal of public health programs. Beginning with the laws that banned lead paint and leaded gasoline, public health agencies have worked hard to get additional laws passed to prevent new lead poisoning cases. In 1986, the Environmental Protection Agency (EPA) banned lead for use in plumbing, and in 1992, the EPA required landlords and sellers of property built before 1978 to notify tenants and homebuyers of potential lead hazards. In 1995, the U.S. Food and Drug Administration banned the use of lead solder in food cans, and in 1999, the U.S. Department of Housing and Urban Development enacted a lead safe housing rule that targeted homes federally owned or receiving federal housing assistance. The EPA established lead dust and soil hazard standards in 2001 that are used by public health officials when investigating lead exposure associated with housing and taking enforcement actions. Additionally, the EPA established rules that all home renovators must follow to ensure safe work practices where lead is present.

In addition to these prevention laws, public health agencies promote prevention through case surveillance, education, lead testing of children, mandatory blood lead reporting, inspections, and housing regulation enforcement. Public health agencies work closely with geographers to develop risk maps that target older neighborhoods, and they partner with the U.S. Department of Housing and Urban Development to rehabilitate older homes, making them lead safe and preventing future exposures. These types of prevention programs, along with collaboration among government agencies, have resulted in blood lead levels dropping significantly since 1978. However, lead poisoning prevention remains a concern because there is no safe blood lead level, and exposure continues in millions of homes with deteriorating lead paint.

R. Christopher Rustin

See Also: Automobile and Truck Emissions and Controls; Centers for Disease Control and Prevention; Children's Environmental Health; Environmental Protection Agency; Flint, Michigan, Contaminated Drinking Water in; Heavy Metal Pollution

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LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN

Leadership in Energy and Environmental Design (LEED) is a certification program for buildings and communities that promotes sustainability through building design, construction, operation, and maintenance. Projects receiving LEED certification must meet certain prerequisites to become certified at the silver (least rigorous), gold, and platinum (most rigorous) levels. The LEED program is important for environmental health because it leads to building and communities that use less energy, thereby helping to reduce greenhouse gases and other environmental pollutants. Additionally, LEED-certified buildings cost less to operate.

How Green Buildings Benefit Society

Green buildings are buildings where steps have been taken to reduce the amount of energy consumed over the life cycle of the building. Additionally, green buildings reduce impacts on human health and the environment by efficiently using water, reducing wastes, incorporating sustainable materials, and creating a healthy indoor environment. Residential and commercial buildings account for about 40 percent of total U.S. energy consumption, and much of this energy comes from electric power plants that burn fossil fuels—coal, oil, and natural gas. Green buildings help fight climate change by using less electricity, which results in fossil fuel power plants emitting less carbon dioxide, the most widespread greenhouse gas in the United States. Using less electricity also results in power plants emitting lesser amounts of other air pollutants, such as particulate matter and sulfur dioxide, that directly affect human health. Additionally, green buildings typically have lower operating expenses (e.g., lower electric and water utility bills) than other buildings, which helps make green buildings more affordable in the long run. The U.S. Green Building Council's LEED program is one of the most widely used systems for rating green buildings, both in the United States and globally. Additionally, Energy Star, a program run jointly by the U.S. Environmental Protection Agency and the U.S. Department of Energy, qualifies newly built or renovated buildings as being energy-efficient, awarding them the Energy Star label.

The LEED program is sponsored by the U.S. Green Building Council (USGBC), headquartered in Washington, D.C. The USGBC was established in 1993 to "promote sustainability-focused practices in the building and construction industry." Initially, the USGBC comprised a coalition of architects and building industry representatives having the common goal of creating a green building rating system for buildings that achieve environmental and sustainability standards. The result of this collaboration was the creation of the LEED certification program in 2000.

LEED certification applies to all types of buildings, including office buildings, commercial space, factories, warehouses, data centers, hospitals, schools, historical buildings, and homes. Unique standards and rating criteria have been established for each of the following categories:

- Building Design and Construction: buildings that are being newly constructed or going through major renovation
- Interior Design and Construction: projects that are a complete interior fit-out, including commercial interiors, retail, and hospitality
- Building Operation and Maintenance: existing buildings that are undergoing improvement work or little to no construction
- Neighborhood Development: new land development projects or redevelopment projects containing residential uses, nonresidential uses, or a mix
- Homes: single family homes, low-rise multifamily units (one to three stories), or midrise multifamily units (four to six stories)

The LEED certification program is used around the world, with about 1.85 million square feet (172,000 square meters) certified daily.

In addition to running the LEED program, the USGBC advocates for green building policies and programs, establishes strategic partnerships with government and industry leaders, and campaigns for standards, programs, and regulations that promote green buildings and communities. According to the USGBC, its advocacy priorities include government leadership by example, private-sector market transformation, raising the bar on codes and regulations, and community-wide sustainability. Additionally, USGBC presents national awards to individuals and organizations and, in collaboration with Bank of America, provides funding and educational materials to developers interested in constructing LEED-certified affording housing.

Richard Crume

See Also: Climate Change and Human Health; Electric Power Generation, Health Implications of; Energy Star; Environmental Protection Agency; Greenhouse Effect and Global Warming; Renewable Energy, Health Implications of; Sustainable Development and Health

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LEAL, JOHN

John Leal (1858–1914) was a physician and water expert who earned the moniker "father of chlorine" for leading the first large-scale water chlorination project in the United States. Chlorination kills bacteria that cause waterborne diseases. Its use has saved millions of lives, provided untold economic benefits, and transformed water-related leisure activities. Furthermore, chlorination can be done quickly and inexpensively. However, waterborne disease continues to be a major cause of death in areas of the world where chlorination systems are inadequate.

Born in Andes, New York, on May 5, 1858, Leal moved with his family to Paterson, New Jersey, when he was still a child. He attended Princeton University and then obtained his medical education at Columbia College of Physicians and Surgeons, graduating in 1883. Leal then returned to Paterson to practice medicine. As a city health officer, he became a public health expert and later took advisory positions with private water companies, including the Jersey City Water Supply Company. Working to make the water supply safer was a good fit for Leal. The emerging field of bacteriology had long captured his interest. Additionally, while serving in the Civil War, his own father had become ill from drinking contaminated water, dying after almost two decades of suffering.

The Jersey City Water Supply Company was contracted by Jersey City, New Jersey, to improve the city's poor water quality. The expensive project involved damming the Rockaway River and creating Boonton Reservoir, which began delivering water in 1904. Using the results of new bacteriological tests to argue that the water quality was still problematic, the city took the company to court, claiming it had violated the contract. In a 1908 ruling, the court found that the city's water quality was improved but that bacteria rates spiked several times a year after high water and flooding. As a remedy, the city wanted expensive sewers built, but the court agreed to allow Leal's company 90 days to put another solution in place and prove its efficacy. To Leal, who had experimented with disinfection methods in the lab, that solution was chlorination.

The idea of putting chlorine, a potentially lethal chemical, into the water supply was radical at the time. Even though there were some cases of chlorine having limited success in European water supplies, chemical disinfection of water was not a popular idea with many scientists or the public. Leal lacked specific permission to add chlorine to the water supply, so his project was an especially bold and risky move.

Leal enlisted MIT-educated sanitation engineer and filtration expert George Warren Fuller to quickly design a chlorine delivery system that could meet the challenge of treating 40 million gallons (151 million liters) of water daily. Chlorination plant operations were initially directed by George A. Johnson, who had recently used chloride of lime (the same chemical originally used in Jersey City) as a successful disinfection agent for the much smaller Chicago stockyard water supply. Leal took over plant operations a few months after the plant opened.

Jersey City's water treatment plant opened on September 26, 1908, with great success. Infant mortality, cholera, and typhoid fever rates fell dramatically, and water utilities around the country moved quickly to chlorinate. Meanwhile, a second lengthy court case required that Leal defend the project.

Leal died from complications of diabetes on March 13, 1914. For the next century, he remained a relatively obscure name in public health history, with credit for chlorination largely going to Johnson. For unknown reasons, perhaps family tensions, his grave in a Paterson cemetery remained unmarked for a century. Leal was finally commemorated on the 155th anniversary of his birth with the installation of a grave marker heralding him as a "Hero of Public Health."

Kathy Stolley

See Also: Cholera; Drinking Water Quality and Regulation; Environmental Health Profession; Sewage Treatment and Disposal; Waterborne Diseases

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LEGIONNAIRES' DISEASE

Legionnaires' disease is a serious, potentially fatal pneumonia caused by gram-negative bacteria from the *Legionella* genus. The bacterial pneumonia affects 10,000 to 15,000 people per year in the United States and more than 7,000 people per year across the European Union, although these estimates are generally thought to be significantly underreported. In hospitalized patients, Legionnaires' disease can have up to a 39 percent fatality rate, with a typical fatality rate of about 10 to 15 percent seen globally.

The disease was discovered in 1976, when participants of the American Legion's annual convention in Philadelphia developed a strange pneumonia, and 29 subsequently died. The causative agent was later determined to be *Legionella pneumophila*, a previously unrecognized freshwater bacterium. There are currently 60 different species of *Legionella*, and most are considered pathogenic. (Most cases of the disease are caused by *Legionella pneumophila* serogroup 1.)

Legionella bacteria are found naturally in freshwater sources worldwide in concentrations that rarely, if ever, cause human disease. Legionnaires' disease is largely a problem created by humans. The bacteria thrive in created aquatic environments, such as the plumbing of large and complex water supply systems, cooling towers of large air-conditioning units, decorative fountains, hot tubs, humidifiers, and aquariums. In these environments, *Legionella* can become aerosolized in water droplets and inhaled, causing infection.

Hotels, resorts, and cruise ships are frequent outbreak locations for *Legionella* due to their large water systems and other aerosol-generating sources (e.g., a shower head or mist-generating water cooling tower). This is also true for hospitals and long-term care facilities, whose inhabitants may be more susceptible to infection due to illness or age. Risk factors for developing Legionnaires' disease include preexisting renal or hepatic failure, diabetes, chronic lung disease, systemic malignancy, smoking (current or past), immune system disorders, and being age 50 and older.

Symptoms of infection are indistinguishable from other causes of pneumonia. Patients with Legionnaires' disease usually experience fever, loss of appetite, mild cough, headache, malaise, and lethargy. Some people also experience myalgias, rigors, dyspnea, and diarrhea. Those who survive the infection occasionally suffer from long-term health effects, including restrictive lung disease, weakness, poor memory, fatigue, retrograde amnesia, or cerebellar symptoms.

Proper diagnosis of Legionnaires' disease is crucial to appropriate patient management as well as accurate reporting to health departments. Diagnostic tests begin with a general chest x-ray. From there, the gold standard for diagnosis is both a culture of lower respiratory secretions and the *Legionella* urinary antigen test. Treatment centers on antibiotic therapy and supportive respiratory care. Typical antibiotic therapy consists of a combination of potent antipneumococcal betalactam and either a macrolide or fluoroquinolone.

Because there is currently no vaccine for *Legionella*, prevention, infection control, and outbreak investigation are key environmental and public health priorities. There are numerous standards and guidelines for preventing *Legionella* in specific environments, such as the Centers for Disease Control and Prevention's (CDC) Guideline for Prevention of Nosocomial Pneumonia, New York State Department of Health recommendations for hospitals and nursing homes, and the Veterans Health Administration's Directive 2008–010, Prevention of Legionella Disease for Healthcare. The CDC has a vessel sanitation program for cruise ships and heating, ventilation, and air-conditioning systems. Additionally, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers has published

Guideline 12–2000, Minimizing the Risk of Legionellosis Associated with Building Water Systems.

Timothy J. Sutton

See Also: Indoor Environment; Infectious Diseases; Respiratory Disease and Air Pollution

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LEUKEMIA AND ENVIRONMENTAL EXPOSURE

Leukemia is a type of cancer affecting the bone marrow, lymphatic system, and other tissues involved with blood formation. The disease typically causes the formation of white blood cells that are abnormal and function improperly. Because these abnormal cells tend to grow and divide faster and live longer than healthy cells, they can overwhelm the supply of blood cells, resulting in a diminished numbers of healthy white blood cells, red blood cells, and platelets. A combination of genetic and environmental factors appears to cause leukemia, although as with most cancers, the exact mechanism is not well understood.

Cases of leukemia are classified according to how quickly the disease progresses and the types of cells involved. Although often considered a children's disease, most leukemia cases occur in older adults, usually over 65 years of age. Symptoms vary but commonly include fever, fatigue, frequent or severe infections, weight loss, loss of appetite, nosebleeds, enlarged liver or spleen, swollen lymph nodes, swollen or bleeding gums, easy bleeding or bruising, sweating at night, bone or joint pain, anemia, and petechiae (small red or purple spots on the skin). These symptoms are also associated with other often less serious conditions, and diagnosis by a healthcare professional is essential.

In both children and adults, exposure to ionizing radiation (e.g., from cancer radiation therapy) is the most firmly established environmental risk factor for leukemia. (Japanese atomic bomb survivors who were exposed to high radiation levels were also found to have a higher incidence of leukemia.) Additionally, an elevated risk of developing the disease is linked to benzene (e.g., a chemical used in the chemical industry and found in gasoline), agricultural exposure (e.g., pesticides), and smoking. For children, the parent's exposure to pesticides and other chemicals may also increase risk. Other risk factors for leukemia include previous cancer treatments, genetic disorders, and a family history of leukemia. Exposure to certain rare viruses may also be a factor.

Benzene exposure is of particular interest from an environmental health perspective because it is an environmental pollutant that is regulated by the U.S. Environmental Protection Agency (EPA), and the association between benzene exposure and leukemia has been well documented in the agency's Integrated Risk Information System database. The EPA has determined that benzene is a "known" human carcinogen for all routes of exposure, based on "convincing human evidence as well as supporting evidence from animal studies." Cancer-causing substances are designated as "known" when there is sufficient evidence from epidemiological studies to establish a causal relationship between exposure and the formation of cancer.

The type of treatment selected for leukemia depends on several factors, including the patient's age, white blood cell count, the cancer genetics, if there was a preleukemic condition, and whether the patient was previously treated for cancer. The usual treatment is chemotherapy, sometimes in combination with bone marrow transplants, radiation therapy, interferon therapy, and surgical removal of the spleen. According to the Leukemia and Lymphoma Society, the overall five-year relative survival rate for leukemia over the period 2005 to 2011 was about 62 percent. (Survival rates for specific types of leukemia may differ from this overall figure.) With the treatments available today, leukemia can be managed and even cured in many cases.

While medical science does not yet know how to prevent leukemia, the most significant avoidable risk factor for adults is smoking, and avoiding benzene exposure may also lower the risk of developing the disease. The risk of leukemia is higher for people previously receiving radiation and chemotherapy treatments for other cancer types, taking immune suppressing drugs, and having certain genetic conditions like Down's syndrome.

Richard Crume

See Also: Automobile and Truck Emissions and Controls; Cancer Clusters; Cancer Risk from Environmental Exposure; Children's Environmental Health; Environmental Protection Agency; Integrated Risk Information System; Pesticides and Herbicides; Radiation, Ionizing and Nonionizing

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LIFE CYCLE ASSESSMENT

Life cycle assessment (LCA) is a method of evaluating the potential environmental impacts associated with all stages of a product or process. LCAs may be either attributional (the most common type) or consequential. Attributional LCAs are based on known past environmental impacts, while consequential LCAs seek to identify the future environmental consequences of a proposed decision. The product or process stages examined include raw material extraction, manufacturing, distribution, use or reuse, and disposal. LCAs are an important tool for both corporate and government decision makers to limit environmental impacts and avoid unnecessary risks to human health.

The purpose of an LCA is to make comparisons between competing products or processes based on known data. The results may then be used to identify ways to modify a product or process to reduce adverse environmental impacts. LCAs are used primarily within industries to design and develop products. However, LCAs may also be used to help policymakers decide which plans to implement, and they may be helpful to consumers in making informed decisions when purchasing products.

Whereas a traditional cost-benefit analysis focuses on financial considerations, the primary benefit of an LCA is the ability to evaluate environmental impacts. For instance, a company might choose to use LCA if they want to model the environmental implications of changing various steps of their production process. However, the downside of an LCA is that it can be quite time-consuming and expensive.

The LCA process has been established by the International Organization for Standardization under two standards:

- ISO 14040:2006, Environmental Management—Life Cycle Assessment—Principles and Framework: overview of the practice, applications, and limitations of LCA

- ISO 14044:2006, Environmental Management—Life Cycle Assessment—Requirements and Guidelines: guidance on preparing, conducting, and reviewing LCAs, including assessing impact, interpreting results, and evaluating the nature and quality of data collected

A typical LCA assessment involves three phases: (1) defining the goal and scope of the project; (2) compiling an inventory of inputs and outputs; and (3) evaluating potential impacts and making a recommendation. These phases are described next.

Defining Goals and Scope. The first LCA phase is to establish the goal and scope of a given LCA. This begins with defining the processing steps, or "gates," which may range from (1) extracting raw materials to disposing of goods (called cradle-to-grave); (2) extracting raw materials to finishing the production of goods (called cradle-to-gate); or (3) one processing stage to another (called gate-to-gate). Additionally, discrete environmental impact categories must be identified, for example, toxicity to humans, depletion of abiotic resources, emissions of greenhouse gases, stratospheric ozone depletion, toxicity to aquatic or terrestrial organisms, and eutrophication. A final step in identifying the goals and scope of an LCA is to define the functional unit to be compared across products. For example, to compare energy required by compact fluorescent lamps (CFL) versus incandescent light bulbs, the functional unit might be defined as "450 lumens of light for 5,000 hours," and the LCA might demonstrate that the energy used by one 9-watt CFL is comparable to that of five 40-watt incandescent light bulbs.

Compiling an Inventory. The second phase of LCA involves quantifying all the inputs and outputs of materials as well as evaluating how these materials may affect the environment. The inventory is based on either national data (known as environmental input-output data) or on a survey of the actual process or product (known as unit process data). The resulting life cycle inventory is usually illustrated with a flowchart or process tree. Given the technical nature and the volume of data usually involved, LCA inventories are often performed using computer models, for example, Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model.

Evaluating Potential Impacts. The third phase involves evaluating the significance of potential environmental impacts. For example, an industry might use LCA to develop a plan that is less damaging to the environment than other possible plans. In the impact assessment process, various outputs are converted to equivalent measures. As an illustration, because both atmospheric carbon dioxide and methane contribute to climate change, methane would be converted to equivalent units of carbon dioxide for the purpose of evaluating the global warming potential of competing processes.

One well-known example of the usefulness of LCA is the evaluation of environmental impacts related to the "eat local" movement in the United States. By calculating miles traveled per item of food, researchers found that conventional food distribution networks use more fuel and emit more carbon dioxide than locally sourced food. Thus, proponents of eating locally held that buying food produced within 100 to 250 miles (161 to 402 kilometers) of their homes would have less environmental impact. Yet, the initial research overlooked several factors, including the resources needed to grow the food and the method of transportation. For example, if local tomatoes are grown in greenhouses while imported tomatoes are grown in sun-warmed fields, then the local tomatoes may have a greater environmental impact. In another example, potatoes shipped via train for 1,000 miles (1,609 kilometers) may emit the same amount of carbon dioxide as potatoes trucked for 100 miles (161 kilometers) because freight cars are less resource-intensive than trucks. If every step of the process in food production is equal—from growing conditions to transportation methods—then "eating local" does indeed have less impact on the environment, but in most cases, the circumstances of local and imported food products are not the same. Therefore, LCA helps people make decisions based on holistic data.

Alisha K. Newton

See Also: Environmental Auditing; Environmental Impact Assessment; Laboratory Quality Assurance; Recycling

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LIGHT POLLUTION

It is difficult to imagine a world without lighting. We depend on artificial lighting (light created by humans) for a wide range of activities that would otherwise be difficult if not impossible. However, sometimes lighting can become a nuisance when it disturbs sleep or interferes with stargazing. When this happens, we refer to the lighting as light pollution.

Light pollution is usually caused by outdoor lighting, for example, a security light on a house that shines through a bedroom window next door, keeping the neighbor awake at night. And a flashing neon sign on a local business might also interfere with sleep patterns for people living nearby. When this happens, light pollution becomes a health issue that needs to be addressed. However, unless one's property is large or in a remote area, it can be difficult to prevent outdoor lighting from spreading onto neighboring properties and becoming a nuisance.

Astronomers also struggle with light pollution when they attempt to view celestial objects from an urban location. The light from buildings, motor vehicles, and streetlights can fill the evening sky, making astronomical observations difficult with even the most powerful telescopes. This is why observatories are often located on mountaintops or in secluded areas, far away from the city lights.

Furthermore, light pollution can be a hazard to certain wildlife species that depend on light for navigation and biological cues. City lights can easily disorient birds that migrate at night and navigate by the moon and stars. And female sea turtles may not lay eggs if the lighting from beachfront homes and businesses causes the turtles to confuse day and night. Sometimes a bright light at night will act like a magnet, attracting moths and other insects, which, in turn, can entice hundreds of bats looking for a meal.

The behavior of animals, including feeding and migration patterns, can also be altered when nighttime lighting disrupts their circadian rhythms. In plants, the closing of flowers and changes in leaf position at night can be thrown off rhythm if artificial lighting disturbs the evening darkness. Humans need darkness too: to regulate our internal clockwork, sleep well at night, and wake up in the morning feeling refreshed.

Issues surrounding light pollution can be complicated. For example, homeowners may feel it is their right to protect their property with a security light, whereas neighbors may contend that the light interferes with their right to privacy and a good night's rest. In most cases, these issues can be resolved through friendly conversations. But sometimes to resolve the matter, a local conflict resolution service is needed, or a city or state light ordinance must be invoked.

Several steps can be taken to reduce light pollution. One effective approach is to locate outdoor lighting far from neighboring properties or to direct the light away from the properties. Another approach is to put the lighting on a timer switch that turns the light off later at night when neighbors are trying to sleep. Of course, outdoor lights should always be switched off when not needed, which saves energy too. Using low-wattage, energy-efficient light bulbs also reduces energy consumption and, depending on the type of bulb, may reduce light intensity. In a high-rise building, closing the curtains at night can prevent birds from crashing into windows while improving visibility of the moon and stars for others.

Security lighting is often located over an entry door or in a dark corner of a property to discourage intruders. Reducing light pollution from security lighting can be especially challenging because it is not always possible to locate security lights where they are not visible from a neighbor's bedroom window. However, if the light fixture is equipped with a motion detection switch, the light stays off unless an intruder is in the vicinity. Another option is to fit the light fixture with a shield that blocks light from the neighbor's view. A spot light, which focuses more narrowly than other types of lighting, can also be helpful.

Specific concerns about light-emitting diode (LED) street lighting have been raised by the American Medical Association (AMA), which has issued community guidance for reducing the harmful human and environmental effects of roadway lighting systems using LEDs. This type of lighting consumes less energy than conventional lighting, resulting in a lower reliance on fossil fuels to generate electricity, and about 10 percent of existing street lighting in the United

States has already been converted to LED technology. However, according to the AMA, LED lighting emits large amounts of blue light that appears white to the naked eye and can cause a hazardous nighttime glare for drivers. Furthermore, the blue LED light suppresses melatonin at night, resulting in a five times greater impact on circadian sleep rhythms compared with conventional street lighting. This can result in reduced sleep time, diminished sleep quality, impaired daytime functioning, and even obesity. Outdoor LED lighting can also disorient birds, insects, turtles, and fish. The AMA guidelines recommend that communities use the lowest intensity lighting possible to minimize blue-rich light, properly shield the lights to minimize glare, and consider dimming the lighting during off-peak periods.

Richard Crume

See Also: Energy Star; Leadership in Energy and Environmental Design

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LONDON SMOG DISASTER

In early December 1952, a blanket of deadly smog lay over the city of London for about four days, killing around 4,000 people. The smog spanned roughly 1,000 square miles (2,590 square kilometers), but the public was not too alarmed at the time. Due to London's developing industrial sector and geographic location, residents were used to a heavy fog.

Power plants in London burned large amounts of bituminous coal, which the city heavily relied on. Also, industrial plants constantly emitted a smoky soot full of hydrocarbons, a by-product of burning coal containing high amounts of sulfur and nitrogen. In the early 20th century, 76,000 tons (68,900 metric tons) of soot were emitted in London each year, about 650 tons (590 metric tons) for every square mile. But the industrial companies were not to blame for the majority of this soot.

Londoners were very fond of their domestic open-fire kitchens. While other European countries had transitioned to stoves and ovens, London was less interested in these new cooking technologies. Roughly two-thirds of London's soot was a result of these domestic fires. During World War II, the British government even encouraged residents to burn these fires in their homes, thinking the soot would serve as camouflage from enemy air bombings.

On December 4, 1952, the soot mixed with fog to create a thick, lethal smog. The particular toxicity of this fog was caused, in large part, by a temperature inversion that tended to prevent the smog from dispersing, holding it in place. (London is susceptible to this type of meteorological phenomenon because of its topography, surrounded by low hills that allow air to stagnate above the bustling streets.) That morning in December, a cool, high-pressure system encroached upon London, trapping the fog beneath and preventing the pollution from dissipating. In addition, house fires during the evening were created to warm the houses from the cold air, in turn emitting large amounts of sulfur dioxide and other noxious gases into the stagnant air. Soot and smoke from industrial plants added to the mix.

The smog was at times nearly black and at other times yellow, and some reports say it turned green. The visibility that morning was only 70 to 80 yards (64 to 73 meters), and street lamps were lit during the daytime. The port of London on the Thames River had to be closed because of the limited visibility, shutting in over 100 ships and excluding another 200 waiting to enter, and the poor visibility also resulted in an uptick in burglaries around the city. Londoners coughed up soot, felt pain in their throats and lungs, and experienced difficulty breathing, especially babies and the elderly. By the third day of the smog, the insides of London homes were covered in soot.

A few weeks after the incident, reports of nearly 1,000 deaths surfaced, but the health minister subsequently reported the number to be closer to 3,000, and later studies estimated 7,000 to 12,000 deaths. The devastation the city felt after so many illnesses and deaths eventually caused momentum to build for the passage of the British Clean Air Act of 1956. The act required Londoners to burn smokeless fuel in their homes or switch to gas or electricity. Since then, London has only had one other dangerous fog, this one occurring in 1962.

Mallory L. Daily

See Also: Air Pollution; Electric Power Generation, Health Implications of; Hazardous Air Pollutants; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Polycyclic Aromatic Hydrocarbons; Regional Haze Pollution; Respiratory Disease and Air Pollution

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LOVE CANAL INCIDENT

The Love Canal incident is perhaps one of the best known examples of the serious adverse health effects resulting from the indiscriminant dumping of toxic wastes. Love Canal is officially defined as a 36-square-block area in Niagara Falls, New York, where refuse was dumped for decades, including 22,000 tons (19,960 metric tons) of toxic waste buried by the Hooker Chemical Company.

Lessons from Love Canal

After all these years, the scars still remain with the former residents of Love Canal.

An Interview with Luella Kenny

Former Love Canal resident

Luella Kenny, a former resident of Love Canal, helped lead the fight to clean up the Love Canal hazardous waste dump site and address the adverse health conditions, including cancer, experienced by many residents. Kenny has remained active in community and environmental organizations, including serving on the boards of the Center for Health, Environment, and Justice and the Love Canal Medical Fund, and she has participated in panels sponsored by the New York Department of Health and the U.S. Environmental Protection Agency. Kenny has spoken about hazardous waste to many high school and university students and to various grassroots community groups. Her passion lies in educating young people about the dangers of exposure to toxic chemicals.

The Love Canal incident is recognized as one of the great environmental disasters of the twentieth century in the United States, leading to creation of the Comprehensive Environmental Response, Compensation, and Liability Act (also known as Superfund) in 1980. Having lived through the Love Canal tragedy, can you comment on the challenges that were faced by residents of

the area, both physical and emotional? After all these years, have families recovered or are there lingering effects?

The Love Canal period was a time of great stress and chaos for the residents of Love Canal. Because the danger was not immediately evident to the residents, it caused conflict within families. This was not like a hurricane or tornado, where residents seek shelter because they know it is coming. There were times when chemicals permeated the air or barrels surfaced. But most of the residents grew up in Niagara Falls, whose primary industry was the chemical plants, and the chemical odors were familiar. Husbands and wives were always arguing, usually because the wife wanted to leave and protect her family, whereas the male of the time felt duty bound to provide shelter for his family. As children and family members became ill, it was difficult to be told you had to remain in your contaminated house until the government finally purchased your residence. Enormous stress was caused by the lack of support from government and health officials, family illnesses, burglaries, mothers forced to spend time away from home to fight for their rights, and the uncertain future.

After all these years, the scars still remain with the former residents of Love Canal. Children whose childhood was disrupted were the most vulnerable, and many are still unable to talk about this period of their lives. There are two types of former residents: the ones who want no identity with the Love Canal disaster and those who feel it is important to educate people about the dangers of toxic waste exposure. Certainly, the lives of residents were permanently changed.

Many concerned citizens fought to clean up Love Canal and hold responsible those who caused the physical and financial distress experienced by so many local residents. What were the most important lessons learned, and in retrospect, are there any other actions you wish you had taken?

It was important that the concerned residents be at the forefront of the fight for relocation. Certainly, support from high profile individuals was welcomed and encouraged, but the affected residents were the driving force. Politics was an important dynamic that needed to be gauged and used to the residents' advantage. Regretfully, greater initiative was needed to prevent rehabitation of the area. The dump still contains 20,000 tons (18,144 metric tons) of chemicals that are supposedly contained, but there are signs of leakage, and several current residents are ill with diseases that can reasonably be associated with exposure to Love Canal chemicals.

There may be hundreds of other sites like Love Canal across the United States that have not yet even been discovered. What advice do you have for community groups concerned with hazardous waste dump sites in their neighborhoods?

Communities faced with a hazardous waste problem need to unite and educate themselves about the problem. Take advantage of the leadership training and technical assistance offered by many environmental groups. Persevere until you reach your goal. Government officials may try to get you to settle for less, but you must remain firm until you reach your goal. There can be no compromise when your family's life is at stake.

What would be a good career path for a recent college or university graduate wanting to help communities find solutions to local environmental problems?

There are many avenues open to students who are interested in preserving the environment. Obviously, many branches of science and engineering will further their knowledge of how toxic chemicals affect humans and how the toxic effects can be mitigated. Lawyers and politicians who will make and protect the laws that will protect the environment are needed, as are teachers who will mold young minds to realize the importance of the environment. Leaders in all walks of life are important because we are all responsible for protecting the environment. Together we can make a difference!

In the late 1890s, William T. Love conceived of a plan to dig a canal connecting the Niagara River to Lake Ontario, thereby avoiding Niagara Falls. Before Love ran out of funding, only about a mile (1.6 kilometers) long, 50 feet (15 meters) wide, and 10 to 40 feet (3 to 12 meters) deep section of the canal was excavated. The abandoned canal was used as a municipal dump for the city of Niagara Falls in the 1920s. By 1942, Hooker Electrochemical Company (later becoming Hooker Chemical Company) was given permission to dispose of wastes in the canal. They first drained the canal and lined it with a thick clay, which was supposed to prevent leakage. Then they began placing 55-gallon (208-liter) barrels into the pit. The city of Niagara Falls and the U.S. Army also continued to dispose of refuse there. The dump site remained in operation until 1953, when it was covered over with soil, allowing vegetation to grow on it. On April 28, 1953, Hooker Chemical Company sold the site for $1 to the Niagara Falls City School District, with a written agreement that clearly disclosed the unsuitability of the site for development. Nevertheless, in 1955, the school board completed construction of the 99th Street School beside the site, and soon thereafter, they built the 93rd Street School, located six blocks away. The remaining land was then sold to private developers who built single-family residences and low-income housing. In 1957, sewer lines, which breached the protective clay walls, were installed, and the protective clay cap was partially removed by the city. This allowed the dangerous chemicals buried there to migrate away from the canal bed.

From the 1960s onward, residents of the area complained about the appearance of strong "chemical" odors, foul substances, and puddles of strange oily and odd-colored liquids in their basements and yards. By the mid- to late 1970s, residents, with support from local journalists, began discussing unusually high incidences of birth defects and other abnormalities. Also, children who played in the vicinity of the dump site talked about playing with "hot rocks," which were conglomerations of chemicals that had oozed out and, when smashed, would sometimes release sparks and smoke. Children would sometimes return home with chemical burns on their hands and feet from playing in the area.

Cleanup of the Love Canal waste dump in Niagara Falls, New York, where industrial wastes were dumped for decades. When waste materials began to surface and an abnormal number of illnesses were reported, President Carter declared an environmental emergency for the site. (Centers for Disease Control and Prevention)

The New York State Health Department found an abnormally high rate of miscarriages, and on August 2, 1978, when a state of emergency was declared for the dump site, homeowners began to organize. (When Lois Gibbs was elected president of the Love Canal Homeowners' Association, her son was experiencing an array of health problems, including asthma, epilepsy, low white blood cell counts, and urinary tract infections. She was later to become a well-known environmental activist.) Efforts were mounted to collect evidence indicating the buried toxic waste was responsible for the health problems experienced by residents. It became nearly impossible for houses to be sold, and some families simply abandoned their homes. Over 800 families were eventually relocated and reimbursed for their homes. All of the residences to the west and most of those to the east of the site were demolished. Subsequently, the Comprehensive Environmental Response Compensation and Liability Act (known as Superfund) was passed to help fund remediation of toxic waste sites located in residential areas.

Unfortunately, Love Canal is not a unique environmental catastrophe. In fact, Love Canal is only one of thousands of industrial waste sites around the country that evolved through collaboration between local governments and corporate entities. Many of these sites continue being a threat to the health and safety of the public living near them.

Victor B. Stolberg

See Also: Asthma; Children's Environmental Health; Environmentalism; Hazardous Waste Disposal; Land Disposal of Waste Materials; Superfund Act

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LYME DISEASE

Lyme disease, caused by the bacteria *Borrelia burgdorferi sensu lato* and transmitted by black-legged ticks, is the most common vector-borne disease in the United States. Following a tick bite, bacteria are able to establish a skin infection, resulting in a "bull's-eye" skin rash and then spreading to different organs. This can lead to the severe inflammation of heart and joints and neurological abnormalities. Even after two to four weeks of treatment with antibiotics, some patients still suffer from fatigue, pain, or joint aches, a condition known as posttreatment Lyme disease syndrome.

The number of the Lyme disease cases has surged since the disease was first identified in 1975, and each year about 30,000 cases (mostly in northern, eastern, and midwestern areas of the United States) are reported by state health departments and the District of Columbia. Despite the large number of cases, no human

Avoiding Lyme Disease

If you want to avoid getting Lyme disease, the Mayo Clinic advises staying away from areas that attract deer ticks. This includes wooded and bushy areas with long grass. Other approaches include the following:

- Wear clothes that cover your skin (e.g., long-sleeved shirts and long pants) when walking in wooded or grassy areas. (Do not let dogs run free.)
- Use insect repellents, being careful to follow directions.
- If you have a yard, clear away brush and leaves where ticks can live.
- Check yourself, children, and pets for ticks after visiting wooded or grassy areas. (Taking a shower can help remove ticks too.)

Because deer ticks are often no larger than the head of a pin, they are hard to identify and remove. If you find a tick, remove it with tweezers, pulling carefully and steadily to avoid crushing it.

vaccine against Lyme disease is currently available, although considerable vaccine research is underway.

Vaccination against pathogens has been considered as the most effective way to control an infectious disease such as Lyme disease. (Pathogen proteins are vaccinated into humans to induce antibodies that destroy pathogens during infection.) However, unlike other pathogens, Lyme disease-causing bacteria are transmitted from reservoir animals in the environment (in the United States mostly from white-footed mice) to humans via ticks. Consequently, the work on developing a vaccine against Lyme disease has focused on interrupting bacterial transmission. Researchers believe this can be achieved by immunizing humans or reservoir animals with bacterial proteins or bacteria with reduced virulence.

The only transmission blocking vaccine (LYMErix) approved by the U.S. Food and Drug Administration targets the surface protein OspA from the Lyme disease-causing bacteria. This protein is produced when the bacteria are in ticks and is reduced when the bacteria enter animals. Thus, when humans are immunized with the OspA protein, the OspA antibody is induced to eliminate bacteria during tick feeding. However, a few patients have developed arthritis after immunization, likely because of the autoimmune response triggered by the OspA protein, and this has led to withdrawal of the vaccine from the market. The current research focus is to develop the OspA protein as a reservoir animal-based vaccine by immunizing the white-footed mice as opposed to humans, thereby blocking mouse-tick-human transmission. Another option under investigation is to evaluate other proteins from Lyme disease-causing bacteria as vaccine candidates.

An alternative to human- or reservoir animal-based vaccines is a vector-targeted vaccine. These vaccines would target the tick proteins that facilitate feeding or bacterial survival in ticks or transmission to animals. Therefore, the antibodies targeting on these proteins would be expected to block tick feeding, eventually preventing bacterial transmission. One example is a tick saliva protein (Salp15) that helps the bacteria to escape from the immune response of humans and animals, resulting in efficient transmission. Vaccinating Salp15 protein has been demonstrated to prevent Lyme disease infection in mice, making this protein a vaccine candidate.

The conventional strategy in developing human- or animal-based vaccines for the prevention of Lyme disease is challenging. However, multiple bacterial or tick proteins being tested for their abilities to prevent diseases will likely produce next-generation vaccines against Lyme disease, resulting in improved public health by preventing new Lyme disease cases.

Yi-Pin Lin

See Also: Infectious Diseases; Zoonotic Diseases

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LYMPHATIC FILARIASIS

Lymphatic filariasis is an infection that causes elephantiasis, an irreversible enlarging and hardening of the limbs. The disease is found in tropical and subtropical regions, and it is caused by microscopic filarial worms that are transmitted to humans by mosquito bites. By blocking the lymphatic system, these worms cause fluids to collect in tissues, resulting in swelling and bacterial infections. It is estimated that around 120 million people are infected with the disease, and in the hardest hit communities, up to 10 percent of men and women exhibit swollen limbs critical enough to severely affect their quality of life. Many victims of this disease experience pain and physical disability and must contend with the social stigma associated with their physical appearance.

Infection usually occurs during childhood, but the effects are typically not apparent until later in life, when the condition can become debilitating. There is no cure for lymphatic filariasis, but medicines are available to control the spread of the disease and to limit further disability among patients. Additionally, the severity and progression of the disease can be reduced with simple hygiene and skin

The Carter Center's Fight against Lymphatic Filariasis

The Carter Center has been working with countries in Africa and Hispaniola to stop the spread of lymphatic filariasis by distributing medicines that prevent mosquitoes from transmitting the parasite. And to protect pregnant women and children who cannot take the medicines, the center distributes long-lasting insecticidal bed nets, which have the added benefit of protecting against other mosquito-borne diseases like malaria. In Nigeria, a country especially hard-hit by the disease, the center has delivered millions of medicinal treatments and bed nets and assisted with educational programs, with the result that by 2012 transmission of the disease had been stopped. The Carter Center was created in 1982 by former U.S. president Jimmy Carter to find solutions to the global problems of protecting human rights and alleviating human suffering. It is located near the Jimmy Carter Presidential Library and Museum in Atlanta, Georgia.

care, with exercise, and by elevating affected limbs. And in some cases, tissue swelling can be alleviated with surgery. People living in mosquito-infested areas should avoid mosquito bites by using insect repellents on exposed skin, wearing long-sleeve shirts and trousers, and sleeping under insecticide-treated nets. Indoor mosquito sprays can also be effective.

Lymphatic filariasis infections can be asymptomatic, acute, or chronic. Most cases are asymptomatic, where there are no external signs of the disease, but damage to the lymphatic and immune systems and kidneys can still occur. Acute infections involving inflammation of the skin, lymph nodes, and lymphatic vessels may occur, and these infections often accompany chronic cases of lymphoedema (tissue swelling) or elephantiasis (skin/tissue thickening) involving the limbs, breasts, and genital organs.

Because many lymphatic filariasis patients have difficulty making a living, eradication of the disease would contribute to reducing worldwide poverty. Eradication may be possible on a global scale if the spread of the disease can eventually be stopped, although close monitoring would be required to ensure the disease does not reemerge, and many patients already infected would need continuing care for a lifetime. Although lymphatic filariasis has not been reported in the United States since the early 20th century, nearly 1 billion people in 54 countries are at risk of infection.

Richard Crume

See Also: Carter Center; Communicable Diseases; Infectious Diseases; World Health Organization; Zoonotic Diseases

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MALARIA

Named for the Italian for "bad air," malaria has afflicted the human race for over 4,000 years of recorded history. First described in ancient Chinese medical texts, malaria epidemics may have contributed to the downfall of both the Greek city-states and the Roman Empire. Today, over 200 million cases of malaria worldwide occur every year. While over 800,000 deaths were attributed to this disease in 2000, this number has dropped to just under 500,000 in 2015. This improvement in mortality rates has been attributed to better therapeutics and malaria prevention efforts targeting the vector (carrier of disease).

Malaria is caused by members of the *Plasmodium* genus, a group of eukaryotic single-celled parasites. The life cycle of these organisms is complex, involving both the human host and the mosquito vector. In humans, the parasites grow and multiply in human liver cells before invading the red blood cells. In the case of *Plasmodium vivax* and *Plasmodium ovale* infections, dormant cells can remain in the liver and reactivate after months or years without symptoms. In the red blood cells, the parasites continue to reproduce until the cell bursts, resulting in the release of waste products and merozoites (daughter *Plasmodium* cells) that continue the cycle by invading more red blood cells. Eventually, the parasite is transmitted to a mosquito when the infected individual is bitten. There, the parasite undergoes further different rounds of growth and development until it reaches the mosquito's salivary glands and can be transmitted to another human host. A variety of genetic defenses against this disease have arisen in humans, including sickle-cell anemia, thalassemia, and glucose-6-phosphate dehydrogenase deficiency, all of which make the red blood cells less hospitable for the parasite.

There is an incubation period of 7 to 30 days between infection with *Plasmodium* and the onset of malaria symptoms that correlates with the period the parasites incubate in the liver before expanding to the blood. The exact length of this incubation period varies based on the exact species. If travelers take antimalarial drugs to prevent the disease, this can delay the onset of symptoms, sometimes for months. The classical presentation of malaria involves a cold stage with shivering, followed by fever with vomiting and headache, and then a final "sweating" stage in which the patient returns to normal temperature. This pattern can repeat every two or three days depending on the strain of parasite. However, this presentation is infrequent, and most patients experience a combination of flu-like symptoms, including fever, chills, body aches, nausea, and vomiting. In severe cases, seizures, brain damage, liver disease, coma, and death can occur. A variety of treatments for malaria are currently available, and it is recommended that treatment is initiated as quickly as possible after diagnosis of the disease.

Malaria can only be transmitted by mosquitos in the genus *Anopheles*. There are over 400 identified species in this genus, but only 30 to 40 commonly transmit the *Plasmodium* parasites. *Anopheles gambiae* is particularly well known because it plays a predominant role in the transmission of *Plasmodium falciparum*, which causes the deadliest form of malaria. The mosquito life span and eating habits play a large role in malaria transmission rates, and transmission occurs more frequently in regions where the mosquitos live longer and prefer to bite humans rather than animals. Climate also plays a large role in malaria transmission, as humidity, temperature, and rainfall regulate both the mosquito life cycle and the length of time the parasite must incubate in the mosquito before it can pass to a human host. Because the mosquito plays such a large role in disease transmission, prevention and eradication efforts often focus on preventing mosquito bites and eliminating the vector entirely when possible. In areas where malaria is endemic, the World Health Organization recommends mosquito netting around beds as well as the treatment of indoor surfaces with insecticide.

Repeated exposure to the parasite can cause partial immunity, which reduces the risk of severe disease. Because of this, most malaria deaths in Africa (where the disease is endemic and transmission rates are high) occur in young children who have not previously been exposed to the disease. In areas where people are not as exposed to malaria, and thus cannot benefit from this partial immunity, all age groups are potentially at risk. In 2015, 212 million new cases of malaria and 429,000 deaths due to malaria were reported. Children under the age of five in sub-Saharan Africa accounted for the vast majority of these deaths. While malaria is no longer endemic in the United States, approximately 1,500 cases occur annually among U.S. citizens, primarily among travelers to countries in which malaria is still pervasive.

To date, the most effective methods to prevent malaria target the mosquitos that transmit the disease. Malaria was endemic in the southeastern United States until 1951, when the disease was eradicated by the combined efforts of the Centers for Disease Control and Prevention (CDC) and state and local health agencies. This success prompted the formation of a global program to eradicate malaria. However, along with drainage and removal of mosquito breeding sites, one of the primary mechanisms of eradication was the liberal use of dichlorodiphenyltrichloroethane (DDT). This insecticide has since been linked to adverse reproductive effects and may cause cancer. DDT is capable of traveling long distances in the atmosphere, accumulates in fatty tissue, and is extremely persistent in the environment. Due to controversy surrounding the use of DDT as well as logistical difficulties and challenges, the global effort to eradicate malaria was halted in 1969. However, new advances in drug and vaccine development, as well as a better understanding of the socioeconomic effects of malaria, have recently brought global eradication back into discussion. Various governing and private organizations are actively pursuing this goal.

Marilyn Holt

See Also: Centers for Disease Control and Prevention; DDT Exposure; Infectious Diseases; Insect-Borne Diseases; World Health Organization

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MARINE POLLUTION, INTERNATIONAL TREATIES TO PREVENT

The 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, otherwise known as the London Convention, is an international treaty for protecting the marine environment from human activities. It was developed and administered by the International Maritime Organization, a UN agency responsible for regulating international shipping. The London Convention took effect in 1975, and its primary objective is to control all sources of marine pollution, including waste dumping. There are currently 87 signatory states that are parties to this convention. The London Convention was modernized by the 1996 London Protocol. There are currently 48 parties to the London Protocol, which will eventually replace the London Convention.

The United States has signed but not ratified the London Protocol, which means that the United States is not bound by this treaty. However, the United States actively participates in the annual Consultative Meeting of Contracting Parties to the London Convention and London Protocol and supports the treaty through, for example, compliance and monitoring support, capacity building, and scientific and technical guideline development. The U.S. Environmental Protection Agency, supported by the U.S. State Department, participates in annual joint meetings of the London Convention Scientific Group and London Protocol Scientific Group. These groups of scientists are responsible for advising the Consultative Meeting with the best scientific and technical advice on marine ecology and pollution.

Under the London Protocol, which took effect in March 2006, parties are prohibited from all ocean dumping, except for the wastes explicitly listed in the protocol's Annex 1. Wastes that may be considered for dumping include the following:

- Dredged material
- Sewage sludge

- Fish wastes or material resulting from industrial fish processing operations
- Vessels and platforms or other man-made structures at sea
- Inert, inorganic geological material
- Organic material of natural origin
- Bulky items primarily comprising iron, steel, concrete, and similarly unharmful materials for which the concern is physical impact, and limited to those circumstances where such wastes are generated at locations with no land-based alternatives
- Carbon dioxide streams from carbon dioxide capture processes for sequestration in sub-seabed geological formations

Furthermore, the London Protocol restricts commercial-level ocean fertilization as a greenhouse gas mitigation technique but allows for scientific research on the technique and, in future meetings, for revisiting the topic and developing guidelines. The London Protocol is a critical international treaty to protect and preserve international waters, ocean wildlife, and marine ecosystems. This is particularly so in the context of climate change, which will not only create new challenges for the oceans but exacerbate existing ones as well.

Ans Irfan

See Also: Biosphere, Environmental Threats to; Carbon Capture and Sequestration; Climate Change and Human Health; Environmental Protection Agency; Ocean Dumping and the Pacific Garbage Patch

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MARINE VESSELS, POLLUTION FROM

At any given point in time, there are tens of thousands of ships sailing between our ports and the oceans. Most of this traffic comprises shipping vessels, as over 90 percent of global trade occurs through sea lanes. Also, there has been a global increase in cruise ships over the past few decades, and there are thousands of naval vessels at sea. Those ships generate a large amount of pollution for both the oceans and atmosphere. Marine pollution can be divided between direct sources, such as emissions and waste discharge, and incidental problems, like oil spills or inadvertent transport of invasive species in cargo or on ship hulls.

Exhaust pollution from ships typically includes sulfur oxides, nitrogen oxides, and particulate matter. Not only is this a problem while at sea, but ships can also contribute heavily to local smog while docked, which can lead to respiratory disease and other adverse health issues. Some research indicates that the emissions from marine vessels contribute to a number of premature deaths in port cities every year.

The living organisms that travel on the bottom of a ship's hull or in the ballast water, disrupting destination ecosystems as invasive species, are another form of pollution. Traditionally, people tried to counter this by using antifouling agents like paint. But some of the toxins contained in these agents exacerbated the problem by poisoning the waters the ships sailed through. Today, antifouling paints are regulated by the International Maritime Organization (IMO) to prevent toxic accumulation in the oceans. There are also alternatives to paints, such as ultrasonic waves or electrochlorination.

Some of the worst forms of marine pollution come from accidents at sea, such as oil spills. However, these incidents have declined 85 percent since 1985 as a result of regulation and changes to ship design, including the monitoring of oily water discharges and a requirement that oil tankers have double hulls. Pollution from marine vessels is surprisingly only 10 percent of total oceanic pollution because the majority originates from land. Shipping only accounts for 2.2 percent of global carbon emissions, although these emissions are expected to increase over 200 percent by the year 2050. Nevertheless, shipping is much more energy efficient than land-based transportation.

Much of international marine pollution is regulated through the IMO. Global standards were instituted in 2005 under a treaty that limits emissions of sulfur and nitrogen oxides from engine exhaust. Illegal dumping of toxic materials was addressed in the London Protocol, which went into effect in 2006. Engines installed on U.S. vessels must adhere to fuel standards promulgated under the Clean Air Act. Finally, the U.S. Environmental Protection Agency bans ocean dumping for a variety of hazardous materials, including radioactive waste and other forms of toxic garbage.

Aaron Dorman

See Also: Air Pollution; Clean Air Act; Climate Change and Human Health; Ecosystems, Importance of; Environmental Protection Agency; Invasive Species and Human Health; Particulate Matter and Bioaerosols Pollution; Respiratory Disease and Air Pollution

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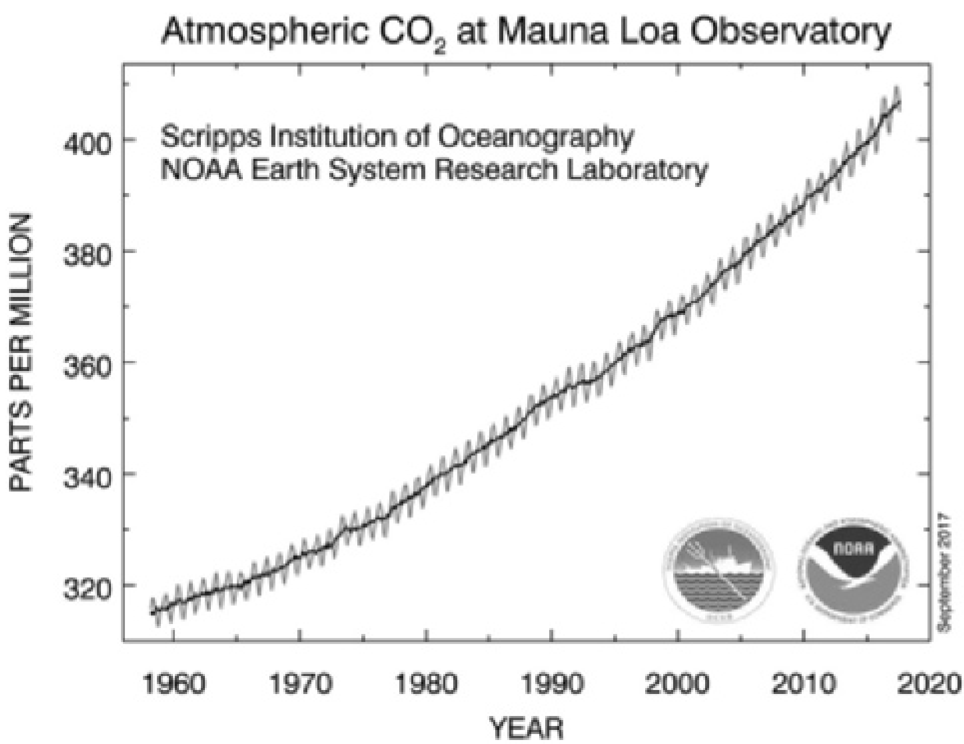
MAUNA LOA OBSERVATORY, CARBON MEASUREMENTS AT

The Mauna Loa Observatory is the site of the longest continuous measurement of carbon dioxide (CO_2) in the atmosphere. Measurements of CO_2 are important because CO_2 is considered the primary cause of climate change, which has the potential to seriously disrupt natural systems and compromise human health.

The observatory is located at an elevation of 3,397 meters (11,145 feet) on the northern flank of the Mauna Loa volcano on the island of Hawaii. This is considered an ideal location because of the elevation and pristine environment. Since measurements began in 1958, there has been a steady increase in CO_2 concentrations in the atmosphere, and the amount of increase has been growing from year to year. For example, in 2015, the increase in CO_2 concentrations over the previous year was 3.05 parts per million, which is the largest year-to-year increase ever recorded at the observatory.

The main cause of increasing CO_2 concentrations in the atmosphere is electric power generation at power plants that are fueled with coal, oil, or natural gas. These power plants emit vast quantities of CO_2, and while some CO_2 is taken in by vegetation or absorbed by ocean waters, enough remains in the atmosphere to



Monthly mean atmospheric carbon dioxide concentrations at the Mauna Loa Observatory, 1958–2016. The darker curve represents seasonally corrected data. (National Oceanic and Atmospheric Administration, https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html)

alter the earth's climate. Measurements at Mauna Loa and other observatories help environmental scientists estimate how much power plants and other CO_2 sources contribute to climate change and predict how much the earth may warm in the future.

Measurements of CO_2 are made using an instrument called CO_2 analyzer, which passes infrared light through a small cell containing a sample of air. An infrared light detector is located at the end of the cell opposite the light source, and because CO_2 absorbs infrared light, the instrument can estimate the amount of CO_2 in the air by the amount of light absorbed. Atmospheric scientists believe that the measurements made at the Mauna Loa observatory accurately represent actual atmospheric concentrations because the analyzer is calibrated frequently and rigorously, and independent measurements using other instruments confirm the accuracy of the analyzer.

Richard Crume

See Also: Biosphere, Environmental Threats to; Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Electric Power Generation, Health Implications of; Greenhouse Effect and Global Warming

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MEDICAL AND INFECTIOUS WASTE MANAGEMENT

Public pressure to regulate medical waste began in the late 1980s when needles and other medical waste washed ashore on beaches in New Jersey during the summer—the height of beach season. The medical waste found on these popular beaches was tracked back to a barge that disposed of hospital waste materials by dumping them into the ocean. Not only was the waste unsightly, but there was much concern about sanitation and safety as well.

In response to the public outcry, the U.S. Congress enacted the Medical Waste Tracking Act (MWTA) of 1988 as an amendment to the Resource Conservation and Recovery Act. The MWTA required the U.S. Environmental Protection Agency (EPA) to promulgate regulations governing medical waste management. The EPA published its final medical waste tracking regulations in 1989, and the rules went into effect as a two-year pilot program in four states (New York, New Jersey, Connecticut, and Rhode Island). Following completion of the pilot program, the EPA determined that medical waste can be safely regulated by the states without the need for federal oversight.

As a result of the two-year pilot program, the EPA found that medical waste is most hazardous at the point of generation (e.g., hospitals, nursing homes, and home-health settings), and the greatest disease-causing potential of medical waste was to healthcare workers. The Centers for Disease Control and Prevention estimates there are approximately 385,000 needlesticks and other sharp-related injuries to hospital workers each year, an estimate that does not take into account needlesticks at healthcare setting outside the hospital, for example, doctor offices and home healthcare settings.

In addition to concerns over the health and safety of hospital and healthcare workers, improper disposal of needles and other sharp items poses a health risk to waste disposal workers. For example, janitors, housekeepers, and sanitation workers could be stuck by needles or other sharps while collecting trash and transporting garbage bags. Sticks from used needles can result in infection or exposure to blood-borne illnesses, such as hepatitis B or C or HIV/AIDS.

In 1991, the U.S. Occupational Safety and Health Administration (OSHA) developed regulations designed to protect workers from blood-borne pathogens. These regulations required employers to evaluate whether their operations could expose workers to needles and sharps, and if so, to create exposure control plans that would reduce exposure and protect employees. The OSHA program relied heavily on educating employees on the health dangers of medical sharps and training employees to use proper disposal techniques and containers when dealing with medical wastes that contain blood or other body fluids. The program also mandated that medical wastes be clearly labeled and placed in bright red-orange containers so that all workers will know to take caution when handling.

The U.S. Department of Transportation (DOT) also developed guidelines requiring those who ship medical waste to take precautions to prevent workers and the general public from exposure to pathogens. Similar to the OSHA regulations, the DOT regulations focus on training workers to properly identify, label, and package medical wastes so that people are warned of the potential for exposure and protected from an accidental stick. In addition to the OSHA and DOT regulations, many states provide additional rules and guidelines for employers to help protect workers from the health risks associated with blood-borne pathogens and other medical wastes.

Prior to 1997, most medical waste in the United States was incinerated. However, public health studies showed that waste incineration contributed to smog and other harmful air pollution, and in 1997, the EPA published regulations reducing emissions from medical waste incinerators. Even with these regulations, medical waste incineration continued to be the third leading source of dioxin emissions and the fourth leading source of mercury emissions in the United States.

The EPA continued to revise its medical waste incineration regulations in response to public health concerns, with the most recent revisions promulgated in 2013.

Elizabeth Ann Glass Geltman

See Also: Centers for Disease Control and Prevention; Dioxin Pollution; Environmental Protection Agency; Hazardous Waste Disposal; Mercury Pollution; Occupational Safety and Health; Occupational Safety and Health Administration; Resource Conservation and Recovery Act; Waste Incineration

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MERCURY POLLUTION

Mercury is a dense element that occurs naturally throughout the world, either in elemental form or in chemical compounds. In its elemental form, it is the only metal that occurs as a liquid. It has been known since antiquity for a variety of uses, such as making mirrors (due to its reflective properties), extracting gold, and a component in medicines. It is most commonly known for its use in thermometers. Mercury can be highly toxic.

Mercury can enter the environment in several ways. It can be released naturally during volcanic activity and by the weathering and erosion of rocks containing mercury and mercury compounds. Additionally, it is present in many (particularly older) manufactured products and can be released when those products are disposed of. Mercury can also be a by-product of industrial processes, including the burning of coal in electric power plants.

Mercury can be very toxic in the environment, and human exposure should be avoided. In aquatic environments, microorganisms can transform mercury into methylmercury, which is a more bioavailable form. Methylmercury is a persistent, bioaccumulating, and toxic substance, which means it persists and magnifies in the food chain and can build up to concentrations high enough in fish and shellfish to be toxic to humans.

Exposure to mercury appears to be predominately via inhalation, while exposure to methylmercury tends to be through diet. There are a wide variety of health effects to humans from mercury and methylmercury, including fetal damage, impacts to childhood development and learning, and various forms of toxicity to adults, including damage to the nervous system. Some symptoms of acute or prolonged exposure include tremors, emotional changes, headaches, and poor performance on tests of mental function. In animals, mercury exposure can cause reduced reproduction, slower growth and development, and abnormal behavior.

One of the most recognized cases of mercury poisoning occurred in Japan and came to be known as Minamata disease. Mercury discharged into Minamata Bay from an industrial source was taken up by the fish and shellfish, which were then eaten by people living along the bay. The first case was noted in 1956, with more cases identified throughout the 1960s. The observed health effects included paralysis and death. Another case occurred in 1965 at a different location in Japan, which was also linked to mercury contamination from an industrial source. The health effects among the Japanese remained long after exposure ended.

Mercury fish consumption advisories remain in place throughout the Great Lakes region of the United States and Canada. Numerous actions to reduce mercury pollution have been underway for a number of years, ranging across local, state/provincial, federal, and binational levels. Work at the federal level has included rules on incineration sources (e.g., municipal and medical waste), rules pertaining to certain industrial sources (e.g., chlor-alkali plants), and more recently, rules addressing mercury and other toxic chemicals from coal-fired power plants. Federal and state laws and rules have restricted mercury use in many products over the past three decades, including paints and batteries, and other programs (e.g., environmentally preferable purchasing) have led to reduced use of mercury-containing products in health care and other fields. Ongoing research, monitoring, assessment, and outreach work around mercury have been carried out through various initiatives over the past decade, including the U.S. Great Lakes Restoration Initiative, and additional work is being carried out under the amended Great Lakes Water Quality Agreement, including an assessment for the International Joint Commission highlighting the continued importance of atmospheric deposition of mercury in the Great Lakes and the need to address mercury sources, both near and far.

Thomas B. Lawrence

See Also: Electric Power Generation, Health Implications of; Fish Consumption Advisories; Great Lakes Pollution; Heavy Metal Pollution; Minamata Disease; Persistent, Bioaccumulating, and Toxic Chemicals

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MINAMATA DISEASE

Minamata disease is a form of poisoning that causes severe damage to the central nervous system among people exposed to methylmercury by eating contaminated fish and shellfish. The contamination occurred when methylmercury in wastewater was released into the environment from industrial facilities and accumulated in marine life. The first outbreak of Minamata disease was reported in 1956 in the town of Minamata in southern Japan, followed by a separate outbreak (known as Niigata Minamata disease) nine years later in the northern Japan town of Niigata.

Methylmercury is a highly potent neurotoxin. The symptoms of poisoning include numbness in hands and feet, ataxia (inability to control muscles in arms and legs), loss of peripheral vision, damage to hearing and speech, excruciating pain, paralysis, coma, and even death. Methylmercury is known to be passed from pregnant mothers to unborn babies, causing congenital Minamata disease, a condition resembling cerebral palsy. There is no cure for Minamata disease, and the treatment options are limited to symptom management and functional rehabilitation. The total number of Minamata disease victims is estimated between 20,000 and 30,000.

The best known pollution source of Minamata disease was the Minamata Plant of Chisso Corporation, which had regularly discharged industrial wastewater contaminated with methylmercury from its acetaldehyde production line into Minamata Bay and the Minamata River over a period of 36 years, between 1932 and 1968. The beginnings of this environmental pollution and its health consequences were insidious, but gradually, people started noticing worrisome indications: sightings of dead fish and the general disappearance of fish and shellfish from the bay, reports of cats and dogs acting strangely and unexpectedly dying, and rumors of people afflicted with a strange disease. Cats were especially susceptible, and the term "dancing cat fever" was coined by local citizens to describe the agonizing jerky movements of cats that had eaten contaminated seafood. Despite increasing suspicion and accusations, Chisso Corporation initially denied any link between the wastewater from its plant and these incidents.

The first cases of Minamata disease in humans were officially recognized in 1956 when Dr. Hajime Hosokawa (1901–1970), the Chisso hospital director, reported an epidemic of an unknown central nervous system disease to the local public health office. Even when its own internal toxicology data conclusively linked their wastewater to methylmercury poisoning, the Chisso Corporation chose to hide this information from the public. Chisso Corporation operated their facility for another 12 years before discontinuing the operation in 1968 when acetaldehyde production was no longer profitable. In that same year, the Japanese government belatedly announced its official determination linking the methylmercury contamination from the Chisso Minamata plant with Minamata disease.

At the center of the controversy surrounding Minamata disease, continuing even today, is the victim certification program. The program started in 1959 and was formalized in 1969 under Japan's Law Concerning Special Measures for the Relief of Pollution-Related Health Damage. When certified, victims become eligible for free medical care, pensions, and lump-sum compensation payments. However, critics point out that the program, in spite of numerous revisions, has been too restrictive, and the burden of proof is too high for many victims in need of assistance. The Japanese Supreme Court agreed with the critics in 2014, ordering the government to be less restrictive in compensating victims. Even so, the total number of certified victims to date remains less than 3,000.

Efforts to control contaminated seafood started in the mid-1950s, including bans on the sale of contaminated seafood, self-imposed fishing restrictions by the fishing industry, a Chisso Corporation buyback program to purchase contaminated fish, and the installation of nets to block contaminated fish from leaving Minamata Bay. These efforts were fueled by economic interests of the local fishing industry along with local health concerns. However, with 77 to 165 tons (70 to 150 metric tons) of mercury remaining in the sedimentary sludge at the bottom of Minamata Bay and surrounding waters, the control efforts were only partially effective. In some areas, the contaminated sludge reached 13 or more feet (4 or more meters) deep. In a 1977 survey, the concentration of mercury in some sludges approached an extremely high level (7,700 parts per million [ppm]).

The environmental restoration of the Minamata Bay and surrounding waters, mainly by dredging the bottom to remove contaminated sludge, started in 1977. In heavily contaminated areas, the contaminants were contained by covering the area with heavy metal sheets. When the restoration project was finished in 1988, the highest concentration of mercury detected in the sludge was 14.7 ppm, which was below the 25 ppm level established by Japanese environmental officials as the restoration goal.

The programs to assist and compensate the Minamata disease victims, as well as various pollution prevention and environmental restoration programs, have been financed jointly by the polluters (Chisso in Minamata and Showa-Denko in Niigata), city and prefectural governments, and the Japanese government. Additionally, the prefectural and national governments created the National Institute for Minamata Disease in 1977 as the hub for medical research focusing on Minamata disease and public education. The institute is designated a World Health Organization cooperative research center for studying the health effects of organic mercury.

Yoko S. Crume

See Also: Environmental Toxicology; Fish Consumption Advisories; Mercury Pollution; Neurotoxicants; Water Pollution; World Health Organization

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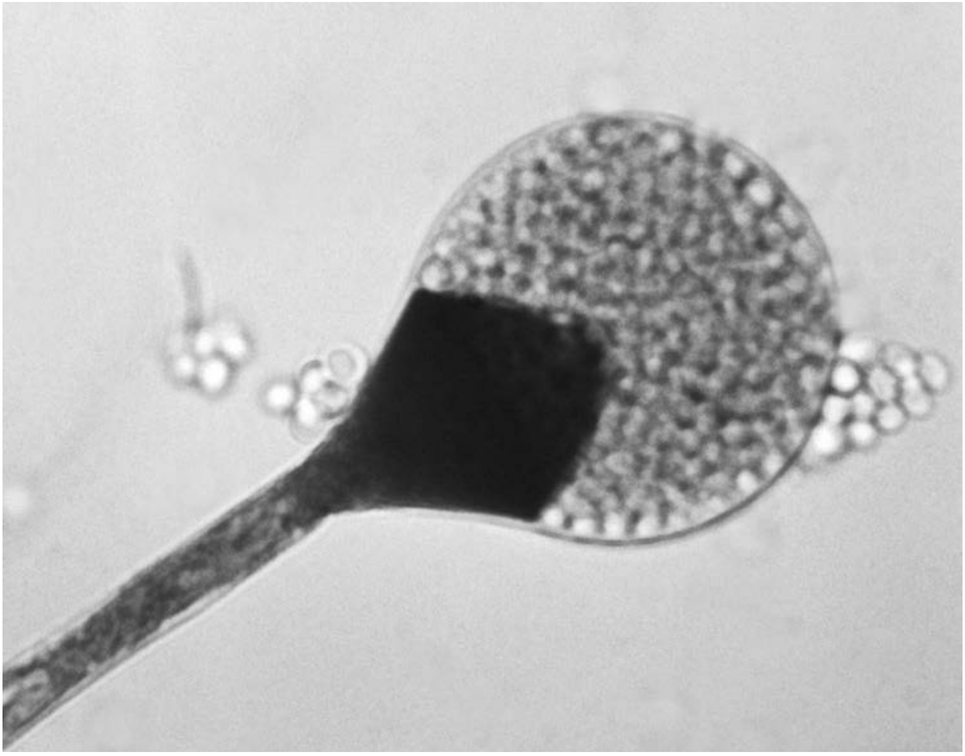
MOLD AND DAMPNESS

Mold is a naturally occurring substance that can be found almost anywhere and cause a variety of adverse health effects, depending on the sensitivity of the exposed individual. Mold concentrated inside a building, particularly in damp areas, can increase exposure and worsen adverse health effects. Common human reactions to mold exposure include an itchy throat or ears, hives, sneezing, runny or stuffy nose, and eyes that are swollen, itchy, or watery. Highly sensitive individuals can develop atopic conditions, such as eczema, allergies, and asthma.

A variety of mold species can trigger allergic symptoms, including rhinitis, wheezing, chest tightness, and difficulty breathing. Rhinitis, the inflammation of mucous membranes inside the nose, is a common nonspecific symptom of mold exposure. Adverse health effects can occur from both chronic and acute exposures to mold. Populations at particular risk are those that have experienced recent flood damage in their homes or workplaces, and children in general, who are more susceptible to the effects of mold than adults.

Exposure to a variety of mold species, including *Cladosporium, Penicillium, Mucor, Aspergillus*, and *Alternaria*, has been associated with the exacerbation of asthma. (When asthma worsens due to mold exposure, the reaction may be called a mold allergy.)

The likeliness of mold causing an asthmatic episode varies with location. For example, spending time in a damp, mold-infested room, such as a basement or an attic with a leaky roof, leads to increased risk of mold-induced asthma attacks. In addition to exacerbating asthma, mold can sometimes lead to the initial onset of asthma, particularly in damp, indoor environments. Populations exposed to mold are twice as likely to develop asthma as those not exposed.



Magnified view of a mold spore. Indoor molds can cause a variety of respiratory and skin infections. (Centers for Disease Control and Prevention/Lucille K. Georg)

Other serious health conditions triggered by mold exposure include allergic bronchopulmonary aspergillosis (a strong response of the immune system, causing dilation of the airways) and hypersensitivity pneumonitis (an inflammation of the alveoli). Inhaling or ingesting mold can also lead to fungal infections that may be difficult to treat. And sometimes mold metabolized by the human body may form toxic compounds known as mycotoxins, which cause chronic effects that persist from months to years, depending on the severity of exposure.

Based on the extent of the mold contamination, there are several ways to remove mold and remediate buildings infested with mold. The two simplest ways to remove mold are damp wiping and wet vacuuming. Damp wiping is the best option for everyday mold and small areas where mold grows following a flood, leak, or plumbing problem. Damp wiping involves scrubbing a surface with water, detergent, or both. Once damp wiping is complete, the surface must be thoroughly dried to prevent mold from growing back. For surfaces with larger swaths of mold, wet vacuuming can be used in conjunction with damp wiping to remove basic mold contamination. (Wet vacuuming can only be used on surfaces that are still wet.) For severe mold contamination of building material (e.g., a wall or ceiling), the only option may be to completely remove and replace the material.

Disposal of mold-contaminated materials must follow environmental guidelines to protect workers doing the removal as well as those handling the garbage. Protections include (1) putting the mold-contaminated materials in large, thick garbage bags that can hold a large volume without breaking; (2) placing a warning label on the bag, indicating it contains hazardous material; and (3) notifying the removal company that they are handling a hazardous substance. Of course, specific disposal requirements can differ by locality.

Preventative measures should be taken whenever possible to avoid or minimize mold growth so that remediation is not necessary. Because mold grows in places with high humidity, keeping humidity levels low (below 50 percent) in homes, offices, and other buildings will reduce mold growth. Additionally, mold growth can be reduced or prevented by regular heating and air-conditioning equipment maintenance (including routine cleaning and filter replacement), repairing leaks as soon as they are found, cleaning damp or wet spots immediately following discovered leaks, and venting kitchens, bathrooms, and equipment like clothes dryers.

Mold represents a serious public health concern that should be addressed immediately. It is especially important as a preemptive measure to help those with asthma or allergies avoid having adverse episodes.

Elizabeth Ann Glass Geltman and Adam Hess

See Also: Allergens in the Environment; Asthma; Children's Environmental Health; Naturally Occurring Toxins

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MUNICIPAL SOLID WASTE MANAGEMENT

Municipal solid waste (MSW), otherwise known as garbage, is a mixture of a wide variety of household and commercial wastes. MSW in the United States, before any recycling, has the following average composition:

- Paper (26.6 percent of total)
- Food (14.9 percent of total)

- Yard trimmings (13.3 percent of total)
- Plastics (12.9 percent of total)
- Rubber, leather, and textiles (9.5 percent of total)
- Metals (9.0 percent of total)
- Wood (6.2 percent of total)
- Glass (4.4 percent of total)
- Other (3.2 percent of total)

Paper, food products, yard trimmings, and plastics make up almost 70 percent of MSW. If properly handled, MSW ordinarily does not present a significant health hazard. However, potential groundwater contamination and toxic air emissions at landfills remain concerns for people living in close proximity to these facilities, as do toxic air emissions at waste incinerators.

Around the time of World War II, American cities began switching from less healthy methods of garbage disposal (e.g., open burning in dumps and use as farm animal feed) to so-called sanitary landfills, where the garbage was capped (i.e., contained) under a layer of soil. At first, there was not much of a difference between a landfill and an open garbage dump other than the landfill's thin cap. However, various health issues associated with landfills have led to tighter regulatory practices over the past 50 years. Many older landfills became toxic Superfund sites by the 1980s, as the U.S. Environmental Protection Agency (EPA) began closing down hundreds of landfills and issuing more stringent standards to make landfills safer to nearby communities.

Today, most landfills are considered safe, although health concerns continue to arise in nearby communities from time to time. Complaints commonly include headaches, respiratory and gastrointestinal problems, objectionable odors, throat and eye irritation, and stress caused by living in close proximity to the facility. Some scientists and government agencies are also concerned about toxic air pollutants coming from landfills that could potentially cause more severe health problems, including cancer. When a garbage truck reaches a landfill, the wastes are sorted and screened for any toxic or hazardous materials, such as paints, cleaning chemicals, motor oil, batteries, and pesticides, which must be handled separately

Garbage Trucks Fueled with Garbage?

Landfill gas is already being used as a fuel to produce useful heat or electricity. What if landfill gas were converted to compressed natural gas and used to power garbage trucks? It is estimated that the average landfill could power a fleet of up to 40 natural gas-powered garbage trucks while reducing pollutants that would otherwise be emitted from diesel-powered trucks. Although the technology exists today, vehicle modifications and refueling infrastructure would be needed to realize such a goal.

and possibly taken elsewhere for processing. Some of these materials, like batteries, can be recycled.

What happens to MSW once it is placed in a landfill? The wastes begin to degrade, the rate and extent depending on the type of waste and landfill design. Some materials deteriorate quickly, while others may take decades or even centuries to break down. During this process, landfills create two major by-products: gas (mainly methane and carbon dioxide), which rises to the top, and a liquid called leachate, which sinks to the bottom.

The methane and carbon dioxide emitted from landfills are generally not a health concern, although they both contribute to climate change. Because methane is a combustible fuel, landfill gas can be converted to compressed natural gas or hydrogen or channeled to waste-to-energy plants, which are basically combustors that recover energy to produce useful steam or electricity. As of 2016, there were 648 sites converting landfill gas into energy, and the EPA estimates there are another 400 landfill sites that are good candidates for such purposes. Landfill gas may also contain small quantities of hydrogen sulfide (which smells like rotten eggs), ammonia (which smells like decaying fish), and various toxic compounds that have the potential to cause more serious, long-term health problems. The toxic leachate created by landfills can also present a health concern if it breaks through the liner and contaminates groundwater or gets into nearby surface water.

Although Americans are recycling more waste materials than ever before, progress has been slow. The EPA estimates that the United States recycles only about one-third of its MSW, and that number may be overstated due to inexact data collection methods. The recycling rates for lead-acid batteries (98.9 percent) and corrugated boxes (89.5 percent) are high, with tires (40.5 percent), glass containers (32.5 percent), and plastic bottles and jars (about 30 percent) at the other end of the spectrum. On average, about half of all aluminum beer and soda cans are recycled. Although recycling rates are improving, increases in population and consumption mean that the quantity of solid waste continues to increase.

MSW is increasingly used for composting. Specifically, organic waste material, such as food scraps and yard trimmings, can be processed and stored under conditions that cause it to decompose. Eventually, the compost can be used as a natural fertilizer. The composting of MSW may be more complicated than it first appears. For example, the waste materials vary widely in size, composition, and moisture and nutrient contents, and wastes unsuitable for composting (including some potentially toxic or hazardous materials) may also be mixed in. Sophisticated technology is required to separate out and process compostable materials that are safe for use in gardens and on agricultural lands.

Aaron Dorman

See Also: Carbon Dioxide and the Carbon Cycle; Composting, Health Benefits of; Environmental Protection Agency; Groundwater Pollution and Depletion; Hazardous Air Pollutants; Hazardous Waste Disposal; Odor Pollution; Open Burning of Waste; Recycling; Respiratory Disease and Air Pollution; Superfund Act; Waste Incineration

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NANOMATERIALS

Nanomaterials are defined by their size, requiring one dimension of the particle to be less than 100 nanometers. (A nanometer is equivalent to one-billionth of a meter.) Although there are many natural particles that fall within the definition of nanomaterials, the particles of concern are those engineered specifically on the nanoscale. These nanomaterials have unique properties that are different from the original bulk materials. For example, engineered nanomaterials can affect chemical reactivity, electrical properties (e.g., conductivity and fluorescence), magnetism, optical properties (e.g., color and transparency), and physical properties (e.g., hardness, strength, elasticity, and melting and boiling points). These engineered properties can be useful for different applications, but they can also introduce health issues.

One important characteristic of the small size of nanomaterials is increased relative surface area per unit of mass, which leads to greater reactivity that can be harnessed for medical and environmental applications, such as drug delivery, improved catalysts, and water purification. However, this greater reactivity can also result in harm to living cells. Other important nanomaterial characteristics are shape, type of material, surface charge, and surface coating, all of which can impact both the fate of the nanomaterials as well as their toxicity. The most common nanomaterials are composed of silver, zinc oxide, titanium dioxide, and carbon-based materials, including carbon nanotubes, fullerenes, and buckyballs. Many nanomaterials are coated to enhance their stability in the environment and to prevent aggregation with other nanomaterials or naturally occurring particles.

Engineered nanomaterials are currently being used in many consumer and industrial applications, which can result in direct and indirect releases to the environmental release. Unfortunately, there is not a full understanding of the implications of such releases. The antimicrobial behavior of nanomaterials is one of the main reasons for their use in consumer products and medical applications. These consumer products include personal care products as well as clothing, both of which likely result in nanomaterials being released into surface waters during normal use and disposal. (Researchers have documented the release of nanomaterials from socks during simulated washing.) Nanomaterials are also increasingly used for environmental cleanup of contaminants in soil and water, resulting in direct release to the environment. Weathering over time releases nanomaterials found in outdoor paints into surface waters. Additionally, accidental releases into the environment would be expected during manufacturing, use, and disposal of nanomaterials and products containing nanomaterials.

Once in the environment, many potential transformations of nanomaterials are likely to occur, including oxidation, reduction, photochemical reactions, dissolution, and aggregation. Nanomaterial fate and transport in the environment are also impacted by properties of the media (e.g., pH, temperature, humidity, ionic strength, and the presence of other particles). Dissolution of nanomaterials can result in the release of toxic-free metals into the environment. While increased aggregation will likely result in nanomaterial settling out of suspension, the smaller, more stable particles will remain suspended longer and travel farther in air and water.

Researchers have demonstrated nanomaterial uptake by aquatic organisms as well as terrestrial plants. Uptake into cells may occur through active mechanisms, such as phagocytosis, or by passive pathways, such as diffusion. In vitro laboratory studies with a range of mammalian and human cell lines indicate that exposure to nanomaterials can result in cell death, oxidative stress, cell dysfunction, DNA damage, increased immune response, and physical impairment. While oxidative stress appears to be the main route of toxicity, nanoparticles may also act as Trojan horses because their small size allows them to enter cells, release free ions, and deceptively cause other harmful reactions. In vivo experiments indicate the uptake and accumulation of nanomaterials, and other research demonstrates that trophic transfer is possible, resulting in nanomaterials accumulating up the food chain.

Humans may be exposed to nanomaterials via contaminated air inhalation and ingestion of contaminated water and food. Research is ongoing regarding the health effects of exposure to nanomaterials in humans and other organisms, particularly at the trace concentrations predicted in the environment. Additional studies are investigating the effects of mixtures of nanomaterials and the nanomaterial properties leading to the greatest toxicity.

Talia E. Abbott Chalew

See Also: Bioaccumulation of Environmental Contaminants; Heavy Metal Pollution; Particulate Matter and Bioaerosols Pollution; Personal Care Products, Health Issues with

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NATIONAL AIR TOXICS ASSESSMENT

The National Air Toxics Assessment (NATA) is a program of the U.S. Environmental Protection Agency (EPA) to assess nationwide health risks from exposure to hazardous air pollutants, also known as toxic air pollutants, or simply, air toxics. Air toxics are air pollutants that may cause or contribute to cancer or other serious adverse health problems, including cardiovascular, immune system, kidney, liver, neurological, reproductive, and respiratory effects. Air toxics can also adversely affect ecology and the environment.

The goal of NATA is to identify the air toxics, emission sources, and source locations representing the greatest concern to public health. This information is then used by air pollution experts and agencies to focus resources on the populations at greatest risk for adverse health effects. Because resources (e.g., funds, agency experts, and field technicians) are often limited for air pollution research and control, NATA helps set priorities and direct air pollution professionals toward the emissions and sources presenting the greatest threat.

NATA allows the risk of cancer and other adverse health effects to be estimated, based on the amount of pollutants inhaled, duration of exposure, and toxicity of the pollutants. Because of uncertainties inherent in determining exposure and toxicity, NATA risk estimates are just that—estimates. These risk estimates are not exact, and for this reason, NATA analyses are usually designed to err on the side of safety. This means that NATA is more likely to overestimate health risk than to underestimate it.

Three examples of the types of air pollutants found in NATA assessments are benzene (present in gasoline), tetrachloroethylene (a solvent sometimes used in dry cleaning), and methylene chloride (an industrial solvent and paint stripper). A total of 187 air toxics are identified in the Clean Air Act, and these are emitted from electric power plants, various industrial and commercial operations, and mobile sources (e.g., cars and trucks). When the EPA uses NATA to estimate risk associated with these pollutants, the results are ordinarily reported at the census tract level.

There are some important limitations to keep in mind when using NATA data. NATA provides information on exposure and risk across broad geographical areas, and it cannot be used to estimate exposure and risk for specific individuals or small regions, such as specific census blocks or areas immediately surrounding a particular industry. Furthermore, the assessments generally use emission data averaged over a year and thus do not estimate short-term risks and acute exposure scenarios. Not all possible air toxics are included in NATA assessments, and the effects of mixtures of air toxics are difficult to evaluate. There are also limitations in the accuracy of computer models, exposure assumptions, and emission inventory data, and episodic emissions are not considered (e.g., higher emissions from certain industrial equipment during periods of startup, shutdown, and malfunction). Finally, NATA does not consider exposure occurring indoors or from ingestion or dermal contact.

Although there are a number of limitations to the use of NATA assessments, they are still very useful for several purposes, including:

- prioritizing pollutants and emission sources for further investigation and control;
- identifying geographical locations for further investigations;
- providing a starting point for more detailed local investigations;
- helping with the placement of air pollution–monitoring equipment; and
- empowering citizens and local governments to make decisions concerning pollution sources and health threats.

When the EPA conducts a NATA assessment, the first step is to create an inventory of emission sources. With this information, sophisticated computer models are used to estimate air toxic concentrations in the ambient air and the population exposed to these concentrations. This work is done on a nationwide basis so that estimates can be made for all regions of the United States. The final step is to characterize the potential inhalation health risks for these regions. NATA assessments are published every few years, with the intervening years needed to analyze data. Thus, the NATA assessment for 2011 was not released to the public until 2015. Other assessments are available for the years 1996, 1999, 2002, and 2005, and the EPA is currently compiling data for future assessments.

When characterizing the possibility that someone in a population might develop cancer due to exposure to air toxics, the EPA often uses a probability calculation. For example, a cancer risk of 1-in-1-million indicates the possibility that one person would develop cancer out of every 1 million people exposed to the same concentration of the same pollutant over the same timeframe. This is generally considered an upper-bound estimate because it assumes a constant exposure, 24-hour per day, over 70 years, whereas people actually move around during the day and often relocate their homes to other neighborhoods or cities. Thus, this approach may be overly protective based on the level and duration of exposure. On the other hand, the estimate does not take into account exposure to other air toxics that may be present or whether a person is more vulnerable to exposure due to factors such as age or preexisting conditions.

The question of what level of cancer risk is acceptable or unacceptable is controversial, although the EPA has made case-specific determinations for some regulatory programs. For health risk other than for cancer, case-specific determinations are also made. Factors considered include confidence in the underlying health and dose-response data, uncertainties inherent in calculations and modeling, the level and duration of exposure, and the hazard quotient (the ratio of the actual exposure level to the level where no adverse health effects are expected).

The 2011 NATA assessment indicates that millions of Americans live in areas where air toxics may present potential health concerns and that, on average, about 1 of every 25,000 Americans (i.e., 40-in-1-million) could develop cancer associated with air toxics if exposed over 70 years. The assessment found that formaldehyde, benzene, and acetaldehyde contribute the most to nationwide cancer risk, and acrolein, diesel particulate matter, and chlorine contribute the most to nationwide health risk other than cancer. (The cancer risk assessment did not evaluate the contribution of diesel particulate matter.) However, for the reasons described earlier, there are considerable uncertainties in the NATA assessments, and caution should be exercised in applying the results and drawing conclusions.

Richard Crume

See Also: Air Pollution; Cancer Risk from Environmental Exposure; Clean Air Act; Dose-Response Assessment; Environmental Protection Agency; Hazardous Air Pollutants; Integrated Risk Information System

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NATIONAL CENTER FOR ENVIRONMENTAL ASSESSMENT

The National Center for Environmental Assessment (NCEA) is one of seven research centers and laboratories making up the Office of Research and Development at the U.S. Environmental Protection Agency (EPA). The NCEA's aim is to inform researchers, regulators, and members of the public about the potential effects that common pollutants and other stressors can have on human health and the environment. Through the integration of research and risk assessments, the NCEA provides technical reporting leading to a better understanding of the impact of exposure to environmental pollutants.

The NCEA is divided into four divisions and an Immediate Office (IO). The IO, located in Arlington, Virginia, manages all assessment programs in NCEA, including the Human Health Risk Assessment (HHRA) and Global Change programs. The HHRA program is largely responsible for providing peer-reviewed human health assessments related to chemicals that are already present in the environment. The Global Change program uses a systematic approach to make vulnerability assessments regarding the future impacts of climate change on ecosystems, human health, and air and water quality.

The Cincinnati Division is responsible for developing the methods that drive the assessments used to determine the risks that certain pollutants pose to human health and the environment. This office also performs assessments of the toxicity found in chemicals for the Integrated Risk Information System (IRIS) program.

In the IRIS Division, which is run out of Arlington, Virginia, and Durham, North Carolina, staff members focus on developing peer-reviewed assessments of pollutants relating to EPA's regulatory mandates. These IRIS assessments are used throughout the EPA and other organizations around the world to inform regulatory action. The IRIS database is made up of over 550 assessments that can be accessed and searched by the public using chemical names, Chemical Abstract Services Registry Numbers, or keywords.

The Research Triangle Park Division, located in Durham, North Carolina, focuses on developing integrated science assessments (ISAs). Starting in 2008, these ISAs have been used for reviewing the National Ambient Air Quality Standards (NAAQS), which were established by the Clean Air Act Amendments of 1990. These standards were implemented to protect the public from six criteria pollutants—carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. The ISAs, representing evaluations of the most current scientific knowledge available, are essential to keeping the NAAQS up to date.

Another major initiative of the NCEA is the administration of HERO (Health and Environmental Research Online). HERO is a database of over 600,000 references to peer-reviewed scientific literature and data that are used by EPA researchers to inform regulatory and policymaking activity. The HERO database is part of the EPA's efforts to comply with the Obama administration's Memorandum on Transparency and Open Government. All citations from the HERO database are made publicly available for members of the public to actively participate in the rulemaking process. HERO staff members solicit members of the public to suggest additional studies to be included in the assessment process. Citations are generated from highly comprehensive and complex literature searches conducted by HERO personnel.

Anthony C. Holderied

See Also: Ambient Air Quality; Clean Air Act; Environmental Protection Agency; Integrated Risk Information System

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NATIONAL ENVIRONMENTAL POLICY ACT

The National Environmental Policy Act (NEPA) requires federal agencies to assess the environmental and related social and economic effects of their proposed actions and to invite public review and comment on those assessments. Airports, federal buildings, military complexes, and highways are examples of projects ordinarily subject to NEPA review. NEPA was signed into law in 1970, and it applied to all federal agencies.

NEPA established the Council on Environmental Quality, which has three major duties: (1) ensuring federal agencies meet the requirements of NEPA, (2) providing oversight for the environmental impact assessment process, and (3) developing regulations and guidance for agencies complying with the provision of the act. (Many agencies supplement the CEQ regulations and guidance with their own internal NEPA procedures.) NEPA also requires federal agencies to take steps to ensure humans and nature exist in harmony and to include environmental considerations in their planning and decision-making processes. To consider the environmental consequences of a significant action, a federal agency may be required to prepare an environmental assessment (EA) and environmental impact statement (EIS).

A federal action can be categorically excluded from having to perform a detailed environmental analysis if the action is determined not to have a significant effect on the human environment. If not categorically excluded, the agency prepares an EA, which assesses whether the action has the potential to cause significant environmental effects. If no significant environmental effects are expected, the agency issues a finding of no significant impact, providing the rationale for this conclusion. On the other hand, if the EA determines that the action is expected to significantly affect the quality of the human environment, an EIS is prepared.

The steps to preparing an EIS include the following:

- Publishing a notice of intent in the *Federal Register* that notifies the public about plans to conduct an environmental analysis and how to get involved in the process
- Conducting a scoping process, where issues and potential alternatives are identified
- Publishing a draft EIS for public review and comment
- Considering all substantive public comments and conducting any additional analyses justified by the comments
- Publishing the final EIS
- Issuing a record of decision that explains the agency's final decision and alternatives considered and presents a plan for any mitigation and monitoring requirements

If a supplement to the EIS is required due to new circumstances or information justifying changes to the proposed action, the agency follows the same procedures required for approval of the initial EIS.

Federal agencies must consider environmental justice when complying with NEPA. The U.S. Environmental Protection Agency (EPA) defines "environmental justice" as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." The EPA has a special role under NEPA, which is to review and comment on the EISs prepared by other agencies, including environmental justice concerns, and to maintain an EIS repository. Additionally, the EPA must prepare EISs for its own actions.

In the years following NEPA enactment, a variety of environmental advocacy groups, law firms, consulting engineers, research organizations, and university researchers have come to specialize in NEPA actions and analyses, representing a small but significant segment of the environmental health field in the United States.

Richard Crume

See Also: Environmental Impact Assessment; Environmental Justice; Environmental Protection Agency

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NATIONAL ENVIRONMENTAL PUBLIC HEALTH TRACKING NETWORK

The National Environmental Public Health Tracking Network is a Web-based surveillance tool designed to track diseases related to environmental contaminant exposures. It is funded and managed by the U.S. Centers for Disease Control and Prevention's Tracking Network program. This online network of federal, state, and city surveillance systems enables users to query, chart, map, tabulate, and download standardized data on environmentally related diseases, environmental hazards, human exposures to those hazards, and population characteristics. Some individual surveillance systems include private portals where users can request access to confidential data for research purposes.

The Tracking Network was developed to fill an "environmental health gap" (i.e., the lack of standardized data to track and link environmental hazards with chronic diseases) identified by the Pew Environmental Health Commission in 2000. The list of Tracking Network indicators grows each year but currently includes measures to track (1) environmentally related chronic diseases (e.g., asthma, birth defects, cancer, childhood lead poisoning, developmental disabilities, and heart disease); (2) exposures to environmental hazards (e.g., exposure reports for pesticides and biomonitoring data for arsenic, benzene, cadmium, chloroform, cotinine, lead, mercury, naphthalene and pyrene metabolites, toluene, and uranium); (3) environmental hazards (e.g., air quality, water quality, toxic substances, and heat); and

(4) population vulnerability (e.g., vulnerability relative to climate change, community design, and housing and lifestyle risk factors). Funded programs may also track additional measures that are important to a state or city. For example, New York City's tracking system includes data on pedestrian and bicycle traffic-related injuries, and Maine's tracking system includes data on Lyme disease case rates.

Data from the Tracking Network have been used by researchers and government agencies to (1) facilitate data requests and analyses for epidemiologic studies that establish relationships between chronic diseases and environmental hazards; (2) support public health surveillance activities to identify at-risk populations and emerging threats and to respond to outbreaks; (3) inform and improve the public health basis for policy decisions, government planning, and prevention activities; (4) educate people about risks to their health and promote lifestyle changes; (5) support citizen rights to know about their environment and health; and (6) promote citizen involvement, oversight of polluters, and prompt industry compliance with environmental regulations.

As an example of the Tracking Network's public health relevance, Connecticut used the network to evaluate potential associations between excess cases of bladder cancer around a former manufacturing site and releases of asbestos, lead, and polychlorinated biphenyls. In South Carolina, Tracking Network staff worked with the state's occupational safety and health program to identify worksites with high rates of adult lead poisoning and to target them for inspection. Some Tracking Network programs have developed more advanced surveillance tools that are available for use with their tracking systems. For instance, California's Tracking Network staff developed a tool to identify high-traffic areas, and this tool is being used by San Francisco city planners to evaluate potential air contaminants near planned development projects.

The variety of surveillance tools and abundance of standardized data measures that are available in the Tracking Network make it a valuable information source and tool for researchers, communities, teachers, students, policymakers, and environmental and public health officials.

Adrienne L. Katner

See Also: Cancer Risk from Environmental Exposure; Environmental Epidemiology; Integrated Risk Information System; Socioeconomic Status and Health; Toxic Substances and Disease Registry, Agency for

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NATIONAL ESTUARY PROGRAM

The National Estuary Program (NEP) is a nonregulatory program administered by the U.S. Environmental Protection Agency (EPA). The NEP was authorized under the Clean Water Act to "protect and restore water quality and ecological integrity of estuaries of national significance." An estuary is a body of water partly surrounded by land where freshwater from rivers and streams meet and mix with saltwater from the oceans. Estuaries have characteristics of both freshwater and saltwater, and they represent one of the most fertile and productive ecosystems on the earth, providing habitat for a variety of wildlife.

The NEP is administered using a community-based approach. States identify nationally significant estuaries that are threatened by factors such as land use, development, and pollution, and then the EPA provides grants to develop management and restoration plans. Currently, there are 28 estuaries that have been identified as of national significance and participate in the NEP. These estuaries are listed in Table 10.

Table 10. Nationally significant estuary programs participating in the NEP.

Estuary Program Name
Albemarle-Pamlico National Estuary Program
Barataria-Terrebonne National Estuary Program
Barnegat Bay Partnership
Buzzards Bay National Estuary Program
Casco Bay Estuary Partnership
Charlotte Harbor National Estuary Program
Coastal Bend Bays and Estuaries Program
Delaware Center for the Inland Bays
Galveston Bay Estuary Program
Indian River Lagoon National Estuary Program
Long Island Sound Study
Lower Columbia Estuary Partnership
Maryland Coastal Bays Program
Massachusetts Bays National Estuary Program
Mobile Bay National Estuary Program
Morro Bay National Estuary Program
Narragansett Bay Estuary Program
New York-New Jersey Harbor Estuary Program
Partnership for the Delaware Estuary
Peconic Estuary Program
Piscataqua Region Estuaries Partnership
Puget Sound Partnership
San Francisco Estuary Partnership
San Juan Bay Estuary Partnership
Santa Monica Bay Restoration Foundation
Sarasota Bay Estuary Program
Tampa Bay Estuary Program
Tillamook Estuaries Partnership

Each estuary program develops and implements a Comprehensive Conservation and Management Plan that establishes long-term priorities and provides guidelines for environmental protection activities, funding, and research. These plans are developed and approved using a collaborative approach involving coalitions representing many stakeholders. Local priorities are established through consensus-building at management conferences, thus ensuring that unique plans are developed, tailor-made to address local conditions and needs.

The NEP is a critical program for protecting and restoring estuary ecosystems. It is also unique in terms of its coalition-building approach, which serves as a model for solutions to many other environmental challenges. This approach provides sustained cooperation among federal, local, and state governments and other stakeholders, ensuring that nation's critical estuaries are protected for future generations.

Ans Irfan

See Also: Clean Water Act; Ecosystems, Importance of; Environmental Protection Agency; Estuary Pollution; Stormwater Runoff; Wetlands and Healthy Waterways

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NATIONAL INCIDENT MANAGEMENT SYSTEM

The National Incident Management System (NIMS) is an approach used in the United States to manage emergencies, disasters, and other incidents that threaten life and property and require immediate response. The goal of NIMS is to provide a comprehensive national approach for managing incidents that improves the effectiveness of response for a wide range of possible threats and hazards. These include natural disasters like earthquakes and hurricanes, terrorist activities, and human-caused disasters such as accidental explosions and releases of toxic chemicals. NIMS is designed to address all U.S. threats and hazards, regardless of size, location, and complexity.

Incidents often involve multiple government jurisdictions and may require support from local agencies, nonprofit organizations, the private sector, and the federal government. When multiple agencies and organizations are involved, success depends on a common approach to sharing resources, integrating tactics, coordinating response activities, managing emergency personnel, and communicating with the public. NIMS provides this common approach by establishing a framework for coordination among all parties involved in a response so that the incident can be addressed in the most effective and efficient manner possible.

There are countless cases where the well-managed response to a serious incident has saved many lives.

The NIMS concept has evolved over the years, becoming more urgent in the aftermath of the September 11, 2001, terrorist attacks. Lessons learned by September 11 responders and public concerns about future attacks heightened awareness of the need for a system to standardize response structures, terminology, processes, and resources. Thus, NIMS was born several years later in 2004 by consolidating, expanding, and enhancing existing emergency response systems, policies, and guidelines.

To unify various emergency management and incident response programs across the United States, NIMS is designed around five focus areas:

- Command and Management: incident command, multiagency coordination, and public information systems
- Preparedness: planning, training, exercises, personnel qualification and certification standards, equipment acquisition and certification standards, and publication management processes and activities
- Resource Management: mechanisms and requirements to describe, inventory, mobilize, dispatch, track, and recover resources associated with an incident
- Communications and Information Management: standardized framework for communications, information management, and information-sharing
- Ongoing Management and Maintenance: strategic direction and oversight of NIMS, including routine review and continuous refinement

These components work together in an integrated manner to create a comprehensive incident response system that serves the entire country.

An important component of NIMS is the Incident Command System (ICS). The ICS is a management system that integrates the key response components—facilities, equipment, personnel, procedures, and communications—into a common organizational structure. The ICS concept is intended to help incident managers identify and manage critical response components, often during emergency conditions, without overlooking other important responsibilities. The ICS has been applied to many types of incidents, including hazardous material spills, natural disasters, serious fires, air and ground transportation system accidents, and search and rescue missions.

Although not part of NIMS, Congress passed related legislation in 1986 called the Emergency Planning and Community Right-to-Know Act (EPCRA), which requires state and local governments and private industry to plan and prepare for emergency releases of hazardous and toxic chemicals at industrial facilities and to make this information available to the community. The goal of the EPCRA is to improve the handling of chemicals and to protect public health and the environment. Among the EPCRA requirements are the preparation of emergency response and notification plans and safety data sheets. Additionally, the EPCRA establishes a toxics release inventory, to be compiled and maintained by the U.S. Environmental Protection Agency using data submitted by industries.

Richard Crume

See Also: Disaster Preparedness and Response; Emergency Planning and Community Right-to-Know Act; Environmental Protection Agency; Federal Emergency Management Agency; Natural Disasters; Safety Data Sheet; September 11 World Trade Center Attack; Toxics Release Inventory

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NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

The National Institute for Occupational Safety and Health (NIOSH) is charged with researching and recommending measures to prevent injury and illness for more than 150 million Americans in the U.S. workforce. Along with the Occupational Safety and Health Administration, NIOSH has played a leading role in providing a safe and healthy workplace environment, which protects workers and strengthens families and communities. Additionally, by reducing lost workdays due to injury and illness, a healthy workforce helps companies be more competitive.

NIOSH Vision

Safer, healthier workers

NIOSH Mission

To develop new knowledge in the field of occupational safety and health and to transfer that knowledge into practice.

NIOSH was created by the 1970 Occupational Safety and Health Act, and it is part of the Centers for Disease Control and Prevention. Because of their multidisciplinary work, NIOSH hires experts from a wide range of professions, including chemistry, economics, engineering, epidemiology, industrial hygiene, medicine, nursing, psychology, safety, and statistics. NIOSH consults with private and public partners to identify the most important workplace safety and health issues, and then it pursues research aimed at finding solutions, including innovative technologies, protocols, and training materials.

NIOSH research covers the following areas:

- Agriculture, Forestry, and Fishing: Accomplishments include reducing child death rates from agricultural worksite risks, reducing fatalities from tractor rollovers, and helping the commercial fishing industry adopt lifesaving personal flotation devices.
- Construction: Projects include investigating the causes of falls and electrical hazards, studying musculoskeletal disorders in the construction industry, and examining health threats such as noise, asphalt fumes, silica dust, and welding fumes.
- Health Care and Social Assistance: In partnership with other organizations, NIOSH has helped to improve facility designs to minimize risks, and researchers have developed safe patient handling guidance to protect nurses from musculoskeletal disorders.
- Manufacturing: NIOSH's educational materials and programs have reduced injuries and fatalities from contact with equipment, falls, and other exposures, and NIOSH is actively pursuing worker safety and health issues in the new field of nanotechnology.
- Mining: Workers have benefited from NIOSH involvement with engineering controls to reduce mining noise levels, proximity detectors for mining equipment, LED lighting in miner caps, self-contained emergency oxygen devices, improved communication systems, training materials, and response protocols.
- Oil and Gas Extraction: NIOSH researchers have helped address the major causes of injury and illness among oil and gas extraction workers, including preparing training videos and safety checklists, and NIOSH is working with partner organizations to control silica exposure during hydraulic fracturing operations.
- Public Safety: NIOSH has prepared a large volume of literature and educational materials on safety and health in the law enforcement and wildland firefighting fields, and research has been conducted on integrating psychological, physiological, and subclinical measures of stress, disease, and mental dysfunction associated with policing.
- Services: For workers in the service industry, including hotels and fast-food restaurants, NIOSH has studied safety and health issues and prepared hazard evaluations, and other research has focused on health risks in the education sector.
- Transportation, Warehousing, and Utilities: Projects include developing guidance for commercial truck drivers, conducting research on safety ordinances for violence against taxi drivers, reducing the risk of musculoskeletal disorders among package drivers and airport baggage handlers, and establishing the Center for Motor Vehicle Safety.
- Wholesale and Retail Trade: Products developed include keyboards to improve work posture and a video to help identify risk factors for workplace violence, and research has resulted in nonskid mats being installed for warehouse workers handling liquids and in improved dust exhaust hoods at lumber stores.

America's population is aging, and it is estimated that by the year 2020, about one quarter of all workers will be over the age of 55. These changing demographics demand a new focus on the safety and health of an aging workforce. To address these concerns, NIOSH created the National Center for Productive Aging and Work (NCPAW), with the goal of promoting lifelong well-being for all workers and supporting productive aging throughout one's working life.

The NCPAW helps organizations identify interventions and strategies to promote safety and health for workers of all ages. Several strategies known to be effective as workers grow older are (1) encouraging workplace flexibility, particularly with regard to work schedule and location; (2) matching tasks to individual strengths and recognizing that some older workers thrive in self-paced work environments with fewer repetitive tasks; (3) avoiding or reducing sedentary work and providing, for example, sit/stand or walking workstations and breaks for physical activity; (4) providing optimal illumination and ergonomically designed workstations, chairs, and tools; (5) encouraging multigenerational teamwork, taking advantage of the insight and problem-solving experience of older employees; (6) providing training for all ages, including guidance for older employees in adapting to new technologies; and (7) encouraging return-to-work programs and reasonable accommodation following illness or injury.

Richard Crume

See Also: Centers for Disease Control and Prevention; Occupational Safety and Health; Occupational Safety and Health Administration

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NATIONAL INSTITUTE OF ENVIRONMENTAL HEALTH SCIENCES

The National Institute of Environmental Health Sciences (NIEHS) is one of 27 research institutes that make up the National Institutes of Health, part of the U.S. Department of Health and Human Services. The NIEHS is located in Research Triangle Park, North Carolina, and is focused on studying the impact that the environment has on human health.

One of the main research organizations at the NIEHS is the Intramural Research Division (IRD). This division consists of 11 branches and laboratories that conduct research on wide-ranging areas, including epidemiology, epigenetics, genomics, neurobiology, reproductive and developmental biology, and biostatistics. The IRD also houses the Clinical Research Branch, which is active in studying the interactions between genetic susceptibility and environmental factors in human disease. This branch is involved in identifying at-risk populations and developing strategies to prevent and treat disease. Additionally, it supports multiple research groups within the institute that are tasked with researching the impact of environmental conditions on a variety of common health problems, including asthma, cardiovascular diseases, and cancer.

The National Toxicology Program (NTP), headquartered at the NIEHS, is a federal interagency program responsible for testing and evaluating toxic substances found in the environment. The NTP division takes the lead in carrying out the overall goals of the NTP, and it consists of five branches and laboratories addressing biomolecular screening, cellular and molecular pathology, toxicology, program operations, and operation of the NTP laboratory.

The need for the NTP arose out of concern in Congress and the scientific community for the impact of chemical agents in the environment on human health. When the NTP was created, there was increasing evidence that many human diseases may be related to chemical exposures, and therefore, limiting or eliminating exposure to those chemicals could be a major factor in preventing disease and disability. To address these concerns, the NTP was designed to coordinate toxicology testing across the federal government, strengthen the science of toxicology, improve testing methods, and ultimately, provide information on potentially toxic substances to regulators, scientists, and the public.

The NIEHS funds a large portfolio of research each year across different disciplines within the environmental health sciences through its Extramural Research and Training Division. Grants from the division provide funding for investigators from a wide variety of organizations. Current research addresses a range of environmental health issues, including autism, bisphenol B exposure, breast cancer, oceans and human health, climate change, and nanotechnology. The NIEHS is currently leading a five-year, $25 million consortia research program with community and regional university partners to evaluate health effects stemming from the 2010 Deepwater Horizon oil spill in the Gulf of Mexico.

Anthony C. Holderied

See Also: Autism and Environmental Exposure; Bisphenol A (BPA); Breast Cancer and Environmental Exposure; Deepwater Horizon Incident; Environmental Epidemiology; Environmental Toxicology; Epigenetics; Nanomaterials; National Toxicology Program; Toxicogenomics

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The National Oceanic and Atmospheric Administration (NOAA) is an agency under the U.S. Department of Commerce charged with marine and atmospheric affairs. NOAA's motto is "Science, Service, and Stewardship" and their mission is to (1) understand and predict changes in climate, weather, oceans, and coasts; (2) share that knowledge and information with others; and (3) conserve and manage coastal and marine ecosystems and resources.

Ocean Currents and Climate Change

We are only beginning to understand what changes in the Atlantic Ocean circulation may mean for future climate.

Interview with Dr. Julia Gottschalk

Paleoclimate Researcher, University of Bern

Dr. Julia Gottschalk conducts paleoclimate research at the Oeschger Center for Climate Change Research at the University of Bern, Switzerland. She completed her PhD in the Godwin Laboratory for Palaeoclimate Research at the University of Cambridge, where she was a Gates Cambridge Scholar. Dr. Gottschalk's latest research concerns how ocean processes, in particular in the Southern Ocean, are involved in shaping the observed variability of atmospheric carbon dioxide concentrations. Additionally, Dr. Gottschalk studies a variety of climate archives to understand the role of past abrupt climate events in the long-term evolution of glacial and interglacial climate states.

Recent studies have discovered that ocean currents in the Atlantic have slowed down during the past few decades. Is this a sign of climate change, and if the trend continues, what does this mean for the rate of climate change in the future?

The latest assessment report of the Intergovernmental Panel on Climate Change emphasizes that the lack of observations with sufficient spatial and temporal resolution is a challenge for identifying changes in the speed of ocean currents in the Atlantic Ocean. However, based on new data from the North Atlantic Ocean, it has been proposed that ocean currents over the last decades have weakened, causing cooling in the North Atlantic region, which is distinct from the global warming trend of mean annual land and sea surface temperatures. It has been suggested that the slowdown of the ocean circulation in the North Atlantic may be linked with freshwater input into the North Atlantic from the melting Greenland ice sheet, which may be associated with global warming. However, unequivocally determining the causes of these observations is still extremely difficult due to the lack of multi-annual and multi-decadal observational records, and we are only beginning to understand what changes in the Atlantic Ocean circulation may mean for future climate.

The last time the Gulf Stream was severely perturbed was at the end of the most recent ice age, about 12,000 year ago. Is there danger of this happening again this century, and if so, what would be the consequences for human health and the environment?

Model simulations and paleoclimate observations indicate that deep and surface ocean currents in the Atlantic Ocean (in fact, globally) are very sensitive to the freshwater injected into the North Atlantic stemming from the melting of ice sheets still in existence, such as on Greenland, and from those that no longer exist, such as the Fenno-Scandinavian ice sheet. A recent study has suggested a link between the freshening of the North Atlantic surface due to the decaying Greenland ice sheet and the slowdown of the currents. Further, freshening of the North Atlantic surface due to Greenland ice sheet melting or loss of Arctic sea ice may cause further changes in ocean currents—a process that is plausible but remains to be further investigated. Ocean circulation is very important for the distribution of heat and moisture, and therefore, for regional climate. Northward flowing western boundary currents, such as the Gulf Stream, provide heat to the northern hemisphere, resulting in year-round ice-free ports and mild winters along the U.S. East Coast and in Europe. Any changes in the strength or pathway of the Gulf Stream will ultimately have a substantial influence on regional climate, including changes in the water cycle and surface temperatures, which will affect, for instance, energy consumption and agriculture in these regions as well as global trade.

The oceans, which cover about 70 percent of the planet, are huge reservoirs of carbon dioxide, storing 60 times more carbon than the atmosphere. How much longer will the oceans be able to act as sinks for increasing atmospheric concentrations of carbon dioxide? Are we already approaching the saturation point?

The global ocean takes up excess carbon from the atmosphere (up to 40 percent over recent decades), and the carbon isotopic composition of atmospheric and oceanic carbon dioxide bears witness to this excess carbon being largely caused by the combustion of fossil fuels (e.g., for electric power generation). Although atmospheric carbon dioxide has already reached levels of more than 400 parts per million (by volume), present-day atmospheric carbon dioxide concentrations would be even higher, by about 55 parts per million (14 percent), in the absence of the oceanic buffer capacity of anthropogenic carbon dioxide. Global climate change alters the behavior of the ocean in taking up carbon from the atmosphere, and with increasing oceanic carbon dioxide uptake and rising atmospheric carbon dioxide levels, the buffer capacity of the ocean will decrease. As the ocean is a complex system, and its influence on atmospheric carbon dioxide levels is spatially and temporally variable, predicting the exact role of the ocean in shaping future atmospheric carbon dioxide concentrations remains a major challenge.

Looking back tens of thousands of years, changing ocean currents have been linked with abrupt climate events. Is there any evidence that this same phenomenon is happening now or could happen this century?

Ocean currents both in the surface and deep ocean, which are driven by winds and by temperature and salinity differences, distribute heat and the carbon stored in the ocean. This also determines which regions of the world are warm (e.g., Europe) and which are not (e.g., Antarctica). The paleoclimate record indicates that past global climate events were closely linked with perturbations of the ocean circulation in the Atlantic Ocean, causing changes in the redistribution of heat and carbon. However, it is still unclear whether this relationship is a cause or a consequence. Abrupt changes in the speed of ocean currents in the geological past predominantly occurred during glacial periods, when ice sheets were more extensive and the global ocean circulation was likely more sensitive to perturbations during glacial periods than at present-day due to larger ice sheets. Therefore, there is not a direct analog for the current period and events in the geological past. Nevertheless, there are few studies suggesting that the ocean currents are changing today, but whether this is a sign of global warming or natural climate variability, or a combination of both, is an open question.

What would be a good career path for a recent college or university graduate wanting to study ocean currents, climate change, and implications for human health?

Students wishing to understand the earth and climate system are advised to enroll in geosciences or the earth sciences programs at national or international universities that offer specializations in (Paleo-)Climatology or (Paleo-)Oceanography, or both. Interdisciplinary research connecting the earth and climate sciences with social sciences (including public health) may be appropriate for graduate and doctoral dissertation projects.

One of the most critical ways NOAA contributes to the field of environmental health is by collecting long-term measurements necessary to track and understand climate change. The National Center for Environmental Information is one repository of such data. Another resource widely used by the public, the National Weather Service, provides key insights into weather prediction, with a mission to provide (1) weather, water, and climate data and (2) forecasts and warnings for the protection of life and property and enhancement of the national economy.

NOAA also supports a number of programs at the cutting edge of coastal and marine environmental health research, including a few of the more prominent ones listed below:

- Center for Sponsored Coastal Ocean Research: supports a wide variety of extramural (e.g., university) research on coastal topics
- National Sea Grant College Program: provides direct support to selected universities that is then subawarded locally to support a broad national network of locally relevant environmental research and outreach
- Center for Coastal Environmental Health and Biomolecular Research: studies a variety of coastal environmental health topics, including harmful algal blooms and pollution impacts on marine ecosystems
- Northwest Fisheries Sciences Center: one of several regional hubs conducting research on issues relevant to coastal zone management, including characterizing blooms of harmful algal bloom toxins like domoic acid

In addition to its many contributions to science, NOAA also has key regulatory responsibilities. It is the chief agency tasked with implementing many federal laws, including the Marine Mammal Protection Act, the Coastal Zone Management Act, and the Magnusson-Stevens Fishery Conservation and Management Act. NOAA's Offices of Law Enforcement and General Counsel deal with a wide range of legal issues, including criminal prosecution.

Matthew O. Gribble

See Also: Air Pollution; Climate Change and Human Health; Estuary Pollution; Greenhouse Effect and Global Warming; Marine Pollution, International Treaties to Prevent; Marine Vessels, Pollution from; Naturally Occurring Toxins

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NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM

The National Pollution Discharge Elimination System (NPDES) was added to the Federal Water Pollution Control Act (also known as the Clean Water Act, or CWA) in 1972 to limit and control pollution of waters in the United States. The NPDES is the primary permitting program that monitors and limits discharges of pollutants from industrial and municipal sources into surface waters, which are important for drinking water, recreation, and fishing. Thus, the NPDES plays a vital role in protecting public health and the environment.

When the CWA was first enacted in 1948, its purpose was to abate the pollution of waters to protect human health and welfare. However, the focus prior to 1972 was on the health of the water body itself. There were no uniform standards for controlling the discharge of pollutants to water and no regulatory mechanism to trace pollution found in water bodies back to its source. This made enforcement difficult. The 1972 CWA amendments strengthened existing water quality standards (which were based on human health), added new nationally uniform technology-based standards for wastewater discharges into water bodies, and established a robust permitting system aimed at controlling the quantities of pollutants allowed to reach the nation's surface waters. The NPDES made discharge requirements clearer to the dischargers (e.g., industrial facilities and municipal wastewater treatment plants) and easier for the U.S. Environmental Protection Agency (EPA) and other regulatory agencies to effectively enforce.

NPDES permits work by imposing "effluent limitations" on the discharger. "Effluent" is the term used to refer to the polluted wastewater that is discharged from a source into a water body, and "effluent limitations" are the permit terms that define the maximum quantity of pollutants allowed to be discharged from these "point sources" into certain water bodies. A point source is any identifiable structure that conveys the pollutants into surface waters, including a pipe, ditch, tunnel, well, and even a coal pile or heavy equipment.

The effluent limitations in NPDES permits are nationally uniform technology-based limits set by the federal government in industry-specific rulemakings or, in the absence of federal action for a particular industry, by individual federal or state permit writers directly applying the CWA's language. To establish technology-based effluent limitations, the EPA or individual permit writers review the pollution reduction that can be achieved by applying certain "best" technologies and then require the permitted discharger to meet that pollution reduction standard (i.e., the level of reduction achieved by the "best" technology). The discharger does not have to use the same technology the EPA used to develop the standard and only needs to achieve the same pollution reduction. Technology-based limits may differ depending on the type of discharger and pollutant. For example, new facilities are generally expected to invest more in the best pollution control technology available, whereas installing the same technology at an older facility may be cost-prohibitive for the industry, and consequently, a less stringent technology-driven standard may apply to these existing sources. Effluent limitations in NPDES permits also impose water quality-based effluent limitations to protect the specific water body to which a source discharges.

The NPDES program provides the foundation for enforcing effluent limitations and attaining water quality goals. The CWA makes it illegal to discharge pollutants into federal waters from a point source without an NPDES permit or in violation of the terms of a permit. The CWA also empowers the EPA, states, and even private citizens to enforce these requirements in the federal courts. Significant civil penalties can be levied for violations, and intentional violations may also be met with criminal sanctions.

States may apply for permission from the EPA to administer the NPDES program but must first establish that their state programs are at least as stringent as those required by the EPA under the CWA. The vast majority of the states currently administer their own NPDES permit programs.

The EPA and delegated states may issue both "general permits" and "individual permits" under the NPDES program. Individual permits authorize discharges from a single source, such as a specific city wastewater treatment plant or a manufacturing facility. General permits authorize discharges from an entire category of sources within a state or EPA region. Examples of the types of sources that are often authorized by general NPDES permits include concentrated animal feeding operations, seafood processing operations, and notably, the thousands of stormwater discharges that are regulated under the CWA.

NPDES permits are often very detailed in their requirements. In addition to imposing effluent limitations (defined in terms of maximum concentrations or mass of pollutants discharged), they also establish specific maintenance and inspection requirements, sampling and reporting procedures, and a variety of other notification and operational requirements designed to assure that compliance with the effluent limitations is maintained and that facility changes do not render the permit obsolete.

The NPDES permit program is generally recognized as a successful innovation in terms of improving surface water quality in the United States. It is the primary means of assuring attainment of human health-based water quality criteria, and it provides an effective mechanism for policing the extensive pollution reductions necessary to ensure the protection of human health and the environment. As science continues to identify water-borne risks to human health, the NPDES program stands ready to manage those risks to levels protective of the public, thereby ensuring that waters remain suitable for fishing and swimming and that drinking water sources are protected.

Leah A. Dundon and Richard S. Davis

See Also: Clean Water Act; Concentrated Animal Feeding Operations, Pollution from; Drinking Water Quality and Regulation; Environmental Protection Agency; Sewage Treatment and Disposal; Stormwater Runoff; Water Pollution

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NATIONAL RENEWABLE ENERGY LABORATORY

The National Renewable Energy Laboratory (NREL) was designated by President George H.W. Bush in 1991 to help study and research integration of renewable power into the utility grid so as to have a measurable impact in reducing fossil fuel emissions. Its predecessor, the Solar Energy Research Institute, was created several decades earlier as a result of the burgeoning environmental movement and the oil crises in the Middle East. The name was later changed to NREL to encompass energy efficiency and other renewable sources, including wind power. The NREL is funded through the U.S. Department of Energy.

The NREL's main campus and education center are located in Golden, Colorado, and the affiliated National Wind Technology Center is located nearby in Boulder. Examples of the research topics investigated by the NREL include (1) how to incorporate the expanding renewable energy infrastructure into the existing electric power grid, (2) how energy investors can access and understand data on resource potential and generation costs, (3) what the best practices are for governments to expand the renewable energy market, and (4) what research and development priorities are necessary to help the United States generate 80 percent of its electricity needs from renewable sources by 2050.

The health benefits that can be derived from the NREL's research include replacing fossil fuels for energy generation with cleaner renewable alternatives, with the result of reducing emissions of greenhouse gases and other air pollutants having adverse effects on human health. Carbon dioxide, the greenhouse gas contributing the most to climate change, is not directly harmful to humans, but the buildup of carbon dioxide and other greenhouse gases in the atmosphere will lead to adverse climate change effects, including more frequent and severe droughts and the spread of diseases. By replacing energy sources using fossil fuel with cleaner renewable energy alternatives, greenhouse gas emissions will be reduced, and air pollution like the smog that forms in urban areas will be less severe.

Recently, the NREL has been studying the use of microorganisms to convert methane into lactate, which can then be used to make bioplastics. By finding a use for methane, a potent greenhouse gas, less methane will be emitted into the atmosphere. The NREL is also developing less toxic, more efficient methods of producing biofuels like ethanol. Other research is aimed at making solar, wind, and fuel cell energy more efficient and less expensive. The ultimate goal is to make renewable energy sources cost competitive and ultimately preferable to traditional energy technologies, in particular those using fossil fuels.

The National Wind Technology Center has been working with wind power companies to make wind turbines safer for birds, a major concern among some environmentalists. For example, the center has been collecting flight pattern data that can be used in conjunction with radars to shut down turbines as flocks of birds approach. Work on issues surrounding offshore wind arrays is also in progress.

Aaron Dorman

See Also: Electric Power Generation, Health Implications of; Greenhouse Effect and Global Warming; Ozone and Smog in the Urban Environment; Renewable Energy, Health Implications of; Sustainable Development and Health

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NATIONAL TOXICOLOGY PROGRAM

The National Toxicology Program (NTP) comprises three federal agencies charged with coordinating toxicology research and testing on chemicals of public health concern in support of health regulatory and research agencies, scientific and medical communities, and the public. The three NTP agencies are the National Institute of Environmental Health Sciences (under the National Institutes of Health), the National Center for Toxicology Research (under the U.S. Food and Drug Administration), and the National Institute for Occupational Safety and Health (under the Centers for Disease Control and Prevention). The NTP places emphasis on the health and safety of industrial chemicals, pharmaceuticals, food additives, metals, and pesticides. The role of the NTP is to ensure the safety of these chemicals by determining safe exposure levels and identifying effects on human health during their use, manufacturing, distribution, and disposal and when present in air, water, and soil.

The NTP regulates the approximately 2,000 novel chemicals proposed for use in the United States annually, in addition to more than 80,000 currently registered chemicals. These new and existing chemicals are typically found in household products, prescription drugs, personal care items, foods, and lawn care products.

In the United States during the 1970s, increased attention was directed toward the effects of chemical agents prevalent in the environment. To learn more about how exposure to chemicals may contribute to human disease, regulatory agencies were tasked with studying human health issues, particularly related to cancer, reproductive and developmental disorders, genetic damage, and diseases of the cardiovascular, immune, and nervous systems. In 1978, Joseph A. Califano Jr., secretary of health, education, and welfare (later known as the Department of Health and Human Services), established the NTP, and in 1981, Secretary Richard S. Schwiker granted the program permanent status. The program's original goal, which remains today, was to establish an interagency effort to strengthen the scientific basis of toxicology, coordinate toxicology testing programs, improve current testing methods, and disseminate information about toxic chemicals.

The field of toxicology combines the disciplines of biology, chemistry, and pharmacology to study the potentially hazardous effects of chemicals in living organisms and biological systems by determining appropriate dose responses. The NTP strives to establish a scientific approach to addressing significant issues in toxicology by using best practices to design, conduct, and interpret scientific studies, thereby improving the ability to predict the toxicological impact of environmental agents. For example, NTP scientists study how exposure to common agricultural chemicals affects allergy and asthma symptoms and may contribute to the onset of Parkinson's disease.

The NTP is continually striving to use the most modern scientific research and methods to develop and apply new technologies, such as testing chemicals faster and more efficiently with robotics and computational models, while decreasing the use of animals in toxicity testing. Other objectives of the NTP are to increase the transparency of scientific inquiries, strengthen literature-based hazard assessments, and improve training for the next generation of toxicologists. Additionally, the NTP plays a role in creating database resources for scientists around the world for use in (1) standardizing toxicological terminology and (2) allowing toxicologists to formulate a comprehensive picture of toxicity with greater efficiency than with traditional methods. For example, the NTP supports the Chemical Effects in Biological Systems database, under the National Institute of Environmental Health Sciences, which presents data in the context of biology and study design and allows the integration of data across studies.

Simon Waldbaum

See Also: Allergens in the Environment; Asthma; Environmental Toxicology; National Institute for Occupational Safety and Health; National Institute of Environmental Health Sciences; Neurotoxicants; Parkinson's Disease and Environmental Exposure; Toxicogenomics

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NATURAL DISASTERS

Natural disasters increase suffering and cause great loss of life. Many natural disasters result from environmental conditions, such as hurricanes and floods, and they cause environmental health challenges, including the contamination of water sources following hurricanes or floods. A natural disaster is defined by three components: (1) it is a disruption of normal conditions; (2) it features significant human and property damage; and (3) it exceeds the capacity of the affected community or area to respond. Natural disasters often affect communities in many ways, such as by interrupting communication lines and community access, disrupting utilities, and causing long-term damage, such as medical casualties and reduced food sources.

Climate change, which will cause more heavy precipitation events and increased variability in temperature, is expected to result in more natural disasters. Therefore, there will be a greater need for disaster management and emergency preparedness programs. From the perspective of public health, disaster management must assess the needs of disaster-affected populations, match available resources, prevent further health effects, implement disease control strategies, evaluate effectiveness of disaster relief programs, and develop contingency plans for various disaster types. The medical and public health needs will vary for each disaster type. Better knowledge and prediction of causes of death and types of illness and injury during natural disasters will allow for better allocation of resources. Therefore, efficient planning and execution of disaster relief requires knowledge of which types of disaster may occur and the associated morbidity and mortality.

Floods are the most common natural disaster in the United States, causing more deaths than any other type of natural disaster. Flash floods cause most fatalities. Primary causes of death are drowning and impact by large debris in flood waters. Floods can also have longer-term public health impacts by disrupting water treatment and sewage disposal facilities and causing toxic waste site overflow. These events can increase the exposure to infectious pathogens, such as *E. coli* and *Cryptosporidium*.

Aerial view of flooded New Orleans in the aftermath of Hurricane Katrina in 2005. Climate change is expected to cause heavier and more prolonged precipitation events, resulting in a greater need for disaster management and emergency preparedness programs. (U.S. Coast Guard)

Hurricanes and tornadoes are other natural disasters that can have significant public health impacts. Tornadoes are violent natural disasters that typically cause extensive property damage and can result in loss of life. North America is most prone to tornadoes, and it is estimated that over 700 tornadoes occur in the United States each year. Hurricanes, or tropical cyclones, can lead to tornadoes and flooding, which together with storm surge can cause high rates of morbidity and mortality. In the future, hurricanes are predicted to have greater impact as climate change leads to stronger hurricanes and coastal areas become more densely populated.

Volcanic eruptions and earthquakes are also natural disasters with considerable public health consequences. While most volcanoes are in thinly populated areas, the U.S. Geological Survey has identified 35 volcanoes that are likely to erupt in the future. Eruptions have immediate life-threatening health effects due to inhalation of airborne ash, burning steam from the eruption, and inability to escape mudflows. Indirect effects of volcanic eruptions include the toxic gases that are released during the eruption. Earthquakes can also result in significant loss of property and life. The greatest impacts from earthquakes are immediate due to injury and death from building collapse or falling debris. Public health preparedness efforts can rely on early warning systems for floods, hurricanes, and tornadoes. However, earthquakes are much more difficult to predict, and public health preparedness must focus on preventative efforts, such as strengthening buildings and instructing people in earthquake-prone areas to have emergency supplies on hand.

Jyotsna S. Jagai

See Also: Climate Change and Human Health; Disaster Preparedness and Response; Emergency Planning and Community Right-to-Know Act; Federal Emergency Management Agency; National Incident Management System; Sewage Treatment and Disposal

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NATURALLY OCCURRING TOXINS

The science of naturally occurring toxins, called toxinology, is a broad field that includes contributions by various professions, including microbiologists, mycologists, botanists, veterinarians, and marine biologists. Research on toxinology can be found in *Toxicon*, the official journal of the International Society on Toxinology, and in a wide variety of other professional publications. Naturally occurring toxins are important to the field of environmental health because they can cause serious health problems in humans and even death.

Perhaps the most lethal substance on the earth is botulinum toxin, produced by the bacterium *Clostridium botulinum*. It is also the active ingredient in a popular injection treatment to tighten muscles, which may be used cosmetically to offset the appearance of aging skin. This illustrates one common theme in toxinology: that there may be valuable uses (e.g., in pharmacy) for substances that are highly toxic in other contexts or at other doses. This is a major rationale for the interest pharmaceutical and bioengineering professionals have in discovering and characterizing naturally occurring toxic substances.

Toxins can have acute or chronic toxicity, as illustrated by some of the more infamous mycotoxins (toxins produced by fungi). For example, psilocybin, produced by "magic mushrooms" of the genus *Psilocybe*, and lysergic acid diethylamide (LSD), derived from the fungal genus *Claviceps*, are street drugs abused for their hallucinogenic effects, typically occurring 1.5 hours after consumption and lasting up to 12 hours. (These hallucinogenic mycotoxins activate the serotonin 5-HT_2 receptor.) A slower-acting, but far more deadly acute mycotoxin is α-amantin, produced by the mushroom *Amanita phalloides*, aptly nicknamed the "death cap" mushroom. This toxin disrupts the enzyme RNA polymerase II, leading to a cessation of new protein synthesis that results in liver damage and possible death. An example of a common mycotoxin contributing to chronic disease risk is aflatoxin, which may be responsible for 4.6 to 28.2 percent of hepatocellular carcinoma (HCC) cases worldwide and has synergistic toxicity with hepatitis B and C viruses for HCC risk. Aflatoxin is primarily produced by molds, such as *Aspergillus flavus*, which can grow on corn and peanuts.

Animals delivering toxins by injection (e.g., with fangs or stingers) are called venomous, while creatures delivering toxins more passively are called poisonous. Many poisonous creatures actually are carrying toxins produced by another organism. For example, the toxins from poison dart frogs are produced primarily by their insect prey.

Batesian mimicry is a defensive strategy whereby an organism imitates the appearance of another organism that is toxic (or sometimes just tastes bad). An example of this is how the nonvenomous scarlet kingsnake, *Lampropeltis elapsoides*, looks similar to the venomous American cobra, *Micrurus fulvius*, which shares a similar habitat.

Life began in the ocean, and over millennia, the evolutionary struggle to survive in the marine environment has given rise to particularly interesting and potent toxic species. One example is the cone snail, which produces offensive venoms to subdue prey and defensive venoms to deter predators. These "conotoxins" are secreted by different parts of the toxic gland and are released under different conditions. Another interesting example concerns algae, which under certain environmental conditions can proliferate, causing harmful algal blooms. A common consequence of algal blooms is depletion of oxygen from the water when the bloom of algae begins to die and decay, resulting in hypoxia and the subsequent deaths of large numbers of fishes. Additionally, sufficient doses of some algal toxins can produce very distinct toxidromes. For example, high doses of the domoic acid produced by the diatoms in genus *Pseudo-nitzschia* cause amnesiac shellfish poisoning, while high doses of the saxitoxins produced by *Alexandrium* cause paralytic shellfish poisoning. Even a low dose of ciguatoxins produced by *Gambierdiscus* can cause the disease ciguatera, which presents with a range of neurological, gastrointestinal, and sometimes even mental health symptoms in humans. The most distinctive symptom of ciguatera is reversed sensation of hot and cold. It is thought that ciguatera may be increasing in frequency due to climate change.

Matthew O. Gribble

See Also: Climate Change and Human Health; Environmental Toxicology; Neurotoxicants

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NEUROTOXICANTS

Neurotoxicants are synthetic chemical compounds that cause damage to the central or peripheral nervous systems and to sense organs. Researchers have accumulated evidence that these compounds contribute to a wide range of neurological illnesses and conditions, including Parkinson's disease, Alzheimer's disease, and amyotrophic lateral sclerosis in adults as well as learning and developmental disorders in children. In addition to specific diseases and disorders, neurotoxicants also cause numerous general symptoms, such as nausea, dizziness, vertigo, irritability, physical incoordination, and impaired memory. Such general symptoms are typically reversible once exposure to the toxicant is stopped. However, many neurological, learning, and developmental disorders are permanent.

Neurotoxicants can cause neurological and developmental damage to the body in several ways, depending on the particular chemical. For example, they can (1) change enzyme activity and other biochemical balances; (2) lead to physiological changes through damage to the myelin sheaths of nerve fibers or changes to sensory organs; and (3) prompt morphological changes in nerve cells, including inflammation of cells, alterations within cells, and cell death.

Chemicals classified as developmental neurotoxicants are of special interest because they damage the fetal, infant, and child brain. Only a relatively small number of compounds have been conclusively demonstrated to cause neurodevelopmental disorders in immature humans, but many more compounds have suspected neurotoxicity characteristics based on animal studies and other research. Scientific research and clinical evidence have revealed links, both potential and proven, between prenatal and postnatal exposure to more than 100 chemicals and neurobehavioral and neurodevelopmental conditions, such as the following:

- Learning and memory disabilities
- Reduced intelligence quotient
- Autism spectrum disorders
- Attention-deficit/hyperactivity disorder
- Physical developmental delays (including delays in sexual development)

Such conditions have been diagnosed in as many as 20 percent of children in the United States, according to some estimates, with the number of diagnosed cases on the rise. Some research has even drawn associations between childhood exposure to certain developmental neurotoxicants, such as lead, and later antisocial and criminal behaviors. According to the National Research Council, 3 percent of neurodevelopmental disabilities can be attributed to direct environmental exposure to neurotoxicants, and 25 percent of neurodevelopmental disabilities can be linked to epigenetic interactions of environmental neurotoxicants with genetic factors.

Neurotoxicants are found in many common household products, including the cadmium metal in batteries and pigments (e.g., the colored designs on drinking glasses), the polybrominated diphenyl ether flame retardants in upholstered furniture and electronic circuitry, and various pesticides found in house and yard sprays and pet flea-and-tick killers. One of the best known neurotoxicants is lead, which was widely used in house paint until it was banned in the late 1970s, although it is still present in the paint of many older buildings. A number of suspected neurotoxicants have been found in cigarette smoke, urban air pollution, drinking water, foods, and drinks. Some neurotoxicant effects have been associated with certain pharmaceuticals and vaccines. Neurotoxicants are also among the hazardous chemicals encountered in many manufacturing facilities and other work environments.

Specific chemical compounds with evidence of neurotoxicant properties include the following:

- Acrylamide: used to make many plastic products and cosmetics. It is also produced during certain cooking processes, such as the roasting, baking, and frying of potatoes
- Aspartame: a common synthetic sweetener used as a substitute for sugar

- Benzene: incorporated into the plastics, resins, nylon, and synthetic fibers found in detergents, dyes (including food dyes), lubricants, rubber items, certain medicines, and other products
- Bisphenol A: found inside the resin lining and polycarbonate plastic of many beverage and food cans, baby bottles, and water bottles
- Fluoride: added to public drinking water supplies in most communities because it has been shown to reduce tooth decay, although some research identifies it as a developmental neurotoxicant
- Manganese: a metal used in the manufacture of aluminum drink cans, glass and rubber products, and fertilizers and fungicides
- Mercury: found in various products, including batteries, electronics, old thermometers, jewelry, light bulbs, and skin cream
- Monosodium Glutamate: one of the most widely used flavor enhancers (often listed under alternate names in food ingredients)
- Polychlorinated Biphenyls: production banned in the United States but may still be found in products manufactured before the ban, including electrical equipment, surface coatings, inks, paints, adhesives, and fire retardants
- Trichloroethylene: present in some cleaning and degreasing products

Some scientists suspect that there may be at least 200 neurotoxicants in many kinds of consumer products that have not yet been testing for evidence of neurotoxicity. Manufacturers create new products at a faster rate than researchers can evaluate them, and U.S. Environmental Protection Agency regulations allow companies to market certain kinds of products without first testing them for safety. Often tests of those items are conducted only after evidence develops of potential harm to humans following the marketing of the products. Toxicologists have called for greater testing of suspected neurotoxicants to provide more data relevant to public health and product safety.

A. J. Smuskiewicz

See Also: Bisphenol A (BPA); Environmental Protection Agency; Environmental Toxicology; Epigenetics; Heavy Metal Pollution; Lead Poisoning Prevention; Mercury Pollution; Pesticides and Herbicides; Polychlorinated Biphenyls

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NOISE POLLUTION

We ordinarily do not consider noise a form of pollution, but a noisy environment can lead to health issues, just like other forms of pollution. People exposed to excess noise often experience stress-related illnesses, high blood pressure, speech interference, sleep disruption, lost productivity, and hearing loss. A condition known as noise induced hearing loss (NIHL) is the most common effect of living and working in a noisy environment.

NIHL is a very common health condition in the United States, and unfortunately, hearing loss is ordinarily irreversible. Working in a loud factory can cause hearing loss, but so can going to a rock concert and even using a noisy leaf blower. Typically, the louder the sound and the longer the exposure, the greater the likelihood of permanent hearing loss. Among U.S. adults in the 20 to 69 age range, it is estimated that about 40 million suffer from NIHL. Half do not have noisy jobs, which means their hearing loss is associated with noise exposure at school or home or in the community. Of those adults who think their hearing is good to excellent, about 25 percent actually have some degree of hearing damage.

Instruments that measure noise levels use a unit of measure called the decibel (dB)—the higher the dB, the louder the noise. Hearing professionals generally consider noises louder that are about 85 dB in the range where extended exposure can cause hearing damage. Table 11 shows some common noises and associated dBs. As you can see, many noises we take for granted, such as running the washing machine or attending a sporting event, can result in high dB levels. According to the Centers for Disease Control and Prevention, exposure to a loud rock concert for as little as two minutes can cause hearing damage.

Over 45 million Americans suffer from tinnitus, a ringing or buzzing in the ears that is primarily associated with noise exposure and hearing loss. The likelihood of developing tinnitus increases with age, and it is estimated that roughly 30 percent of older adults experience tinnitus symptoms. Other groups at high risk for developing tinnitus are active military personnel and veterans, people working in loud workplace environments, musicians and music lovers, motor sports fans, hunters, and people with past behavioral health issues, such as depression, anxiety, and obsessive-compulsive disorder. Males tend to get tinnitus more than females,

Why So Little Concern over Noise Pollution?

Noise is around us almost all the time during our waking hours, and while it can be annoying at times, we usually do not consider it a danger to our health. But in fact, even a little unwanted noise can increase our stress level and lead to sleepless nights. We cannot see, taste, smell, or touch noise pollution, and perhaps, this is why it does not receive more attention. However, as with other forms of pollution, noise pollution can diminish our quality of life and even present a serious health hazard.

Table 11. Common noises and associated dB levels.

Activity	dB Level
Washing machine	70
Traffic noise while inside a car	80
Leaf blower	90
Sporting event	100
Rock concert	110
Emergency siren	120

perhaps because they have noisier jobs and participate in more hearing-risk behaviors like hunting. For unknown reasons, white, non-Hispanic people suffer more from tinnitus than other racial and ethnic groups.

There are several steps you can take to prevent hearing loss. Most important is simply limiting exposure to loud noises—walk away from the noise, lower the volume, or wear hearing protection, such as earplugs or earmuffs. And be careful wearing headphones and earbuds—there is increasing evidence they can cause hearing loss if the volume is too loud. Parents can help their children avoid hearing loss by turning the volume down on TVs and music players and requiring ear protection while working outside, for example, when using a noisy lawnmower or leaf blower.

Richard Crume

See Also: Centers for Disease Control and Prevention; Children's Environmental Health; Occupational Safety and Health; Quiet, Benefits of

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NOROVIRUS INFECTION

Norovirus is a highly contagious virus that causes inflammation of the stomach or intestines or both, a condition called acute gastroenteritis. Common symptoms are diarrhea, vomiting, nausea, stomach pain, and sometimes fever, headache, and body aches. Diarrhea and vomiting can lead to dehydration, particularly in children, older adults, and people having other illnesses. (Dehydration symptoms include decrease in urination, dry mouth and throat, and dizziness when standing up.) Following exposure, people develop symptoms within 12 to 48 hours, and most people begin to recover within one to three days. Of course, if you are concerned about exposure to norovirus or any other health condition, you should see your doctor.

The first known outbreak of norovirus occurred in 1968 at Norwalk-Bronson Elementary School in Norwalk, Ohio, where 150 students experienced nausea, vomiting, and diarrhea over a period of 12 to 24 hours. (The "noro" in norovirus is derived from Norwalk.) However, the viral agent was not actually identified until 1972, when the virus was first visualized using electron microscopy. This discovery was important because it was the first time a virus specifically associated with acute gastroenteritis had been identified. Following further investigation with sensitive molecular techniques, norovirus became the official genus name in 2002.

In the United States, norovirus infections are common and widespread. According to the Centers for Disease Control and Prevention, each year norovirus causes, on average, 19 to 21 million acute gastroenteritis cases, 1.7 to 1.9 million outpatient visits, 400,000 emergency room visits (mainly young children), 56,000 to 71,000 hospitalizations, and 570 to 800 deaths (mainly children and older adults). Only the common cold is more prevalent.

When a norovirus outbreak occurs, it often begins when an infected person spreads the virus to others. Additionally, norovirus can spread through contaminated food or by touching contaminated surfaces. (Because norovirus is resistant to many common disinfectants, it can persist on surfaces, even after they are

Staying Healthy on Your Cruise

While cruise ship viral infection outbreaks are uncommon, they do happen, and norovirus is usually to blame. To protect yourself, wash your hands frequently with soap and warm water, especially before and after meals and after using the restroom. Avoid touching your face after using the restroom and whenever your hands are dirty. Although an occasional handshake is acceptable, minimize contact with others as much as possible. Avoid eating uncooked food and touching unsanitized surfaces, drink bottled water, and do not share drinking glasses and eating utensils. Report any symptoms to the ship's medical clinic, and unless caring for a friend or loved one, stay away from other passengers who are sick. In other words, just use common sense to avoid situations where norovirus may be present—and wash your hands a lot!

cleaned and sanitized.) In the United States, about half of all food-related illnesses are caused by norovirus. Enclosed areas, such as daycare centers, nursing homes, schools, college dormitories, and cruise ships, are particularly conducive to the spread of norovirus. Around 50 percent of norovirus outbreaks in the United States are in long-term care facilities, and most outbreaks occur during the winter months.

Norovirus is particularly notorious for outbreaks on cruise ships, where it causes over 90 percent of diarrheal disease outbreaks. From 2008 to 2014, 133 cruise ship acute gastroenteritis outbreaks were reported for cruises sailing in U.S. jurisdiction (passenger vessels carrying 13 or more passengers and within 15 days of arriving in the United States), and almost all of the outbreaks were attributed to norovirus. While this may appear to be a large number of outbreaks, it actually represents only about 0.5 percent of voyages and 0.2 percent of passengers traveling during this period. Because cruise ships are required to submit detailed reports on norovirus outbreaks, we hear more about outbreaks occurring at sea than those occurring on land.

Currently, there are no medicines that are effective in treating norovirus infections. For example, antibiotics, which are used to treat bacterial infections, have no effect on viral infections. Furthermore, because there are many different types of noroviruses, being infected in the past and building up a resistance may not protect you from future infections from a different norovirus strain. Patients are often advised to drink plenty of fluids to help prevent dehydration, which can be a serious problem, even requiring hospitalization. If you believe you or someone you are caring for may be severely dehydrated, you should see a doctor.

There are several steps you can follow to avoid getting a norovirus infection and to prevent it from spreading to others. These include (1) washing hands frequently with soap and warm water, (2) washing fruits and vegetables and thoroughly cooking seafood, (3) throwing out any food that might be contaminated, (4) ensuring sick infants and children are kept away from food preparation areas, and (5) cleaning and disinfecting contaminated surfaces. If infected with norovirus, stop caring or preparing food for others for at least two days after symptoms disappear and stay home from school or work to avoid infecting others.

Richard Crume

See Also: Food Safety and Technology; Foodborne Diseases; Infectious Diseases

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NUCLEAR REGULATORY COMMISSION

The Nuclear Regulatory Commission (NRC) is an independent regulatory agency of the United States authorized by the Energy Reorganization Act of 1974. The NRC succeeded the Atomic Energy Commission (AEC) in 1975 due to calls by critics for the need to separate the AEC's conflicting roles of both promoting and regulating nuclear materials. Critics claimed that the AEC had been a victim of regulatory capture—a condition where regulators advance the interests of the industries and groups they regulate rather than the interests of the public they are mandated to protect. To remove any conflicts of interest, the AEC was disbanded, and the role of regulating nuclear materials was assigned to the NRC.

The NRC's ultimate responsibility is to protect public health and safety by ensuring the safe use and disposal of nuclear materials associated with civilian applications. The NRC's regulatory role is carried out through its powers to set and enforce rules and to license and inspect operations. While most often associated with the regulation of nuclear power plants, the NRC also oversees and regulates applications of nuclear materials in medicine, research, and other industries, and it regulates the storage and disposal of nuclear waste. Additionally, the NRC conducts research to inform regulatory decisions and develops public information and regulatory guidance.

One of the NRC's primary roles is to ensure the safe operation of nuclear power plants in generating nuclear energy. Operators of any facility proposing to use nuclear fuels and reactors to generate electricity must obtain permits from the NRC for both construction and operation. The NRC is also authorized to regularly inspect nuclear plants and enforce regulations when violations are found. The NRC's enforcement actions include issuing notices of violation, imposing monetary penalties, and modifying, suspending, or revoking licenses. Some issues confronting the NRC today are the renewal of licenses on aging plants, the decommissioning (dismantling) of older plants, and the storage and disposal of spent (used) nuclear fuel.

The NRC has several layers of controls to prevent outside influence from manipulating NRC activities and to ensure public trust in their decisions. The commission is headed by five members who must be appointed by the president of the United States and confirmed by the U.S. Senate. Neither the commission members nor the NRC staff may have any financial or personal interests in the entities they regulate. Regular reviews of NRC activities are conducted by an independent inspector general to ensure they are not only effective and efficient but also ethical. Prior to conducting any licensing activities, guidance must be considered from two advisory committees consisting of expert scientists. Finally, the public must be allowed to provide input prior to rulemaking, to access any materials used in decision making, and to attend any meetings in which decisions are made.

Adrienne L. Katner

See Also: Atomic Energy Commission; Electric Power Generation, Health Implications of; Nuclear Safety; Radiation, Ionizing and Nonionizing; Radiation Sickness

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NUCLEAR SAFETY

Nuclear safety refers to the safety of nuclear power facilities and the waste generated by these facilities in terms of human health and the environment. Potential safety problems with nuclear power plants mainly involve the release of excessive amounts of radiation to workers or the public due to explosions or other mechanical failures. The most serious failures involve (1) partial meltdowns, where insufficient coverage by cooling water causes cracks and other damage to fuel rods, leading to the release of some radiation and (2) complete meltdowns, where the loss of all cooling water causes fuel pellets to fall to the bottom of the reactor and heat up to several thousand degrees, breaching the reactor vessel and leading to the release of massive amounts of radiation.

The Future Role of Nuclear Power

We need a meaningful price and trading regime on greenhouse gas emissions in all sectors, and then we'll see what a sensible role for nuclear power will be.

An Interview with Dr. Peter A. Bradford

Professor, Vermont Law School

Dr. Peter Bradford teaches Nuclear Power and Public Policy at Vermont Law School. He previously served on the U.S. Nuclear Regulatory Commission, and he chaired utility regulatory commissions in Maine and New York. Dr. Bradford also taught Energy Policy and

Environmental Protection at the Yale School of Forestry and Environmental Studies. He is currently vice chair of the Board of the Union of Concerned Scientists, and he is author of Fragile Structures: A Story of Oil Refineries, National Securities, and the Coast of Maine.

Because nuclear power plants do not emit greenhouse gases like carbon dioxide into the atmosphere, they do not contribute to climate change. As such, why are so many environmentalists opposed to further nuclear power development?

Having licensed about 20 plants and allowed funds to operate a dozen others during my regulatory career, I may not be the right person to answer. The problem faced by new reactors is the cost. Many low-carbon approaches appear to cost much less and to be available much more quickly, but a multibillion-dollar commitment to a new reactor ten or more years in the future crowds out these other solutions. As of this interview, a new nuclear power plant has not prevented a molecule of greenhouse gas emissions in the United States in this century, despite the proclamation of a nuclear revival by the Bush Administration in 2001 and the voting in by Congress and some states of every subsidy the industry requested a decade ago. This is not because of environmentalist opposition. Every one of the two-dozen or more plant cancellations and closings during that time has been for business reasons.

In the United States, the Clean Power Plan would have provided carbon-reduction credits for new nuclear power plants and allow existing nuclear plants to continue operating. Should nuclear power be viewed as an interim solution to reducing greenhouse gases, or will nuclear power inevitably be part of the final solution?

New reactors can't be an interim solution. They take too long to build in meaningful numbers. Wise energy policy is a matter of sound principles, not some gift of prophecy. We need a meaningful price and trading regime on greenhouse gas emissions in all sectors, and then we'll see what a sensible role for nuclear power will be. Neither the nuclear advocates nor their strongest opponents know nearly as much about the future as their claims suggest. That said, we also need to support research, development, and demonstration of new technologies that show promise of being able to reduce climate change cost-effectively.

Many nuclear power plants in Japan and several other countries shut down following the March 11, 2011, Great East Japan Earthquake and tsunami and subsequent meltdown of the Fukushima Daiichi reactors. As a result, Japan is now burning more coal for power production than ever before. Is this trade-off between nuclear power and coal power inevitable given the slow market penetration of renewable energy and challenges of infrastructure development?

Unplanned shutdowns of substantial nuclear capacity will inevitably cause other existing power plants to run longer hours and cause the construction of some capacity (as well as transmission and load control) on an emergency basis. However, given a little lead time and public policies that require low-carbon replacement, market-based approaches are usually fully capable of delivering such solutions. This should become even more feasible as storage technologies develop and their costs fall. Parts of the United States have closed nuclear plants without burning more coal, and recent marginal coal burning in Germany has been for export, not to replace the closed German nuclear units, which are increasingly being replaced by renewables.

What would be a good career path for a recent college or university graduate wanting to develop environmental law and policy and protect public health?

If such a student is inclined toward law or economics, the interplay between market performance and public policy is fascinating and crucial. If scientifically inclined, energy storage technologies and renewable resources seem likely to provide challenging, useful, and lucrative careers.

From 1952 to 2016, more than 30 serious accidents occurred at nuclear power plants around the world, ranging from relatively minor radiation releases that sickened a worker to partial meltdowns in which large amounts of radiation were released throughout the region surrounding the reactor, causing many illnesses and deaths. Six serious accidents have happened in the United States, the worst being the partial meltdown at the Three Mile Island facility in 1979.

Nuclear power plants in the United States, with some 60 years of experience and improvement in operations, are considered among the safest in the world. Their operations are regulated and overseen by the Nuclear Regulatory Commission (NRC), headed by five commissioners appointed by the president and confirmed by the Senate. Stringent government and industry regulations require these facilities to have multiple layers of security to protect workers, the public, and the environment. On-site inspectors with the NRC, who are independent from the facility's owners and operators, monitor a plant's performance regarding reactor safety, radiation safety, employee training and performance, and facility maintenance and security. The NRC establishes limits on the allowable annual amount of radiation to which nuclear plant workers can be exposed, which, on average, is lower than that airplane crews are exposed to due to background radiation.

Workers undergo extensive background checks, training, and federal licensing tests. All plants have detailed plans to respond to on-site and off-site emergencies, and these planned responses are practiced and tested every two years with the participation of local, state, and federal agencies. The NRC uses assessments made by the Federal Emergency Management Agency when evaluating a facility for operational approval.

Many of the technical systems in U.S. nuclear facilities are automated and redundant so that backup systems can quickly replace malfunctioning systems. Security procedures are tight to prevent terrorists or other intruders from entering facilities. Most reactors are surrounded by thick steel-reinforced concrete containment structures designed to withstand the impact of hurricanes, tornadoes, earthquakes, floods, and commercial airplane impacts. Cyberattacks are also taken into account in security strategies.

The most serious nuclear accident in the United States occurred at the Three Mile Island facility in Pennsylvania in March 1979. A malfunction in the cooling system and employee error led to a partial meltdown, in which about half of the reactor core melted, forming a puddle of radioactive material at the bottom of the reactor vessel. Although the vessel remained intact, a small amount of radiation escaped into the surrounding environment. This accident ranks 5 on the International Nuclear and Radiological Event Scale (commonly abbreviated INES), which ranges from 1 to 7, with 7 being the worst.

Internationally, the World Association of Nuclear Operators (WANO) collects, consolidates, and distributes the operational data of nuclear power plants in all countries. Annual evaluations are made by the WANO about the safety performance of these facilities. Data collected in 2015 revealed that 98.5 percent of facilities met targets for safety system performance, 87.7 percent met targets for radiation exposure, and 85.3 percent met targets for accident rate.

The April 1986 accident at the Chernobyl nuclear facility in Ukraine is considered the most serious nuclear accident in history, ranking 7 on the INES. A power surge caused an explosion in one of its reactors, resulting in the release of enough radiation throughout the region to lead to widespread and long-term health and environmental effects. Thirty workers at the facility died from radiation poisoning, and thousands of people in Ukraine, Belarus, and Russia are believed to have contracted thyroid cancer from the radioactive fallout.

An accident at Japan's Fukushima Daiichi nuclear power plant in March 2011, ranking 5 on the INES, involved the release of radioactivity into the surrounding environment. This was caused by a powerful earthquake and associated tsunami that led to explosions and the loss of electricity, requiring the subsequent decontamination and disassembly of all six reactors at the site, a process that could take four decades or longer.

The radioactive waste generated by nuclear power plants remains hazardous to humans and the environment for thousands of years. The management and disposal of this waste in the United States is regulated by the NRC's Office of Nuclear Material Safety and Safeguards. Most spent nuclear fuel is stored in specially designed steel-lined, concrete-walled pools of water at reactor sites throughout the country. Some fuel is stored in air-tight steel or concrete dry cask storage systems at current reactor sites, decommissioned reactor sites, or off-site interim storage facilities. A proposed permanent waste repository inside deep geological formations at Yucca Mountain in Nevada has yet to be approved by the NRC.

A. J. Smuskiewicz

See Also: Chernobyl Incident; Electric Power Generation, Health Implications of; Fukushima Daiichi Incident; Nuclear Regulatory Commission; Radiation, Ionizing and Nonionizing; Radiation Sickness; Radioactive Wastes; Three Mile Island Incident

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OCCUPATIONAL SAFETY AND HEALTH

The field of occupational safety and health (OSH) involves protection of workers through identification and control of risks that arise from chemical, biological, physical, biomechanical, and psychosocial hazards in the workplace. As a multidisciplinary field, exposure prevention calls upon industrial hygienists, occupational safety professionals, engineers, and ergonomists to monitor and mitigate adverse working conditions. (On the other hand, recognition, diagnosis, treatment, and management of occupational illnesses and injuries are the purview of health-care providers—physicians, nurses, psychologists, and other health professionals.) Engagement of managers, workers, and worker advocates is critical to ensuring safe operations that protect the health and safety of workers. Legislated oversight and support of the OSH system is provided by the governmental agencies listed in Table 12.

Table 12. Government agencies supporting occupational safety and health.

Agency	Occupational Oversight
Occupational Safety and Health Administration https://www.osha.gov	• Arm of the U.S. Department of Labor • Sets and enforces protective workplace standards • Provides information, training, and assistance to employers and workers
Mining Safety and Health Administration https://www.msha.gov	• Develops and enforces safety and health rules for all U.S. mines • Provides technical, educational, and other assistance to mine operators
Bureau of Labor Statistics https://www.bls.gov	• Collects, processes, analyzes, and disseminates statistical data (surveillance) related to employment, labor economics, and occupational illness and injury
National Institute for Occupational Safety and Health http://www.cdc.gov/niosh	• Responsible for conducting research and making recommendations for the prevention of work-related injury and illness
Environmental Protection Agency https://www.epa.gov https://www.epa.gov/pesticide-worker-safety/agricultural-worker-protection-standard-wps	• Protects human health and the environment by enforcing compliance with environmental laws • Oversees agricultural workplaces through the Worker Protection Standard, reducing risk of pesticide poisoning and injury

(*Continued*)

Table 12. Continued

Agency	Occupational Oversight
Workers' Compensation *State agencies:* https://www.dol.gov/owcp/dfec/regs/compliance/wc.htm *Federal agency:* https://www.dol.gov/owcp/dfec/ *Longshore and Harbor Workers' Compensation Act:* https://www.dol.gov/owcp/dlhwc/lhwca.htm	• A form of social insurance providing wage replacement and medical benefits to employees injured in the course of employment, in exchange for mandatory relinquishment of the employee's right to sue the employer for the tort of negligence
US. Department of Labor https://www.dol.gov	• Oversees employment laws regarding wages, hours, workers' compensation, and other workforce protections • Has specific programs for migrant and seasonal farm workers, temporary employment sector, immigrant workers, maritime workers, and federal employees

Workplaces include contained, indoor work environments (e.g., factories, hospitals, offices, warehouses, homes, and schools), outdoor settings (e.g., farms, construction sites, oil rigs, power line maintenance sites, and parks), and mobile containments (e.g., trucks, trains, airplanes, and automobiles). Health effects arising from hazards in these settings may be classified by hazard category, specific hazard, or health outcome, as illustrated in Table 13.

In the United States, workplace fatalities have gone from 6,217 in 1992 to a low of 4,551 in 2009, with a rise to 4,836 in 2015. Causes in 2015 were roadway and transportation incidents (42.5 percent); falls, slips, and trips (16.5 percent); contact with objects and equipment (14.9 percent); violence and other injuries by persons or animals (14.5 percent); exposure to harmful substances or environments (8.8 percent); and fires/explosions (2.5 percent). Construction remained the sector with the highest number of fatalities (935, representing 19.4 percent of the total), while agriculture had the highest rate per employed worker (22.8 per 100,000 full-time equivalent workers, compared with 3.4 per 100,000 full-time equivalent workers overall).

Why Is Worker Health Important?

Most of the population is employed, and "work" can contribute both positively and negatively to the health and well-being of the workers and their families and communities. Attention to worker health and safety through legislation has led to a greater awareness and a substantial decrease in occupational injuries and illnesses. In addition, the workplace is increasingly becoming recognized as a venue for *promoting* health. Nevertheless, on-the job illnesses and injuries cost workers, employers, insurance companies, and taxpayers billions of dollars each year in health care and work-time lost.

Table 13. Categories pertaining to adverse health outcomes from occupational hazard exposures.

Hazard Type	**Examples**
Chemical	• Solvents, metals, pesticides, simple irritants, fibers, particulates
Biological	• Infectious agents: bacteria, viruses, fungi, parasites
Physical	• Noise, radiation, heat, cold, vibration
Biomechanical	• Moving machinery, hand tools, vehicles
Psychosocial	• Shift work, low wages, part-time work, harassment, stress
Disorder by Organ System	
Musculoskeletal	• Acute traumatic injury: amputation, burn, head trauma, cumulative trauma (e.g., carpal tunnel syndrome)
Respiratory	• Acute inhalation injuries, asthma, chronic obstructive pulmonary disease, pneumoconiosis, hypersensitivity pneumonitis, metal fume fever, lung cancer
Neurologic/psychiatric	• Encephalopathy, cognitive defects, peripheral neuropathy, brain cancer
Dermatologic	• Irritant contact dermatitis, allergic contact dermatitis, chloracne, vitiligo, skin cancer
Reproductive	• Sexual dysfunction, fetal toxicity, poor reproductive outcomes
Cardiovascular	• Atherogenesis, cardiomyopathy, hypertension
Hematologic	• Methemoglobinemia, leukemia, aplastic anemia
GI/Hepatic	• Hepatitis due to infection, chemical toxicity, cirrhosis, cancer
Urinary tract	• Acute kidney disease, chronic kidney disease, cancer of bladder/kidney
Condition	
Cancer	• All organ systems, caused by chemical, biological, physical hazards
Infectious disease	• Systemic or organ system infection (e.g., healthcare workers)
Traumatic injury	• Machine operators, work at heights, vehicle drivers

The top five industries reporting the highest rates of nonfatal occupational injuries and illnesses with days away from work in 2015 were nursing and residential care facilities (6.8 per 100 full-time workers), hospitals (6.0 per 100 full-time workers), schools (4.8 per 100 full-time workers), and general merchandise stores (4.5 per 100 full-time workers). Public sector workers had a higher proportion of occupational injuries than their proportion in the workforce. Injuries represented 95 percent of reported cases, with the remaining 5 percent of cases made up of skin diseases (15.2 percent of the 2.9 million illness cases), hearing loss (12.7 percent of illness cases), respiratory conditions (8.4 percent of illness cases), and all other illnesses (i.e., systemic illnesses and cumulative trauma cases), representing 62.6 percent of illness cases.

There is increasing interest in health promotion among employers because of rising healthcare costs and recognition that a stable, highly skilled workforce is more profitable. Workplace health promotion activities include (1) worksite management of chronic conditions, such as diabetes and hypertension; (2) programs that promote physical activity, such as providing walking paths and longer lunch breaks, monetary incentives for going to the gym, fitness contests, and active transportation options; (3) lifestyle interventions to prevent smoking, such as smoke-free workplaces and smoking cessation programs; and (4) dietary support, including dietician counseling and healthy food choices.

Over the past several decades, the workforce has been downsized and outsourced, leading to many structural and practical changes. These include (1) increased size of single businesses (e.g., large agricultural producers with attendant hazardous operations, such as concentrated animal feeding operations that house hundreds to thousands of animals in a single facility); (2) decreased number of labor unions, resulting in fewer worker protections; (3) contracted labor, where the employee and the employer do not have a direct relationship and health insurance is not provided; (4) increased reliance on migrant labor, which is subject to lower wages and exploitive labor practices; and (5) more difficult work circumstances, including unstable employment, irregular work hours, and limited benefits. These conditions have led to increased safety and health risks for the American workforce, and they highlight the urgent need for professionals working in the field of OSH.

Linda Forst

See Also: Concentrated Animal Feeding Operations, Pollution from; Environmental Protection Agency; National Institute for Occupational Safety and Health; Occupational Safety and Health Administration; Safety Data Sheet

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OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

The Occupational Safety and Health Administration (OSHA) is a federal agency of the U.S. Department of Labor charged with protecting the safety and health of workers in America. The OSHA was created by the Occupational Safety and Health Act (the act), signed into the law on December 29, 1970, by President Nixon.

The OSHA is headed by the assistant secretary for occupational safety and health, a presidential appointee, who is responsible for enforcing the act in the 50 states and certain territories and jurisdictions under federal authority. In the majority of states, territories, and jurisdictions, OSHA covers most private-sector workplaces but not those in the public sector operated by state and local governments. Exceptions to this arrangement are the six states and territories (Connecticut, Illinois, Maine, New Jersey, New York, and Virgin Islands) that have elected a hybrid option of mixing OSHA coverage of private-sector workplaces with state enforcement for governmental workplaces under an OSHA-approved state plan.

Twenty-two other states and territories chose to develop their own job safety and health programs through the OSHA state plan approval process, as strongly encouraged by Section 18 of the act. To be approved, a state program must be at least as effective as the federal OSHA program and cover both private- and public-sector employers and workers. Once approved by the OSHA, these states are responsible for enforcing the act in their own states. The states and territories with OSHA-approved state plans are Alaska, Arizona, California, Hawaii, Indiana, Iowa, Kentucky, Maryland, Michigan, Minnesota, Nevada, New Mexico, North Carolina, Oregon, Puerto Rico, South Carolina, Tennessee, Utah, Vermont, Virginia, Washington, and Wyoming. All federal employees fall under the jurisdiction of the federal OSHA and therefore are excluded from any state plan.

The OSHA is responsible for ensuring the safety and health of workers in American workplaces by setting and enforcing standards; monitoring the effectiveness of the OSHA-approved state plans; providing training, outreach, and education; and promoting workplace safety and health. OSHA health standards specify exposure limits for hazardous substances in the workplace, such as asbestos, cotton dust, benzene, lead, and blood-borne pathogens. OSHA safety standards establish requirements to prevent injuries, for example, standards for fall protection, trenching, and machine guarding. The OSHA issues fines to employers who violate the standards. The largest fine ever paid was $50.6 million by BP PLC in 2010 for failing to correct safety problems identified after a 2005 explosion at its Texas City refinery that killed 15 workers and injured 170.

The OSHA implements a complaint process whereby workers can file complaints with the OSHA about what they consider to be dangerous working conditions. Furthermore, the OSHA's whistle-blower protection program is designed to protect workers from retaliation for exercising their rights under the act. These rights include raising safety and health concerns with an employer, filing a complaint with the OSHA, requesting an OSHA inspection, or testifying related to an OSHA inspection. Critics point out that the OSHA has not been able to expand its capacity to respond to complaints in a timely manner.

To highlight its accomplishments, the OSHA points to statistics showing that work-related fatalities and injuries declined more than 65 percent since 1971, while the size of the workforce population nearly doubled during the same period. However, critics contend that this downward trend began well before the OSHA was created, and therefore, the OSHA's accomplishments may not be as impressive as they claim. Nevertheless, it is undisputable that the OSHA plays a key role in making the American workplace safer and healthier.

Yoko S. Crume

See Also: Asbestos; Black Lung Disease; Indoor Environment; Lead Poisoning Prevention; National Institute for Occupational Safety and Health; Occupational Safety and Health

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OCEAN ACIDIFICATION

Carbon dioxide (CO_2) is a gas that has both natural and human sources. The issue with CO_2 today is that it is a widespread greenhouse gas, contributing more than all other atmospheric gases to climate change. There is near-unanimous agreement in the scientific community that CO_2 concentrations in the atmosphere are on the rise and that these elevated levels are causing long-term climate change, a trend that at this point may be difficult if not impossible to reverse.

In addition to climate change, the increasing concentrations of CO_2 in the atmosphere are having another impact, perhaps less recognized, but every bit as troubling: the acidification of the oceans. Ocean water is a CO_2 sink, which means it absorbs CO_2 from the atmosphere, including up to one-third of the CO_2 emitted into the atmosphere from human activities like the combustion of fossil fuels for electric power generation. If it were not for the carbon uptake capacity of the oceans, scientists have calculated atmospheric CO_2 concentrations would be about 20 percent greater than they presently are, and as a consequence, the earth would be a much warmer place.

The continued absorption of greater and greater quantities of CO_2 into the ocean is concerning. Once dissolved in seawater, CO_2 gas reacts with water to form carbonic acid (H_2CO_3), which then dissociates by losing hydrogen ions to form bicarbonate (HCO_3^{-}) and carbonate ($CO_{3\_}{}^{2}$) ions:

$$CO_{2(atmos)} \leftrightarrow CO_{2(aq)} + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow 2H^+ + CO_3^{2-})$$

The more CO_2 that is added to ocean water, the more hydrogen ions increase and the more acidic the water becomes. Since preindustrial times, the average ocean surface pH has fallen by approximately 0.1 units, from about 8.21 to 8.10. Projections show that a further decrease of 0.3 to 0.4 pH units can be expected by the end of the century at the current trajectory.

What impacts will manifest from such changes in ocean chemistry? The potential consequences to marine life and also to economic activities that depend on a healthy marine ecosystem are difficult to assess and predict but potentially devastating. Reduced carbonate ion concentrations would provide less body building material for marine calcifiers, and experiments show stunted growth in marine organisms, subjecting them to potentially greater predation. The shells of some organisms dissolve more quickly in the low pH environment, potentially disrupting vital food webs in the oceans. Entire marine species in these food webs could become extinct if ocean acidification continues, further altering the ocean ecosystem. Acidosis from increasing carbonic acid concentrations in the body fluids of larger animals may cause problems with respiration, growth, and reproduction.

Of more immediate concern, declining oyster beds along the West Coast of the United States and declining coral reefs around the world are suspected to be related to the ocean acidification phenomenon. Coral reefs provide habitat to many species and are often regarded by ecologists as centers of biodiversity in the oceans. Mathematical modeling suggests that ocean acidification will generally reduce fish biomass and catch, and fisheries, tourism, and coastal protection will all be impacted.

While the chemistry of ocean acidification is well understood and verified by field measurements, the long-term impacts and potential adaptation of the marine environment is not. Models and other research suggest that the impact of rising CO_2 levels on marine biota will be varied, with both ecological winners and losers. However, the acidification of oceans impacts processes so fundamental in the marine ecosystem that the consequences, like those of climate change, could have far-reaching consequences. Geo-engineering solutions that attempt to slow global warming based on, for example, solar radiation management will not abate acidification. Reduction of atmospheric CO_2 is the most effective method to mitigate ocean acidification, but unfortunately, CO_2 concentrations continue rising at an accelerating pace.

John K. Borén

See Also: Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Greenhouse Effect and Global Warming; Mauna Loa Observatory, Carbon Measurements at

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OCEAN DUMPING AND THE PACIFIC GARBAGE PATCH

Ocean dumping and other human activities cause ocean pollution, including the Pacific garbage patch. As a result, the ocean is contaminated with a wide variety of toxic chemicals and plastic trash that harm wildlife and accumulate in fish and shellfish. This creates a health risk for people who eat seafood.

Garbage Patches—Not Just the Pacific

The North Pacific garbage patch has the largest and densest amount of plastic debris, but plastic trash is also found in the Atlantic and Indian Oceans. The Atlantic Ocean garbage patch, first documented in 1972, has an estimated 11,700 tons (10,600 metric tons) of plastics, and the Indian Ocean garbage patch, discovered in 2010, contains an estimated 2,200 tons (2,000 metric tons) of plastics. To raise awareness about ocean pollution, Italian artist Maria Cristina Finucci proclaimed the State of Garbage Patch at UN Educational, Scientific, and Cultural Organization (UNESCO) headquarters in 2013. The UNESCO subsequently granted Garbage Patch symbolic statehood status.

Throughout the industrial period, ships could dump treated and untreated sewage, industrial and radioactive wastes, and military munitions into the ocean without restriction. The United States banned ocean dumping in 1972, and in later international treaties, other countries agreed to stop dumping industrial products. As of 2015, practically every country with shipping had banned dumping. However, illegal dumping still occurs, and waste also enters the ocean through rivers. In particular, nitrogen fertilizer from agricultural runoff causes “dead zones” resulting from eutrophication (a process whereby algae and cyanobacteria grow rapidly and eventually deplete the oxygen supply). In these areas, excess algae or bacteria deplete the oxygen in the water. Other ocean pollution comes from offshore mining and oil/gas exploration.

Are Plastics in Your Diet?

Did you know that if you eat ocean fish, you may also be ingesting tiny particles of plastic? This is because the 8.8 million tons (8 million metric tons) of plastics that end up in our oceans every year (equivalent to one garbage truck each minute) eventually break down into minute pieces that are ingested by fish. According to a study by the Scripps Institution of Oceanography, about 9 percent of fish sampled near the North Pacific Subtropical Gyre contained plastics, and the researchers believe this to be a low estimate. And another study by researchers at the University of California–Davis found plastics and textile fibers in about 25 of the fish sampled at one California fish market. Plastics in the oceans may absorb toxic chemicals that are released into a fish's bloodstream or tissues while being digested, and one common plastic ingredient, styrene, is considered a possible human carcinogen by the International Agency for Research on Cancer. Furthermore, the volume of amount of plastics in the oceans is dramatically increasing, such that by 2050, there may actually be more plastics in the ocean (on a weight basis) than fish! Despite these concerns, the consensus of most public health professionals, at least for now, is that the health benefits of eating these ocean fish generally outweigh the potential risks. (On the other hand, be cautious about eating certain species of fish known to have high mercury concentrations, including swordfish, shark, mackerel, and tuna.)

Healthy Oceans and Human Health

I just worry that in a hundred years, people will look back at our generation and say, "They knew, they had a choice, but they did nothing."

An Interview with Dr. Iain Kerr

Chief Executive Officer, Ocean Alliance

Dr. Kerr, chief executive officer of the Ocean Alliance, is an international leader in whale research and ocean conservation. He has led oceanographic expeditions all over the globe, including the Voyage of the Odyssey, *which provided the first complete set of data on the concentration and distribution of synthetic contaminants and effects on top predator species in the world's oceans. The Ocean Alliance collects information on whales and other ocean life, with the goal of educating policymakers and the public on wise stewardship of the oceans to prevent the collapse of marine mammal populations and promote ocean and human health.*

You have said humans are "utterly dependent" on preserving the marine environment. Why is a healthy marine environment important to human health?

It is popular to talk about preserving "planet earth," but we should really be discussing "planet ocean." Over 70 percent of the world is covered with water, and almost all of this is in the oceans. And about 70 percent of the oxygen in our atmosphere comes from marine plants, mainly phytoplankton (Prochlorococcus).

Over half the world's population lives within about 125 miles (200 kilometers) of a coastline, and about three billion people rely on wild-caught and farmed seafood for their primary source of meat protein. As land resources continue to be depleted, humans will increasingly turn to the oceans for essential resources, especially food. Thus, the critical importance of the oceans to human health and survival is undeniable.

You also believe that environmental conservation should be a "state of mind." What exactly does this mean, and how can humanity's general apathy about the oceans be reversed?

I met an astronaut once who told me I would never meet another astronaut who is not a rabid environmentalist after seeing our fragile planet from space. We spend a lot of time protecting ourselves with safer cars, home security systems, and healthy diets, but few people appreciate the connection between healthy oceans and their own health. This is probably because environmental degradation in the oceans is hard to see for the average person. There are dead zones all over the oceans, but we just don't see them. There are fish die-offs in the oceans all the time, but we usually are not aware. Environmental issues are complex, and none of us are perfect citizens when it comes to protecting the environment, but if 90 percent of everyone would do just one thing for the environment every day (like picking up trash or recycling a bottle), we would live in a very different world.

Much of your current research focuses on whales, specifically studies of toxicology, behavior, bioacoustics, and genetics. Are there any lessons from your research that can be applied to protecting the human species?

Humanity is a cosmopolitan species at the top of the food chain, and research shows that it is the most complex species that are most at risk from environmental pollution. We have learned that whales and other mammals bioaccumulate toxins and pass them on to their offspring. I believe whales serve as excellent bioindicators for the health of the planet, and when whales suffer from toxins, plastics, and other ocean pollutants, we are all at risk.

The Ocean Alliance promotes wise stewardship of the oceans. Is there any hope for the future of the oceans given the problems that are already occurring, such as coral reef bleaching, ocean acidification, dead zones, invasive species, mercury pollution, and giant gyres of trash?

I believe in humanity, and I try to see every crisis as an opportunity. Many organizations are working very hard to solve our environmental issues, and a number of large corporations are showing leadership in protecting the environment. Working together, we can solve this problem. I just worry that in a hundred years, people will look back at our generation and say, "They knew, they had a choice, but they did nothing." Let's not let that happen!

What would be a good career path for a recent college or university graduate wanting to make a real difference in preserving the oceans and protecting public health?

Whatever career one pursues, do pro bono work for the environment, pick up trash when you see it, and most importantly, believe you can make a difference!

Dumping materials into the ocean can endanger marine ecosystems and human health. For instance, mercury from industrial dumping accumulates in the bodies of marine animals, resulting in contaminated seafood. The highest mercury concentrations are found in swordfish, shark, mackerel, and tuna. Women of childbearing age are encouraged to limit their consumption of these fish because mercury can cause neurological problems in developing infants. The World Health Organization lists mercury as one of 10 chemicals of "major public health concern."

The Pacific garbage patch is a vast area in the northern Pacific Ocean with a high density of plastic trash. This area contains items such as bottles, plastic bags, fishing nets, and cigarette lighters, but most of the patch is a "soup" consisting of tiny pieces of plastic. The patch was first discovered in 1997 by Captain Charles Moore, who has since established the Algalita Foundation to investigate the scope and significance of this floating debris. Recent estimates of the size of this debris field range between 270,000 and 5.8 million square miles (700,000 and 15 million square kilometers). This represents an area covering up to 8 percent of the entire Pacific Ocean. The density of plastic in the northern Pacific Ocean is estimated to be 64,700 pieces per square mile (25,000 pieces per square kilometer).

Worldwide, the ocean receives an estimated 8.8 million tons (8 million metric tons) of plastic trash every year. In the Pacific Ocean, a large circular system of currents known as a gyre transports and concentrates the plastics into one large area, the Pacific garbage patch. Plastics are generally not biodegradable, so sunlight and other weathering processes break down plastic trash into increasingly smaller pieces. Most of the plastics retrieved from the ocean are less than the size of a person's smallest fingernail. Some of the smallest pieces, called microplastics, come from strands of rope, nets, textiles, and microbeads found in exfoliating soaps and some toothpastes.

This trash is harmful to many species of birds and fish as well as humans. A well-documented case concerns albatross chicks on Midway Atoll, a national marine sanctuary that receives up to 20 tons (18 metric tons) of plastic debris every year. These chicks die when their parents feed them bottle caps and other trash. Additionally, other animals get stuck in large pieces of trash and cannot free themselves. The plastics also present risks to human health. For example, plastics absorb from the seawater toxic chemical pollutants like polychlorinated biphenyls and the pesticide dichlorodiphenyltrichloroethane (better known as DDT), and when these plastics are ingested by jellyfish and small fish, the absorbed toxins are passed up the food chain to larger fish and finally humans. Additionally, bacteria, algae, and other microbes grow on the plastic trash, creating what has been termed the "plastisphere." The impact of the plastisphere is relatively unknown, but one study of the microbial life on plastic trash in the ocean has identified bacteria in the genus *vibrio*, which includes the bacteria that cause cholera.

Efforts to clean up ocean pollution, including plastic debris, are expected to be costly. The National Oceanic and Atmospheric Administration sponsors the Marine

Debris Program to support locally driven marine debris prevention and removal projects, benefiting coastal habitats, waterways, and wildlife. The Ocean Cleanup is a foundation established in 2013 to remove plastics from the oceans and prevent future contamination. They have designed a passive removal system of barriers that funnels debris to extraction platforms, and they plan to begin large-scale trash removal in 2020. However, reducing consumption of plastic in the form of throw-away utensils, water bottles, and synthetic textiles is key in preventing future trash from entering the garbage patches of the world.

Alisha K. Newton

See Also: Estuary Pollution; Fish Consumption Advisories; Marine Pollution, International Treaties to Prevent; Mercury Pollution; National Estuary Program; National Oceanic and Atmospheric Administration

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ODOR POLLUTION

If it smells bad, it must be bad for you. This is what many people believe about odors, but this is not always the case. Countless substances having a pungent smell are harmless, while other odorless substances may cause serious health problems. Regardless, no one likes being around something that smells bad. Historically, odor complaints represent a large fraction of the citizen complaints made to local environmental health agencies.

Keeping a Personal Odor Diary

Are you bothered by an odor in your community? If so, try keeping an odor diary. Odor diaries provide information that help local environmental health officials identify the source of the odor and take action to reduce or eliminate the offensive smell. The information typically found in an odor diary includes the date the odor was detected, start and end times, location, odor type and severity, effects on normal activities, weather conditions, and any comments that may be helpful in locating the source. With this information, combined with other data about air pollution emissions and air quality, local officials can assess the problem and formulate a solution, for example, ordering the source of the odor to modify or cease operations or requiring technology to capture, disperse, or destroy the odor.

Many odors are associated with human activities, for example, making compost, treating sewage, collecting garbage, or operating diesel-fueled vehicles. Other odors emanate from industrial operations, including oil refineries, landfills, paper mills, and wastewater treatment plants. Concentrated animal feeding operations (agricultural operations where animals are kept and raised in confined situations) can also be sources of offensive odors.

Among the five senses, our ability to smell is the most complex. Humans can distinguish over 10,000 different odors, some of which are perceived as pleasant and others the opposite. Pleasant odors help us enjoy a delicious meal at our favorite restaurant or a walk through the woods on a cool spring morning, while unpleasant odors can sometimes indicate a hazard, for example, a gas leak. Having to live with unpleasant odors in a community can diminish the quality of life and sense of well-being. While humans are excellent in distinguishing odors, it is an interesting fact that we almost always have great difficulty describing them in words.

There are four characteristics that determine our perception of odors, for example, how strong the odor is and whether it is pleasant or unpleasant. The first characteristic is *detectability*, which refers to the minimum concentration of the substance in the air that we can smell. (In other words, our noses cannot detect concentrations lower than this minimum level.) Because detectability varies from person to person, someone may be able to detect a faint odor that someone else misses. Nevertheless, the ability to detect odors is similar for most people.

The second characteristic of odor is *intensity*, which refers to whether the odor is perceived as strong or weak. Intensity increases with concentration of the substance in the air. The third characteristic is *character*, which is what the odor smells like or reminds us of. Odors often have a smell described as fishy, hay, nutty, creosote, turpentine, rancid, sewer, and ammonia. Sometimes we can recognize specific chemicals or sources from their smell.

The fourth characteristic of odor is *hedonic tone*, which represents subjective judgment about whether an odor is pleasant or unpleasant. (The word "hedonic" is derived from the Greek word *hedone*, which means "pleasure.") A variety of factors influence hedonic tone, including the odor intensity, character, duration, and frequency of occurrence. Location and time of day can also be factors. For example, freshly baked bread may smell wonderful in a bakery but may be annoying if we are trying to fall asleep.

Odors can cause various adverse health experiences, depending on the substance causing the odor, the concentration in the air, how long and often exposure occurs, and a person's age, general health condition, and sensitivity to the substance. Some examples of odor symptoms are headaches, nasal congestion, sore throat, coughing and wheezing, chest tightness, shortness of breath, heart palpitations, nausea, and irritation of the eye, nose, and throat. Strong odors can interfere outdoor activities and sleep, and if the odor is associated with a toxic chemical, serious health episodes may occur. In some cases, the substance causing an odor can worsen asthma, chronic obstructive pulmonary disease, and emphysema. In general, children, older adults, and pregnant women tend to be more sensitive to odors than the general population.

Some hazardous substances have no odor, making detection difficult. For example, natural gas (methane), which is widely used in the United States for heating and cooking, is odorless, colorless, and tasteless, making leak detection difficult. This is a problem because if a natural gas leak occurs, for example, in the furnace that heats your home, and if gas concentrations build up, a fire and explosion can occur. To make natural gas leaks more easily detectable, a harmless but smelly substance called mercaptan (also known as methyl mercaptan and methanethiol) is routinely added, giving the mixture an odor similar to rotten eggs.

Carbon monoxide (CO) is another example of a substance that has no detectible odor. CO occurs when fuels are combusted in engines, stoves, lanterns, grills, fireplaces, gas ranges, and furnaces. If the fuels are used in an enclosed area with poor ventilation, the CO can build up to dangerous levels, resulting in CO poisoning that can kill you. Common symptoms of CO poisoning include headache, dizziness, vomiting, chest pain, and confusion, and sometimes CO symptoms are described as flu-like. People who are asleep or drunk can die from CO poisoning before knowing they have symptoms. According to the Centers for Disease Control and Prevention, over 400 Americans die each year from accidental CO poisoning (excluding fires), and more than 20,000 visit emergency rooms.

The U.S. government does not regulate odors per se, but some air quality regulations reduce concentrations of pollutants that happen to be odorous. For example, sulfur dioxide gas, which has a strong, pungent odor, is regulated by a National Ambient Air Quality Standard. Additionally, many cities and local governments have nuisance codes for odors that residents find objectionable.

Richard Crume

See Also: Air Pollution; Ambient Air Quality; Concentrated Animal Feeding Operations, Pollution from; Respiratory Disease and Air Pollution

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OIL SPILLS, HEALTH CONSEQUENCES OF

Oil spills have provided some of the worst man-made disasters in history, resulting in devastating impacts on human health and the environment. While many of the oil spills making headlines are offshore, a number of oil spills have also occurred on land. But regardless of where the oil spill occurs, the potential exists for harmful human health effects. While workers and volunteers who respond to spills and assist in the cleanup are at greatest risk, the surrounding population may also be threatened with adverse health consequences, depending on the extent of the spill and the nature of the exposure.

Oil spills can generally be grouped into two different categories: accidental and deliberate. Accidental spills often occur during the storage, handling, and transportation of oil. Many of the well-known oil spill disasters, such as the *Exxon Valdez* oil spill, happened during transportation over ocean waters, but oil spills also occur on land from pipelines and storage tanks. A common example of a storage-related spill is a gasoline leak from an underground storage tank at an automobile

World's Worst Oil Spill

The world's worst oil spill occurred during the 1991 Gulf War as Iraqi forces retreating from Kuwait set fire to oil wells and opened oil rig and pipeline valves to try to slow advancing American troops, releasing 252 to 336 million gallons (0.95 to 1.27 million cubic meters) of oil into the Persian Gulf. The resulting oil slick covered an area about the size of the island of Hawaii. In contrast to other oil spills, this incident was a *deliberate* wartime act. On the other hand, the 2010 Deepwater Horizon explosion and subsequent oil leak, releasing 134 million gallons (0.51 million cubic meters) into the Gulf of Mexico, is world's largest *accidental* oil spill.

fueling station. Depending on how old the gasoline storage tanks are and how long they have been underground, these tanks can leak gasoline into the surrounding soil and even contaminate groundwater. Accidental oil spills can also happen from routine maintenance activities, such as cleaning ships and trucks, and from offshore drilling operations. These types of spills are often caused by carelessness, negligence, or recklessness by those responsible for the oil at various stages of its production and sale.

In contrast to accidental oil spills, deliberate spills are purposeful releases of oil into the environment by a polluter. Two examples of deliberate oil spills are discharges of oil from ships in international waters, where the enforcement of international oil pollution laws is difficult, and from automobile service stations, where oil may be discharged directly into drains and sewers. While accidental oil spills, particularly large releases by offshore oil tankers, typically receive the most attention in the press, deliberate oil spills by industries and even individuals (e.g., disposing of automobile or lawnmower oil down the sewer drain) account for much more of the oil discharged into the environment globally.

Oil is also released into the environment from natural sources. For example, crude oil and natural gas, which occur naturally underground, often seep into both marine and terrestrial environments from cracks and fissures in the ground. However, such releases generally pale in comparison to the accidental and deliberate releases described previously.

The severity of an oil spill, the resulting cleanup effort, and the impact on human health all depend, in part, on the type of oil that spilled. Oil is characterized by its viscosity (a measure of a substance's resistance to flow) and volatility (a measure of how quickly a substance evaporates). Heavy crude oils typically have a high viscosity and low volatility, meaning that they move and evaporate very slowly. Conversely, light oils, such as gasoline or jet fuel, have a very low viscosity and high volatility, meaning that they move and evaporate quickly. Very heavy crude oils, such as Fuel Oil No. 6, which is used in industrial processes and power plants, are difficult to clean up and can cause widespread contamination along a shoreline, often coating animals and birds with a thick oily film. Because heavy oils biodegrade and weather slowly, they have a high risk of causing severe health effects. The medium and light oils also pose significant risks, but their cleanup can be more effective if done efficiently and quickly. Very light oils, like gasoline, are toxic to the environment and difficult to cleanup, but due to their high viscosity, they will evaporate in just a few days.

Once an oil spill has occurred, a number of methods can be used to respond to, clean up, and remediate the spill. If an oil spill was caused by an accident at an oil tanker at sea, booms are often deployed to contain the oil slick. (Booms are floating barriers that prevent the oil from spreading.) Skimmers (boats that skim or collect oil from the surface) can be used to remove oil from the water, or the oil can be set on fire and burned away. Burning is a safe and efficient way for removing oil from the water, although the technique results in air pollution. Dispersants can also be used on oil spills to help decompose the oil into smaller particles so that microorganisms such as bacteria can more efficiently break down the oil. This process also causes the oil particles to sink, which prevents the oil from washing up on coasts and inflicting more damage to coastal ecosystems. Dispersants were widely used in the Deepwater Horizon oil spill in 2010.

For oil spills that reach a coastline, sorbents are often used in coastal areas that skimmers cannot reach. Sorbents are insoluble (will not dissolve in water), oleophilic (oil-attracting), and hydrophobic (water-repellent) materials that both *absorb* and *adsorb* the oil. Sorbents absorb by drawing the oil into the material itself, much like a sponge absorbing water. Sorbents adsorb oil by attracting it to the sorbent surface, like a magnet. Other cleanup methods include vacuuming the oil, washing the oil with high-pressure or low-pressure hoses, and removing contaminated soil from the site. Deciding which method to use depends on numerous variables, such as the weather, type of oil, area of contamination, soil type, and local ecology.

The severity of the health effects associated with an oil spill is related to the amount of exposure to the oil and the specific type of oil. The contaminants found in oil that pose the most severe health risks to humans are polycyclic aromatic hydrocarbons, volatile organic compounds, and heavy metals. Many of these contaminants are carcinogenic and have the potential to disrupt important physiological systems, such as the endocrine and immune systems. Many oil spill health studies target cleanup workers and volunteers who may come into direct contact with the oil. Additionally, the general population may also be at risk during an oil spill by breathing contaminated air, contacting skin with oil, and consuming contaminated food and water. Acute effects can include dermal irritation, respiratory discomfort, nausea, vomiting, light-headedness, and headaches. The vast majority of acute effects are experienced by workers and volunteers who are directly involved with the cleanup. Some studies of workers and volunteers have documented altered blood profiles and liver function.

Other studies have documented psychological effects in the years following an oil spill. For example, one study involving the *Exxon Valdez* oil spill found that those who had high exposure to the contamination were 3.6 times more likely to suffer from general anxiety disorder and 2.9 times more likely to suffer from post-traumatic stress disorder. A similar trend was also observed following the Deepwater Horizon oil spill.

Adverse health effects can be caused not only by the oil spill itself but also by how the cleanup is conducted. For example, in situ burning releases harmful toxins and particulate matter into the air that can cause respiratory discomfort. While the consequences of dispersant exposure are not fully understood, questions have been raised about the safety of these chemicals. While more research is needed, most scientists believe that the health risks posed by an oil spill can be severe and have the potential to cause significant harm, particularly to those who participate in the response and cleanup efforts.

Anthony G. Papetti

See Also: Deepwater Horizon Incident; Disaster Preparedness and Response; Fish Consumption Advisories; Ocean Dumping and the Pacific Garbage Patch; Water Pollution

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ONE HEALTH

Environmental and human health are inextricably connected, and a comprehensive understanding of emerging health issues in human populations requires analysis of both the human and environmental aspects. For example, urbanization of formerly unpopulated areas has increased contact between humans and wild animals, offering more opportunities for diseases to hop from animals to humans. About 75 percent of emerging infectious diseases are now zoonotic (transferred between animals and people), resulting in the beginnings of a public health crisis. To understand these diseases and their impact, we cannot solely focus on human health. One Health is a collaborative effort that hinges on the idea that human, animal, plant, and ecosystem health are all interdependent—that when considering the health challenges of a population, we must also consider how that population interacts with its ecosystem. This approach requires systems thinking and coordinated actions to solve and to prevent health problems at the local, national, and global scale.

The One Health approach integrates multiple disciplines, sectors, and scales. While this may be challenging, the increasing pressures of pollution, disease, food and water security, poverty, conflict, and extreme weather have motivated agencies and organizations to launch One Health initiatives. This can be observed at various levels of training and research. For example, human and veterinary medical colleges are enhancing curricula with One Health training, and researchers are working at landscape scales to benefit the people and animals who live there.

This integration helps us understand, prevent, and treat conditions common to both people and animals, including cancer, heart disease, and diabetes.

While the label is new, the idea of One Health has been around since the 19th century. Rudolph Virchow (1821–1902), Louis Pasteur (1822–1895), William Osler (1849–1919), Rachel Carson (1907–1964), and Calvin Schwabe (1927–2006) all wrote about connections between health and environmental conditions. However, the concept has gained significant momentum in recent years. Veterinary and human medical colleges are increasingly engaged in One Health research and conservation medicine. Public health agencies at the federal level are also leading One Health efforts. Agencies with active One Health programs include the Centers for Disease Control and Prevention, National Institute for Environmental Health Sciences, Department of Agriculture, and Geological Survey.

One Health is also gaining traction globally. The One Health Commission, formed in 2009, serves as a world health network, linking multiple disciplines and sectors and promoting a shared One Health agenda. Since 2010, the International One Health Congress has been held biannually at various locations, with topical discussions on the intersection of health with peace, shelter, education, food, income, and social well-being. This conversation is particularly relevant for underserved, subsistence cultures, where people live off the land in close proximity to domestic animals and wildlife. The One Health approach hopes to advance research and projects that help people in subsistence cultures to improve health, overcome poverty, reduce wildlife conflicts, and preserve ecosystems.

Progress will require breaking down barriers to implementation, including academic traditions of tenure and specialization, isolation within government agencies, international language barriers, and lack of specific funding allocations. Despite these hurdles, the One Health approach presents a potential strategy for collaboratively addressing the growing pressures on human, animal, and environmental health.

Gwen Griffith

See Also: Carson, Rachel; Centers for Disease Control and Prevention; Infectious Diseases; National Institute of Environmental Health Sciences; Zoonotic Diseases

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OPEN BURNING OF WASTE

Open burning of waste is the combustion of discarded material in various environments that are not enclosed. Typically, the material being combusted is household or commercial waste, including yard waste and items such as paper, cardboard, plastic, and construction debris. Open waste combustion often occurs in barrels, open pits, outdoor stoves and fireplaces, and fields. Burning waste is common in rural areas and can be an effective waste management tool when completed in an appropriate enclosed burn unit, such as an incinerator. Improper burning can result in wildfires and increased pollution. Open burning is typically not recommended because it is harder to contain and control.

Under ideal burning conditions, adequate mixing of fuel (i.e., waste) and air occurs over a sufficient time period to ensure the waste fully burns. This situation minimizes the quantity and toxicity of combustion by-products. Lack of adequate mixing results in incomplete combustion, which can produce toxic chemicals that pose health risks to those exposed to the fumes. The release of these toxic chemicals can have an especially adverse impact on people with sensitive respiratory systems as well as on children and the elderly. Many of these toxic chemicals can also end up in the ash that is left behind from open burning. These constituents can leach into the soil, where they are adsorbed by plants or deposited into streams, lakes, and ponds.

Some of the pollutants contained in the smoke and fumes from open burning of waste can include:

- Carbon Monoxide: a product of the incomplete combustion of trash. Carbon monoxide is a colorless, odorless gas that prevents oxygen from being absorbed by the blood and lungs. It is especially dangerous when breathed by young children with immature lungs, the elderly, and people with chronic heart conditions or lung disease.
- Dioxin: one of the most harmful pollutants released during the burning of trash. Dioxin is a known carcinogen and associated with birth defects. It can be inhaled directly or deposited on soil, water, and crops, where it becomes part of the food chain.
- Hexachlorobenzene: a highly persistent toxin that degrades slowly in the air and can travel long distances in the atmosphere. It bioaccumulates in fish, marine animals, birds, lichens, and animals that feed on fish and lichens. Hexachlorobenzene is a probable human carcinogen and may damage a developing fetus, lead to kidney and liver damage, and cause fatigue and skin irritation.
- Formaldehyde: a product of combusting pressed wood products, paints, coatings, siding, urea-formaldehyde foam, and fiberglass insulation. Exposure to formaldehyde can result in watery eyes, a burning sensation in the eyes and throat, nausea, difficulty in breathing (e.g., coughing, chest tightness, and wheezing), and skin rashes. Prolonged exposure to formaldehyde may cause cancer.

- Hydrogen Chloride Gas: or hydrochloric acid, a by-product of burning polyvinyl chloride plastic. Hydrogen chloride can cause fluid buildup in the lungs and ulceration of the respiratory tract.
- Visible Smoke: tiny particles (particulates) that occur due to incomplete combustion. Smoke often contains toxic pollutants, and if inhaled, these microscopic particles can reach deep into the lungs and remain there for months to years. Breathing particulates increases the chances of respiratory infection, can trigger asthma attacks, and causes problems like coughing, wheezing, chest pain, and shortness of breath.

Virtually all state and many local agencies have developed rules prohibiting open burning or restricting the types of materials that can be burned under unenclosed environmental conditions. To complement these rules, some agencies require that individuals and organizations obtain permits prior to burning solid waste. Some agencies also conduct awareness training and outreach on the deployment of less impactful alternatives. For example, when it comes to managing fallen leaves, state and local agencies encourage residents to mulch leaves into the lawn with a mower, or alternatively, to compost them in their backyards or through an organics collection program.

The quantity of open waste burning can be reduced when both household and commercial entities implement waste minimization and pollution prevention practices. Some basic principles include:

- Reduce: Avoid disposable items. Buy products in bulk instead of individually wrapped or single-serving sizes. Buy durable products and products that can be recharged, repaired, or refilled.
- Reuse: Donate items you no longer need, such as clothing, furniture, books, magazines, and toys. Mend and repair items rather than discarding or replacing them.
- Recycle: Separate the recyclable items from your garbage for collection or drop-off at a local recycling depot.
- Compost: Install a backyard compost bin for composting your kitchen and yard waste, and if available, participate in your community's organics collection program.
- Dispose: Put your garbage out for collection or take it to your local landfill.

Richard F. Pandullo

See Also: Dioxin Pollution; Formaldehyde; Hazardous Air Pollutants; Persistent, Bioaccumulating, and Toxic Chemicals; Pollution Prevention; Respiratory Disease and Air Pollution; Three Rs of Waste Management

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ORGANIC AGRICULTURE

Organic agriculture is a food production method that helps protect the health of humans, animals, and the farmed land by using practices that conserve the diversity of life and promote ecological well-being. It focuses on the long-term view of promoting human health and the environment through sustainable farming methods.

The demand for organic agriculture has been increasing as public awareness grows of the possible risks of traditional farming methods to human health, biodiversity, and ecological systems. Since the dawn of the organic agriculture industry nearly three decades ago, the demand for organic food has grown faster than supply, with sales increasing 20 percent annually.

There are many common organic agricultural practices, including crop rotation, the use of natural pest control methods in place of chemical pesticides, and avoidance of growth hormones and antibiotics when caring for farm animals. Many studies indicate that organic agriculture produces food with fewer pesticide residues and higher nutritional value—more essential amino acids, vitamins, and minerals.

Organic agricultural practices are more sustainable over time. Because the practices take a long-term view of overall soil health, organic farming alters the environment much more slowly than conventional farming practices, and it does so in a way that minimized damage to the local ecology. Organic practices help to prevent disease while producing hardier plants without the need for genetic modification to resist certain pesticides.

A sign identifying an organic farm and warning against spraying of pesticides. Organic farming uses sustainable farming methods that conserve the diversity of life and promote ecological well-being. (Elswarro/Dreamstime.com)

In addition to direct benefits to plants, organic methods for farming positively impact the environment surrounding the organic farm. For example, stormwater runoff has fewer pesticides and other chemicals, and pollination methods, crop rotation, soil conditioning, and other practices work to minimize harm to the ecosystem.

Organic animal agricultural practices focus on the welfare of the animal by avoiding antibiotics and growth hormones, providing a more humane living environment, and ensuring animals are fed healthy diets. These practices protect animals from cruelty, avoid contamination of meat products with antibiotics and drug-resistant bacteria, and keep the environment free of chemicals.

Studies have demonstrated that biodiversity within a farm and the surrounding area increases when organic agricultural practices are used. This increase in biodiversity includes more types of foliage and animals, as habitat and species diversity improve compared with similar conventional agricultural sites.

In 2015, there were 2.4 million organic farmers globally, an increase of over 7 percent from the previous year, and the United States continues leading the world in organic product production. While there is debate over the ability of sustainable and organic agricultural practices to produce adequate food supplies for the nation (particularly for grain production), increasing funding for research is helping organic farmers improve practices and increase yields.

Ronda Bowen

See Also: Food Supply, Environmental Threats to; Genetic Engineering and GMOs; Intensive Farming Practices and Health; Pesticides and Herbicides; Stormwater Runoff

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OZONE AND SMOG IN THE URBAN ENVIRONMENT

Smog is a type of air pollution that is found in many metropolitan areas and sometimes in rural areas. It consists primarily of a pollutant called ozone, which can adversely affect human health. Smog is also composed of several other air pollutants, including nitrogen oxides (NOx), sulfur dioxide, carbon monoxide, volatile organic compounds (VOCs), and small particles. These pollutants are caused by industrial operations and by electric power plants that burn coal, oil, or natural gas. Additionally, they are found in the exhausts of motor vehicles, such as automobiles, trucks, and buses, that are powered with gasoline or diesel fuel.

Good Ozone, and Bad

The ground-level ozone in polluted metropolitan areas is often referred to as the *bad* ozone because breathing it can cause adverse health effects, like coughing, shortness of breath, chest pain, and irritation of the lungs, and it can also aggravate asthma. However, ozone also occurs in the stratosphere, which is a layer of the atmosphere about 32 miles (50 kilometers) above the earth's surface. Stratospheric ozone is often referred to as the *good* ozone because it helps block harmful ultraviolet radiation from the sun.

Ozone, the main ingredient in smog, is not emitted directly into the air. Instead, it is formed at ground level when NOx and VOCs react in the presence of sunlight, particularly on warm summer days. The major sources of NOx and VOCs include nonnuclear power plants, motor vehicles, manufacturing facilities, chemical plants, and oil refineries. The ground-level ozone discussed here should not be confused with the ozone that occurs naturally in the stratosphere and helps shield the earth from harmful ultraviolet radiation from the sun.

Breathing ozone and the other components of smog can cause a variety of adverse health effects. In particular, ozone can irritate the respiratory system, cause chest pain, aggravate asthma, and reduce lung function. ("Lung function" is a term the medical profession uses to characterize the volume of air inhaled when taking a full breath and the speed at which the air is exhaled.) Ozone can also inflame and even damage the linings of the lungs, similar to sunburn on exposed skin. Shortness of breath and coughing on a warm day could be a sign of elevated ozone concentrations in the surrounding air.

About one of every three Americans is at a higher risk of experiencing adverse health effects due to ozone. These Americans include children, adults who are active outdoors, people with respiratory diseases, and other adults who for unknown reasons show unusual sensitivity to ozone. Children are especially at risk from ozone exposure because their lungs are still developing, they are likely to be active outdoors when ozone levels are high, and many children suffer from asthma. Ozone inhalation by older adults is also a serious concern if they already suffer from respiratory disease or spend significant time outside.

Ozone can also harm sensitive vegetation, especially during the growing season. Black cherry, quaking aspen, ponderosa pine, and cottonwood trees are notable for their sensitivity, as are certain crops. Ozone damages vegetation by entering the leaves and interfering with food production and storage. Exposure to ozone over long periods can increase the susceptibility of plants to diseases and insect damage.

According to the U.S. Environmental Protection Agency (EPA), over 50 million Americans live in areas where ozone levels exceed government standards intended to protect public health. To help the public know when levels of ozone and other pollutants are elevated, the EPA has set up a website called AirNow, which provides daily reports on air quality. Another EPA service, EnviroFlash, delivers daily e-mail alerts about air quality, with suggested safety measures when local air pollution levels are high.

Richard Crume

See Also: Air Pollution; AirNow and the Air Quality Index; Ambient Air Quality; Asthma; Children's Environmental Health; Crops and Vegetation, Air Pollution Damage to; Environmental Protection Agency; Respiratory Disease and Air Pollution; Stratospheric Ozone Depletion; Volatile Organic Compound Pollution

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PARKINSON'S DISEASE AND ENVIRONMENTAL EXPOSURE

Parkinson's disease is a neurodegenerative disease believed to be caused by the interaction of genes and the environment. People with Parkinson's disease experience a loss of neurons in the midbrain, resulting in a reduction of dopamine, a neurotransmitter responsible for coordinating muscle movement with other parts of the brain. The disease progresses more rapidly in some patients than in others, and while some patients may become severely disabled, the disease may cause only minor motor interferences in others. People with Parkinson's disease generally have a shorter life expectancy compared with the general population.

Because there are no blood or laboratory tests to confirm the presence of Parkinson's disease, the rate of misdiagnosis may be relatively high. Nevertheless, it is estimated that at least one-half to one million Americans have Parkinson's disease, and the prevalence of the disease is increasing as the population ages. The disease can be found among all races, ethnic groups, nationalities, and income levels.

The symptoms of Parkinson's disease include tremors (trembling in the hands, arms, legs, jaw, and face), rigidity (stiffness of limbs and trunk), bradykinesia (slowness of movement), and instability (problems with balance and coordination). As these symptoms worsen, patients may have difficulty walking, talking, and completing simple tasks. Patients may also experience a poor sense of smell, constipation, depression, cognitive impairment, and fatigue, and these symptoms may occur years before motor problems become evident.

Michael J. Fox Battles Parkinson's

Michael J. Fox, a popular professional actor appearing in award-winning theater and television shows, was diagnosed with young-onset Parkinson's disease in 1991. As his symptoms became more severe, he stopped acting in 2000 and launched The Michael J. Fox Foundation for Parkinson's Research. The foundation is the largest nonprofit funder of drug development for Parkinson's disease and "the most credible voice on Parkinson's research in the world," according to the *New York Times*. Finding he could control his symptoms with drug treatments, Fox returned to acting in 2012, playing various roles, including a character with Parkinson's disease. Fox has received several lifetime achievement awards for acting as well as numerous honorary degrees and humanitarian awards, and he is the best-selling author of three books.

The causes of Parkinson's disease are unknown despite many years of study and research. It is possible that the disease is primarily caused by genetic factors in some people and by illness or environmental toxins in others. It is known that age is a factor, with people over 60 years old at greater risk of developing the disease. It is also believed that most Parkinson's cases are not directly inherited. At present, there is no cure for the disease, although medications can lessen the severity of symptoms. In cases where the patient does not respond well to medications, surgery may be appropriate (e.g., implanting electrodes, connected to a pulse generator, into the brain). By understanding what causes the loss of dopamine-producing cells, many researchers are optimistic about finding treatments to slow down or even reverse the disease.

While most scientists believe that Parkinson's is caused by interaction between a person's genetic makeup and the environment, this interaction is quite complex and poorly understood. Some environmental factors may increase the risk of Parkinson's disease, while others decrease the risk, and the same may be said for genetic makeup. The research challenge has been to identify the combinations of environmental factors and genetic makeup that cause the disease.

Some evidence of an association with Parkinson's disease has been found for the following potential risk factors: age (about 1 percent of people over age 60 have Parkinson's disease), gender (it is more common in men than women), history of traumatic brain injury, the geographical area where one lives, occupation, and genetic predisposition. There may also be an association with exposure to solvents, polychlorinated biphenyls (PCBs), and certain pesticides, herbicides, fungicides, and metals, which is of particular interest to the environmental health field because these are all common environmental pollutants. However, presently there is no conclusive evidence that environmental factors acting alone can actually cause Parkinson's disease.

In addition to the factors associated with an increased risk of Parkinson's disease, there are also factors associated with a reduced risk of the disease. These potential protective factors include drinking coffee and tea, certain fats in a person's diet, higher levels of uric acid in blood, use of anti-inflammatory drugs, cigarette smoking (nicotine may be a factor), higher vitamin D levels, and regular exercise. However, as with the potential risk factors, more research is needed to assess these potential protective factors, and you should always consult a medical professional before taking any steps to prevent Parkinson's disease or slow its progression.

Richard Crume

See Also: Heavy Metal Pollution; Neurotoxicants; Pesticides and Herbicides; Polychlorinated Biphenyls

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PARTICULATE MATTER AND BIOAEROSOLS POLLUTION

Particulate matter is defined as solid and liquid particles suspended in the air. These particles can be generated directly through emissions from cars and factories or indirectly through chemical reactions of pollutants in the atmosphere. Once particulate matter has entered the body through inhalation, it can cause disease in a variety of ways. Additionally, fine particulate matter (particles with a diameter of less than 2.5 microns) is the primary cause of reduced visibility (i.e., haze) in many areas of the United States. Particulate matter pollution is regulated by the Environmental Protection Agency, which sets standards to reduce particulate matter emissions and improve the air quality.

Particulate matter is classified into three categories: PM_{10}, $PM_{2.5}$, and $PM_{0.1}$. The subscripts refer to the maximum diameter of particles in each class in microns. PM_{10}, $PM_{2.5}$, and $PM_{0.1}$ are often referred to as coarse, fine, and ultrafine particulate matter, respectively. Each size class necessarily includes those smaller than it—that is, $PM_{2.5}$ includes $PM_{0.1}$, and PM_{10} includes $PM_{2.5}$ and $PM_{0.1}$. Damage from inhalation of particulate matter depends on the size of the particles. Larger particles can lodge in the respiratory tract and cause inflammatory reactions. Fine and ultrafine particulate matter can lodge deep in the lungs and cause respiratory disease and other serious medical problems.

Bioaerosols are organic molecules that have been aerosolized in the environment and contribute to both indoor and outdoor pollution. Types of bioaerosols include bacteria, fungi, viruses, pollen, and endotoxins. Viable (active) bioaerosols can cause illnesses, such as the flu, tuberculosis, and smallpox. Occupational settings, like farms, slaughterhouses, and furniture factories, can subject workers to illness-causing bioaerosols, where health outcomes often depend on an individual's immune response to the bioaerosol. Nosocomial infections (hospital-acquired infections) are a huge cause of morbidity and mortality, and these are often caused by bioaerosols. Hospitals typically try to combat bioaerosols by using isolation techniques (e.g., wearing masks, gowns, and gloves). Pet dander, dust, germs, and viruses are some bioaerosols found in the home that can also cause severe reactions and illnesses.

Andrew P. Barefield

See Also: Air Pollution; AirNow and the Air Quality Index; Ambient Air Quality; Asthma; Bioterrorism; Healthcare-Associated Infections; Legionnaires' Disease; Respiratory Disease and Air Pollution

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PERCHLORATE

Perchlorate is both a naturally occurring and a manufactured chemical typically found as perchloric acid, ammonium perchlorate, potassium perchlorate, or sodium perchlorate. Perchlorate can form naturally in the atmosphere, leading to low levels of perchlorate in precipitation, and high levels of perchlorate occur naturally in some areas such as west Texas and northern Chile. However, most exposure to perchlorate is not from natural sources but from manufactured sources. It is a concern to health professionals because it is ubiquitous in the environment and known to adversely affect human health.

The most common use for perchlorate today is as an oxidizer in rocket fuel, munitions, fireworks, vehicle airbag initiators, matches, and signal flares. Additionally, it is used in some disinfectants and herbicides and in some electroplating operations. Perchlorate was once used by the medical profession to treat hyperthyroidism, but that use was discontinued in the United States due to adverse health effects.

The most common route of exposure for perchlorate compounds is through the ingestion of contaminated food and water. Common foods contaminated with perchlorate are eggs, milk, fruits, and leafy green vegetables. Additionally, small amounts of perchlorate can be inhaled through contaminated soils and dust.

Because perchlorate is very soluble in water, the potential for perchlorate to contaminate groundwater and surface water is a growing concern. It is often found in drinking water and food, and it is known to interfere with thyroid gland's ability to make hormones. Perchlorate can also irritate the eyes, nose, throat, skin, and gastrointestinal tract, and inhaling ammonium perchlorate has been associated with respiratory irritation and pulmonary edema. In 2011, the U.S. Environmental Protection Agency designated perchlorate as a contaminant, thereby permitting regulation under the Safe Drinking Water Act.

Given its widespread distribution in the environment, many sites contaminated with perchlorate require remediation. Some of the common techniques for perchlorate remediation rely on ion exchange technology, bioremediation, and soil remediation. While ion exchange is most cost-effective, it is not suitable for all situations.

Elizabeth Ann Glass Geltman and Nichole LeClair

See Also: Bioremediation for Waste Treatment; Children's Environmental Health; Drinking Water Quality and Regulation; Environmental Protection Agency; Food Safety and Technology; Safe Drinking Water Act

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PERSISTENT, BIOACCUMULATING, AND TOXIC CHEMICALS

Persistent organic pollutants (POPs) are hazardous organic (carbon-based) compounds that resist degradation. Many industrial products fall into this category. For example, incomplete combustion generates polycyclic aromatic hydrocarbons, which can enter the food chain through precipitation (rain, snow, sleet, or hail) depositing the particulate matter in soil and water. Exposure to polycyclic aromatic hydrocarbons has been strongly linked with cancer. Another common POP is polychlorinated biphenyl, which is primarily deposited in the food chain as a by-product of industrialization and can cause skin rashes, fatigue, and liver damage. Resistance to degradation means that these chemicals can accumulate in the environment, magnifying their potential effects on human health.

Health hazards posed by POPs are amplified by the phenomena of bioaccumulation and biomagnification. Bioaccumulation occurs when a POP enters the food chain more quickly than it can be removed, resulting in an accumulation of the pollutant that can lead to disease. This effect can be compounded by biomagnification, the concentration of a substance in an organism as a result of it eating other organisms that have ingested the substance. For example, mercury is a heavy metal introduced to the food chain through industrialization. This metal accumulates in water and is subsequently consumed by sea life. Bioaccumulation of this metal is concentrated in adipose (fat) tissue, and consequently, pregnant women are advised to avoid consuming fatty fish (tuna, swordfish, and shark) so that they will not ingest the mercury accumulated in the fish.

Lead is another product of industrialization that bioaccumulates. A recent epidemic of lead poisoning cases occurred in Flint, Michigan, where the city began sourcing the city's drinking water from the Flint River without using appropriate corrosion inhibitors. The pipes carrying the water from the river to the city were lined with lead, which leached into the public water supply. This resulted in lead levels of up to 13,000 parts per billion (ppb) in home water sources. (The federal limit is 15 ppb.) While the lead concentration has since returned to acceptable levels, the long-term effects, especially upon the children who were exposed to extremely high concentrations of lead, are still unknown.

Many persistent organic pollutants are endocrine disruptors (EDCs). The endocrine system is a series of glands and organs that serve as a long-range signaling system for the body by secreting hormones into the circulatory system. These hormones convey biochemical "messages" to various organs, thereby regulating processes like metabolism, development, and reproduction. An EDC is any chemical or substance that can affect the endocrine system by acting as an agonist (increasing hormonal effects), an antagonist (reducing hormonal effects), or both. EDCs often mimic the sex hormones (estrogen and testosterone). However, EDCs can also affect the thyroid, pancreas, and other organs. Furthermore, EDCs can alter the development of the reproductive tract and cause cancer later in life, and the effects of EDCs can be passed from one generation to another, depending on when they are introduced into the developmental life cycle (prenatally or before the child reaches puberty). Some schools of thought propose that obesity is the result of a perpetual cycle in which the EDCs are a causative factor of obesity, and accumulation in adipose tissue increases the effects of the EDC, resulting in further adipose tissue buildup (and, therefore, further bioaccumulation).

Andrew P. Barefield

See Also: DDT Exposure; Endocrine Disruptors; Fish Consumption Advisories; Heavy Metal Pollution; Lead Poisoning Prevention; Mercury Pollution; Polychlorinated Biphenyls; Polycyclic Aromatic Hydrocarbons

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PERSONAL CARE PRODUCTS, HEALTH ISSUES WITH

Personal care products are used to cleanse and beautify the human body. These products include shampoo and conditioner, toothpaste, soap, deodorant, lip balm, sunscreen, body lotion, hair dye, and makeup. Many of the chemicals found in personal care products have been linked to possible adverse health effects, ranging from mild allergic reactions to disruption of the endocrine system and even cancer. However, most of these concerns are not strongly supported by scientific evidence.

The Food and Drug Administration (FDA) classifies most personal care products as cosmetics, which are distinct from drugs (products that are intended to treat or prevent disease). Some personal care products are both cosmetics and drugs, such as fluoridated toothpaste, antiperspirant, dandruff shampoo, and sunscreen. These products must be labeled with their active ingredients, which must be approved by the FDA.

According to a survey by the Environmental Working Group (EWG), a consumer-safety advocacy group, the average woman uses 12 personal care products every day, the average man uses 6, and the average teenager uses 17. The EWG survey found that consumers are exposed to hundreds of unique chemicals on a daily basis from the application of these products. These chemicals can be absorbed by the skin, inhaled from sprays or powders, or ingested.

Almost any product applied to the skin can cause an allergic reaction, from mild redness and irritation to burning and itching. Manufacturers cannot guarantee that a product will or will not cause an allergic reaction, so many products carry warning labels that instruct users to first test the product on a small patch of skin. Additionally, products with fragrances can cause respiratory allergies or aggravate asthma. The label "hypoallergenic," often taken to mean the product does not cause an allergic reaction, is not regulated by the FDA.

Three chemical groups in particular are currently under scrutiny: parabens, phthalates, and triclosan. These chemicals have been widely used in personal care products for the past 40 to 50 years. Parabens in personal care products act as preservatives by preventing bacterial growth. They have been found in tissue samples of breast cancer tumors, but no study has found a direct connection between exposure to parabens and increased risk of breast cancer. Phthalates are found in some nail polishes, perfumes, lotions, and hair sprays. Various studies have linked phthalate exposure to low testosterone levels, low-quality sperm, and even obesity and insulin resistance in adult men. In 2008, Congress banned phthalates in children's toys, but they are still legal in personal care products. More than three-quarters of the U.S. population have detectable phthalates in their urine. Finally, triclosan, an antimicrobial chemical in soap and toothpaste, is thought to disrupt hormones and has been linked to weakened cardiac function. It may also promote bacterial resistance to medicine. Additionally, triclosan is a persistent environmental pollutant that is toxic to aquatic life, especially algae.

Other chemicals of concern include formaldehyde, coal tar, and hydroxy acids. Formaldehyde may be found in nail polish, and it is also formed as a by-product of chemical interactions. The National Toxicology Program considers formaldehyde as a known carcinogen. Coal tar, linked to cancer, may be found in darker hair dyes. Alpha and beta hydroxy acids are applied to the skin to reduce the appearance of wrinkles, but they can increase skin sensitivity to ultraviolet rays from sunlight.

Some people believe that aluminum in antiperspirants mimics estrogen and thus increases risk for breast cancer. However, the link between antiperspirants and cancer is not supported by scientific research, according to the National Cancer Institute. In general, studies exploring the risks of chemicals in personal care products are currently limited in scope. Animal studies often show endocrine disruption after high levels of exposure to certain chemicals, but there are few conclusive studies in humans.

Not every chemical in personal care products is listed on the ingredients label. For instance, the ingredient "fragrance" may contain phthalates, which may not be listed separately. Additionally, many terms found on product labels do not have a specific definition, and terms such as "natural," "alcohol-free," and "fragrance-free" are not regulated by the FDA. If consumers wish to avoid certain chemicals, they should look for product labels that say "no phthalates" or "no parabens." Consumer-safety advocate groups like the EWG believe that regardless of whether these chemicals cause cancer, all products should be clearly labeled with their actual ingredients.

Despite the limited nature of studies on the toxic effects of chemicals in personal care products, the European Union (EU) has taken a precautionary stance. The 2013 EU Cosmetics Directive banned 1,328 ingredients that are either known or suspected to disrupt hormones or cause cancer. Hundreds of products sold in the United States contain these same chemicals (see Table 14). The EU also requires products to be approved and registered before they are sold.

In the United States, 11 chemicals are banned from cosmetics, including chlorofluorocarbons (CFCs), chloroform, mercury, and zirconium, and no chemicals have been banned since 1989. (In cosmetics, the FDA only has authority to regulate color additives in hair dyes.) The FDA does not approve products before they go to market, although manufacturers may voluntarily register their products with the Agency. Therefore, products cannot be labeled or marketed as "FDA-approved." The FDA can only recall a product if it proves harmful under the label's

Table 14. Chemicals banned in the EU by use and health concern.

Chemical	Use	Health Concern
Selenium sulfide	Dandruff shampoo	Probable carcinogen
Hydroquinone	Skin/hair bleach	Probable carcinogen
p-Phenylenediamine	Dark hair dyes	Asthma, allergic reactions
Salicylic acid	Acne treatment, preservative	Possible salicylate poisoning
Talc	Loose powder	Asbestos, possible carcinogen
Titanium dioxide	Sunscreen	Possible carcinogen when inhaled
Zinc stearate	Anticaking agent	Respiratory problems when inhaled
Lead acetate	Hair dye	Lead poisoning when ingested
Quaternium-15	Preservative	Releases formaldehyde
Triclosan	Toothpaste, antibacterial soaps	Possible endocrine disruption
Butylparaben	Preservative	Possible endocrine disruption

directions or if it is improperly labeled. In 1976, the FDA supported the creation of the Cosmetic Ingredient Review (CIR), an independent panel that evaluates personal care products. The CIR, funded by the Personal Care Products Council (an industry trade group), researches the health effects of chemicals in personal care products and recommends whether their use should continue.

Several large retail stores and manufacturers have recently decided to phase out certain chemicals from their personal care products, including triclosan, diethyl phthalate, and compounds that release formaldehyde. For example, the major retailers Target and Walmart are working in conjunction with the global manufacturing companies Procter and Gamble and Johnson and Johnson to modify certain product ingredients. This market-based regulation preempts possible future federal rulings, as industries themselves ban potentially harmful chemicals in personal care products.

Alisha K. Newton

See Also: Cancer Risk from Environmental Exposure; Chlorofluorocarbons; Consumer Product Safety Commission; Environmental Toxicology; Formaldehyde; Mercury Pollution; Nanomaterials; National Toxicology Program; Phthalates

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PESTICIDES AND HERBICIDES

Pesticides are anthropogenic chemicals used to control or eliminate pests. Pesticides include insecticides, fungicides, herbicides, and rodenticides, and they target plant diseases, weeds, insects, rodents, and animal vectors of disease. By preventing pest-related crop loss, pesticides can improve crop yield and farm productivity. Pesticides can also prevent the spread of infectious diseases by killing, for example, disease-carrying mosquitoes. However, some pesticide ingredients are dangerous to human health and must be used carefully. The health effects of pesticides vary according to the type of pesticide and the level and duration of exposure. Pesticides can irritate eyes and skin and adversely affect the nervous and endocrine systems of the human body. Other pesticides may be carcinogens.

Dichlorodiphenyltrichloroethane (DDT) is a well-known insecticide and a persistent organic pollutant. While still used in some parts of the world, DDT was banned in the United States in 1972 when its registration was canceled by the newly formed Environmental Protection Agency. As a persistent organic pollutant, DDT has a long half-life, which means that it can survive in the environment a long time without degrading. DDT also bioaccumulates in the food chain, and storage in adipose (fatty) tissue can result in biomagnification. This causes humans and large predators to inadvertently accumulate high concentrations of DDT, with possible adverse effects on health. The degradation products of DDT, dichlorodiphenyldichloroethane (DDD) and dichlorodiphenyldichloroethylene (DDE), are also toxic. While DDT use has been banned in the United States, traces of DDT, DDD, and DDE can still be found in the environment and in human adipose tissue. DDT, DDD, and DDE are believed to cause adverse developmental, endocrine, hepatic, neurological, and reproductive effect, and they are reasonably anticipated to be human carcinogens.

One of the better known herbicide incidents involved Agent Orange, which was sprayed during the Vietnam War as a tactical defoliant (a chemical that removes the leaves from trees). Agent Orange has been associated with numerous health complaints from veterans present in the areas that were sprayed. Health effects attributed to Agent Orange include acute and subacute peripheral neuropathy, AL amyloidosis, chloracne, chronic lymphocytic leukemia, B cell leukemia, type 2 diabetes, Hodgkin's lymphoma, prostate cancer, respiratory cancers, soft tissue sarcomas, Parkinson's disease, and spina bifida in offspring. The Veterans Administration alerts veterans to possible long-term health effects related to Agent Orange exposure during military service, and it offers eligible veterans a free health assessment for health issues related to their exposure.

Andrew P. Barefield

See Also: Children's Environmental Health; DDT Exposure; Endocrine Disruptors; Environmental Protection Agency; Environmental Toxicology; Zika Virus

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PHARMACEUTICALS IN THE ENVIRONMENT

Human and animal health greatly benefited from the development of pharmaceutical and personal care products, collectively known as PPCPs. Pharmaceuticals are natural or synthetic compounds used to treat illness and promote wellness. The most common examples include antibiotics, antidepressants, analgesics (pain killers), hormone therapies, and lipid regulators. Their production is regulated for safety and effectiveness in people and animals but not for their presence in the environment. With growing populations and increasing use of human and veterinary medications, the release of pharmaceutical compounds into the environment has become a significant concern.

Pharmaceutical chemicals and their metabolic by-products are now being found in the waters of cities around the world, including surface water, groundwater, and treated drinking water, as well as some soils and food products. In addition to medications, there is a growing list of personal care products entering the environment with natural or synthetic active ingredients that induce biologic effects. The expanding array of these products includes soaps, shampoos, moisturizers, cosmetics, nutritional supplements, fragrances, bug repellant, and sunscreens.

What Is Triclosan?

Triclosan is one example of a ubiquitous bioactive compound found in many personal care products. It is recognized as one of many emerging contaminants that is detectable but not regulated in the environment. Triclosan is best known as the antibacterial ingredient in many hand soaps. Originally created for surgical scrubs in the 1940s, it has since been incorporated into a long list of products, including hand sanitizers, toothpastes, body washes, cosmetics, deodorants, and even countertops, textiles, and kitchenware. At one point, triclosan was present in 76 percent of liquid and 29 percent of bar soaps in the United States. Laboratory studies showed triclosan to be an endocrine disrupter with adverse effects on frogs and rats. In September 2016, the U.S. Food and Drug Administration (FDA) recognized triclosan and 18 other antibacterial compounds in soaps as being unnecessary and potentially dangerous, and the FDA issued a ban of those 19 substances, giving companies one year to remove the chemicals or take their products off the market. The ban applies only to hand soaps, so other products may continue to include this and other antibacterial compounds under the current rules.

As with medications, these active ingredients in personal care products are emerging contaminants of concern. Yet, they too are not commonly monitored or regulated in the environment. The release of this plethora of chemical compounds into the environment poses potential health risks to people, wildlife, and ecosystems. Allergic reactions, increases in antibiotic-resistant bacteria, and disruptions to hormonal systems are all possible. Adverse effects to ecological systems are also a major concern, with effects on fish and aquatic organisms already being detected in many cities around the world.

Pharmaceuticals are designed to have an effect on the body at the lowest possible dose and to persist so that their medical benefits last as long as possible. These are good qualities in the body, but they become a problem when these chemicals enter the environment, where they can have a persistent effect on animals and ecosystems even at very low concentrations.

The most commonly detected pharmaceuticals in waters are human and veterinary medications, including antibiotics, estrogenic steroids (e.g., oral contraceptives and hormone therapies), antidepressants, and chemotherapy agents. However, there are many other unregulated compounds that are being released into the environment, and we do not yet know their effects. The study of emerging contaminants is a burgeoning new field of research working to determine what and where these chemicals are, their potential for harmful effects on people and nature, and how to reduce those negative consequences.

The same is true for the compounds in hundreds of personal care products, which end up in the wastewater stream after they are washed down the drain from sinks, tubs, washing machines, and many other sources. The highest concentrations of these compounds in nature are found downstream of the discharge pipes of municipal wastewater treatment plants. These waters continue downstream and become the source for human drinking water for the next city. Drinking water treatment plants usually reduce the concentrations of these chemicals, but they rarely remove 100 percent. Trace levels have been found to persist in up to 30 percent of public drinking water sources.

Another important source of environmental release is the improper disposal of unused or expired medications or supplements, either by flushing or as leachate that leaks into the groundwater from municipal landfills. Manufacturing facilities for drugs or personal care products are also significant sources of PPCPs in the environment. This is especially true in countries without strict regulatory limits on pollution discharges. Other significant sources for direct environmental releases are farm fields where treated sewage sludge has been used as fertilizer or for sewage disposal. The compounds may run off into streams or be absorbed into crops and return to people or animals through food products grown on those fields.

Sources of contamination from personal care products vary widely depending on the intended use. The primary source tends to be wastewater from homes and buildings. Significant sources beyond homes include healthcare facilities, nursing homes, pharmacies, veterinary operations, meat processors, landfill leachate, and septic sewage tank haulers. The chemicals from PPCPs may come from cleaning supplies, deodorants, cosmetics, disinfectants, and pesticides, along with soaps, shampoos, and hair conditioners. In fact, almost any xenobiotic substance (chemical foreign to living organisms) that enters the environment has the potential to persist and create adverse biological effects.

In people, there are more questions than answers about the effects of these emerging contaminants on health. As researchers get better at detecting very small amounts of contamination, their presence is being found widely throughout the environment. These trace levels are usually in the nanogram or microgram per liter range, which is well below amounts thought to have an effect on people. Most research to date focuses on antibiotics and hormone products for their effect on people and the environment. Antibiotic resistance is already a concern in human health due to prevalent use of prescriptions for people and their use in livestock as growth enhancers. There is concern that chronic, low-level environmental exposure to antibiotics will exacerbate an already existing problem of antibiotic resistance and encourage "superbugs" that are even harder to fight.

Perhaps an even greater concern is the various compounds found in oral contraceptives, hormonal therapies, and certain industrial products, such as Bisphenol A. Unlike most medications, these chemicals are shown to have significant effects on hormonal systems even at the extremely low concentrations found in the environment. They are referred to as endocrine disrupters because of their hormonal effects on people and animals. The risks are increased when exposure occurs during the early developmental stages of children and animals. These medications are designed specifically to persist, bioaccumulate (increase) in the food chain, and resist degradation. Studies have shown effects on aquatic organisms, even at extremely low concentrations in water. This raises concerns about the effects of even trace amounts in human drinking water, especially on children. In addition to the concerns about single ingredient exposures, humans and the environment are being exposed to mixtures of multiple chemicals over a long period of time. The complexity of this system poses tremendous challenges for researchers trying to understand and predict potential harm to people or nature.

There are also measurable effects in land animals from environmental pharmaceuticals. The most dramatic example is the near extinction of three species of Asian vultures caused by feeding on carcasses of livestock treated with the anti-inflammatory drug, diclofenac. Unexpectedly, the vultures were exquisitely sensitive to ingesting small amounts of this drug. A major population collapse and near extinction occurred before the cause was determined and steps taken to stop this exposure of the birds to diclofenac. Another passage of chemicals up the terrestrial (land-based) food chain has been observed when birds eat insects from a field treated with contaminated sewage sludge fertilizer and are affected by those chemicals. These health effects on animals suggest that these chemicals may affect people too, especially as people are potentially exposed to multichemical mixtures in water and food at low levels over a period of many years.

Addressing these emerging contaminants calls for efforts on several fronts. First, at the source of the problem, pharmaceutical products themselves can be redesigned through the use of green chemistry techniques to have less environmental impact. Green chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. For pharmaceuticals, that would mean products that do not persist in the environment or bioaccumulate in the food chain and that break down into inert compounds when released into the environment. Improvements in water treatment techniques that can remove 100 percent of PPCPs from wastewater discharge and from drinking water would also greatly reduce exposure to people and nature. Finally, preventing improper disposal of medications that results in environmental release can be helped through awareness, behavior changes, and organized drug take-back programs.

Gwen Griffith

See Also: Antibiotic Resistance; Bisphenol A (BPA); Drinking Water Quality and Regulation; Endocrine Disruptors; Medical and Infectious Waste Management; Personal Care Products, Health Issues with; Sewage Treatment and Disposal; Water Pollution

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PHTHALATES

Phthalates are chemicals used to create plastic products, and they help make plastics flexible and durable. Polyvinyl chloride (better known as PVC) pipe is a common example of a plastic product made from a phthalate. Health professionals are concerned about phthalates because of adverse effects associated with their use.

Phthalates are ubiquitous in modern life. Most Americans use plastic products containing phthalates repeatedly during the day. Common plastics that contain phthalates include building materials, clothing, cosmetics, perfumes, food packaging, toys, and vinyl products (e.g., flooring, shower curtains, and raincoats). Phthalates are also used extensively in plastic medical devices, such as bags and tubing for blood transfusions and intravenous therapy drips. Additionally, phthalates are added to lubricating oils, solvents, and detergents.

Numerous adverse health effects are associated with phthalates. Studies suggest that phthalates can act as endocrine disruptors or hormonally active agents, and exposure can result in increased incidence of developmental abnormalities in humans, including cleft palate and skeletal malformation. Extensive studies document phthalate exposure having adverse effects on the male reproductive tract, including increased incidence of undescended testes, decreased testes weight, and decreased anogenital distance. Phthalate exposure has been shown to cause increased fetal death in experimental animal studies, and new scientific evidence suggests phthalate exposure in humans may lead to allergies and asthma, neurological and metabolic health effects, and adverse outcomes on pregnancy and female reproduction.

Growing public concern centers on what happens to children exposed to phthalates. Of particular concern is exposure to phthalates in medical supplies, food wrapped in plastic packaging, and plastic toys, cups, bowls, and bottles. Because everyday exposure to phthalates is extensive, phthalate metabolites can be found in the blood and urine of most Americans, and these metabolites have also been found in human breast milk and commercial milk from cows. Thus, infants and small children can be exposed to phthalates regardless of whether the caretaker nurses or feeds the child infant formulas.

The U.S. Congress acted to reduce phthalate exposure by passing the Consumer Product Safety Improvement Act (CPSIA) of 2008, which banned six specific types of phthalates (DEHP, DnBP, BBzP, DINP, DIDP, and DnOP) from use in toys and items sold to children in concentrations of greater than 0.1 percent. In addition, when enacting the CPSIA, Congress tasked the Consumer Product Safety Commission with appointing a Chronic Hazard Advisory Panel to examine the cumulative health risks of both phthalates and phthalate substitutes and to recommend whether any other phthalates or phthalate substitutes should be banned.

The U.S. Food and Drug Administration (FDA) issued guidance restricting the use of two phthalates (DBP and DEHP) in protective coatings for pills for both prescription and over-the-counter medicines. Although the FDA determined DBP and DEHP are not safe or suitable as inactive ingredients in prescription and over-the-counter medicines, the agency did not restrict use or impose labeling requirements for DBP and DEHP in cosmetics.

The U.S. Environmental Protection Agency (EPA) has developed an action plan for phthalates due to concern over their toxicity, widespread use, and human exposure. The EPA regulates the levels of DEHP in drinking water under the Safe Drinking Water Act, lists DEHP and DEP as hazardous pollutants under the Clean Air Act, and regulates phthalates as hazardous wastes under the Resource Conservation and Recovery Act.

California, Vermont, and Washington each have standards exceeding those set by the federal government for the allowable content of certain phthalates in children's items. Additionally, the American Public Health Association and other public health professional groups have urged government regulators to replace PVC in medical care settings, schools, public housing, and building materials.

Elizabeth Ann Glass Geltman and Henry Babatunde Akinleye

See Also: Children's Environmental Health; Clean Air Act; Consumer Product Safety Commission; Drinking Water Quality and Regulation; Endocrine Disruptors; Environmental Protection Agency; Hazardous Air Pollutants; Reproductive Health and Environmental Exposure; Resource Conservation and Recovery Act; Safe Drinking Water Act

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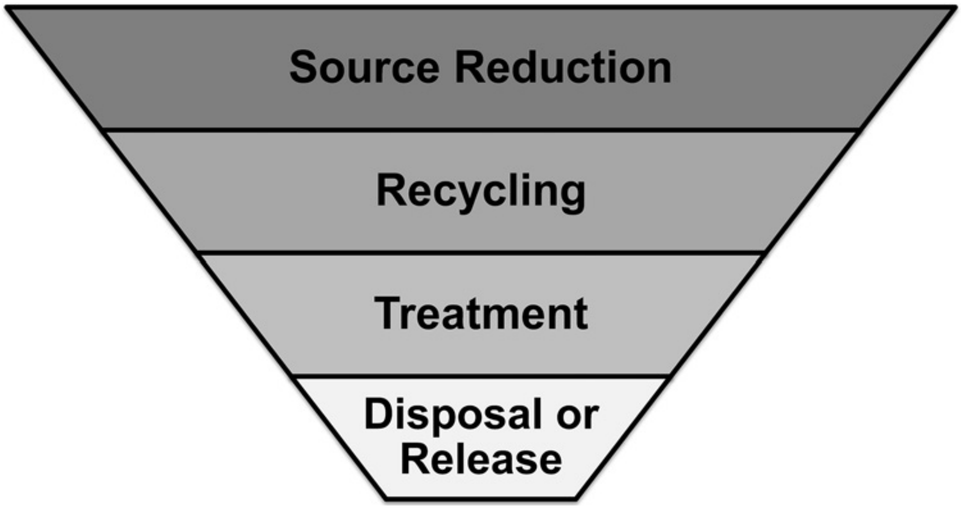
POLLUTION PREVENTION

Environmental solutions are often prescriptive, dealing with problems after they happen. Even recycling and effective disposal methods deal with products or materials at the end of their life cycle. A better approach is to prevent the pollution from occurring in the first place. This is what the field of pollution prevention is all about—preventing pollution so that costly pollution controls and cleanups are not required.

Pollution prevention, also known as source reduction, is defined by the U.S. Environmental Protection Agency (EPA) as any practice that reduces, eliminates, or prevents pollution at its source. The EPA considers source reduction at the top of its environmental protection hierarchy, which means that we should try to prevent pollution before taking other measures, such as recycling, treatment, disposal, or release.



Source reduction is at the top of the environmental protection hierarchy. (U.S. Environmental Protection Agency, Pollution Prevention)

Some specific ways pollutants can be prevented from entering the environment are (1) using improved equipment or technology that pollute less or not at all; (2) redesigning products so that their compositions are less toxic or nontoxic; (3) using recycled materials instead of extracting raw materials; (4) relying on less water and chemicals in agricultural applications; and (5) switching to renewable energy sources like solar, wind, and geothermal power. Individuals can also take actions in their own homes to help prevent pollution, for example, turning off lights when not in use, drinking out of reusable water bottles, and purchasing Energy Star (energy-efficient) appliances.

The need for specific laws and measures to control and prevent pollution became clear after the United States experienced a number of environmental crises in the 1960s and 1970s, resulting in formation of the EPA and passage of several landmark environmental legislations, including the Clean Air and Water Acts. It later became apparent that preventing pollution deserved more attention, and in 1990, the Pollution Prevention Act was enacted. More recently, the EPA has developed a pollution prevention strategic plan, and there have been several executive orders reinforcing the importance of sustainable practices within government.

One of the most successful pollution prevention programs is the grant-funded Pollution Prevention Resources Exchange, created in 1997 by the EPA. Under this program, eight regional centers share information among experts and the public, increase awareness about pollution prevention, and evaluate the impact of various pollution prevention tools. There are nearly 100 participating organizations that help collect data, including state and local environmental agencies, academic institutions, and other nonprofit organizations. Among the findings for the years 2010 through 2012, the economic benefits associated with pollution prevention amounted to \$5.4 billion nationwide, and 4.5 million tons (4.1 million metric tons) of pollution were minimized or eliminated.

Aaron Dorman

See Also: Energy Star; Environmental Protection Agency; Pollution Prevention Act; Recycling; Three Rs of Waste Management

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POLLUTION PREVENTION ACT

The Pollution Prevention Act (PPA) is a federal law, promulgated in 1990 by the U.S. government, that established a new national policy based on the belief that "pollution should be prevented or reduced at the source whenever feasible." Thus, the prevention or reduction of waste was placed at the top of the waste management hierarchy. Furthermore, the act declared that if pollution could not be prevented, it should be recycled. And if recycling is not feasible, the pollution should be treated and, if necessary, disposed of "in an environmentally safe manner" as a last resort.

This policy reflected a shift in the national attitude toward environmental protection in that the focus moved to waste reduction and prevention. Prior to enactment of the PPA, environmental statutes generally focused on "end of pipe" cleanups (i.e., the control, treatment, and disposal of pollution). However, over time it was found that the costs associated with control, treatment, disposal, and responsibility for risks to human health and the environment were not sustainable. Thus, the primary impetus behind this law was the need to reduce costs related to pollution control and liability and to minimize risks to public health and safety. This idea is similar to the central theme of the field of public health—prevention of disease is a preferable strategy to treatment of the disease after it has been acquired.

The PPA authorized the U.S. Environmental Protection Agency (EPA) to establish an independent office to develop and promote strategies to prevent pollution and reduce contaminant sources. The EPA's Office of Pollution Prevention and Toxics (now the Office of Chemical Safety and Pollution Prevention) was formed to carry out the provisions of the PPA, which include funding state pollution prevention activities and developing and disseminating information about source reduction strategies. The PPA defines source reduction as any activity that reduces the release of contaminants into the environment before they are treated, recycled, or disposed of. Source reduction methods can include improved technologies, equipment, industrial processes, materials, and housekeeping. Training on these methods is also important.

The PPA also required certain facilities to report their source reduction and recycling activities each year to the EPA. This report includes information about how much of each reported chemical is recycled or released into the environment as well as source reduction practices employed. These data are used by the EPA to measure source reduction activities and evaluate the success of the program. All such data reported to the EPA are publicly accessible on EPA's pollution prevention website.

Implementing the PPA has been fraught with difficulty due to the small budget authorized for implementation and a lack of mechanisms to force compliance upon the business community. Because business participation in PPA activities is voluntary, the EPA can only offer incentives to ensure its success. Other barriers to success of the PPA include (1) the lack of technical expertise among businesses in how to shift from pollution treatment to pollution prevention and (2) possible economic impacts of imposing pollution prevention strategies on influential industry stakeholders.

Adrienne L. Katner

See Also: Environmental Protection Agency; Marine Pollution, International Treaties to Prevent; Municipal Solid Waste Management; Pollution Prevention; Recycling; Three Rs of Waste Management; Waste Incineration; Water Reuse and Recycling

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POLYCHLORINATED BIPHENYLS

Polychlorinated biphenyls (PCBs) are man-made organic chemicals that are pervasive throughout the environment despite manufacturing being banned in the United States in 1979 due to health concerns. Because PCBs are chemically stable and have excellent electrical insulating properties, they were used in a wide range of products, materials, and industrial processes before 1979, including:

- Electrical equipment, such as transformers and capacitors
- Oils for motors and hydraulic equipment
- Plasticizers in paints, plastics, and rubber products
- Insulating materials, such as fiberglass and foam
- Adhesives, tapes, caulking, floor finish, and carbonless copy paper

In addition to banning the manufacturing of PCBs, imports of PCB-containing products were also banned in 1979, and PCBs were banned internationally in 2001 through the Stockholm Convention on Persistent Organic Pollutants. PCB chemicals were often known by their commercial names (e.g., Arochlor).

PCBs are considered probable carcinogens. Exposure is also associated with heart disease, suppression of the immune system, endocrine disruption, asthma, and birth defects, including impaired cognitive ability in children exposed to PCBs *in utero*.

Although banned for many years, PCBs are still prevalent in buildings and machinery used today that were built or manufactured prior to 1977. Additionally, PCBs are commonly found in abandoned, illegal, or poorly maintained hazardous waste sites, where leaks from PCB-containing electrical transformers are a common source contamination. Improper disposal of PCB-containing consumer products has resulted in contamination of some municipal and public landfills not designed for hazardous waste.

PCBs continue to enter the environment due to the improper disposal practices of the past. The persistence of the chemical, coupled with bioaccumulation in wildlife, has often resulted in the contamination of food, especially predatory fish and wild game. Also, studies have detected low levels of PCBs in the breast milk of women who consume large amounts of predatory fish.

Elizabeth Ann Glass Geltman

See Also: Cancer Risk from Environmental Exposure; Hazardous Waste Disposal; Land Disposal of Waste Materials; Persistent, Bioaccumulating, and Toxic Chemicals

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POLYCYCLIC AROMATIC HYDROCARBONS

Polycyclic aromatic hydrocarbons (PAHs) result from the incomplete combustion of garbage, petroleum products, coal, and other organic substances, and they are also found in tobacco smoke. PAHs can be generated through both natural and man-made processes. Volcanic eruptions and wildfires are examples of natural processes, and car exhaust, coal burning, asphalt production, and various industrial operations are examples of man-made processes.

PAHs can be found in soil and water, and in the air, they contribute to smog. People can also be exposed to PAHs through products like shampoos, cigarettes, and skin creams as well as by eating the char on burnt meat. The health effects from low-level exposure to PAHs are unknown, but higher concentrations can irritate eyes and breathing passages, and some workers have developed blood and liver abnormalities. Skin contact with PAHs can cause reddening and peeling of the skin and sometimes even blistering. Several PAHs and PAH mixtures are considered carcinogenic.

There is a wide diversity of PAHs, with some more toxic than others. They are known to remain in the environment for a long time. Additionally, because many are insoluble, they will biomagnify, allowing concentrations to build up to higher levels. The most studied PAH is perhaps benzo[a]pyrene (BaP), which is associated with a host of potential acute and chronic health effects, including cancer. BaP results from the combustion of plants, wood, and coal, and it is emitted from gasoline and diesel motor vehicles. Indoor sources of BaP include fireplaces, stoves, and tobacco smoking.

Andrew P. Barefield

See Also: Air Pollution; Cancer Risk from Environmental Exposure; Hazardous Air Pollutants; Ozone and Smog in the Urban Environment; Personal Care Products, Health Issues with

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POPULATION TRENDS, HEALTH IMPLICATIONS OF

The year 2015 saw the greatest forced displacement of people since World War II and the highest death rate for migrants on record. Globally, 65.3 million people were displaced by conflict and violence, and 21.3 million of those displaced crossed international borders. Women were the largest group of migrants, accounting for 48 percent of the migrant population, and individuals under 20 made up 15 percent. Approximately one in three of the 21.3 million refugees crossing borders were minors, a quarter without parents.

In addition to conflict and violence, an estimated 19.2 million people were displaced by natural disasters. This displacement, mostly weather-related, is 60 percent more likely now than it was in the previous four decades, partly due to the earth's changing climate.

Human trafficking is a huge risk to the health and safety of more than 21 million people who are forced into labor or sexual exploitation. Over one-third of the victims of trafficking are children, and in the case of sex trafficking, most victims are women and children. Men are more likely to be victims of labor trafficking. Undocumented migrants crossing the U.S. southern boarder are most vulnerable to becoming human trafficking victims.

Mental health is a key issue for people subject to forced migration. Many migrants are moving in response to real or potential trauma in their home country, and mental health resources are key to helping them resettle. Moreover, when individuals can break free from human trafficking bonds, they need trauma counseling.

Poverty is another concern when discussing population trends. Densely populated areas tend to suffer more from the effects of poverty, including hunger and limited shelter. Such areas draw migrants due to their perceived promise of opportunity, but access to health care and education is often a problem, and crime threatens their health and safety. Until individuals become naturalized citizens of the country they have migrated to, it may be very difficult for them to obtain quality health care, and the healthcare system itself may become increasingly taxed as the migrant population grows. Communicable diseases can also spread faster through migrant populations when health care is limited.

The causes of migration are complex, often involving geopolitical conflicts that result from or are exacerbated by limited resources. In particular, drinking water and food shortages are brought about by population growth combined with land use practices and climate change that increase the frequency of floods and droughts and expand desertification. Many governments and international aid agencies are providing assistance to those most in need, but as the world's population grows from today's 7.5 billion to perhaps 9.7 billion by 2050, the fate of tens of millions of future migrants remains uncertain.

Ronda Bowen

See Also: Climate Change and Human Health; Communicable Diseases; Deforestation; Drought and Desertification, Health Consequences of; Natural Disasters

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PRENATAL EXPOSURE TO POLLUTANTS

We need to begin with the reasons for the sensitivity and susceptibly differences of prenatal (before birth) and postnatal (after birth) exposures to pollutants. The greater likelihood of detrimental outcomes from prenatal exposures requires an understanding of early development.

After fertilization of the egg (ovum), the single cell develops into the blastocyst (about 200 cells). The cell proliferation and differentiation takes 6 to 10 days before the blastocyst implants into the highly vascularized endometrium of the uterine wall, which begins the maternal supply of oxygen and nutrients. Prior to implantation, the embryo relies on a low supply of nutrients, maternal hormones, and factors in seminal fluid. Any additional stress from pollutants would be highly detrimental because cell division is occurring in a relatively unprotected environment, the embryo is already undergoing hypoxic stress, and any additional stress could lead to modified intracellular organelles, mutations, and epigenetic modifications that can affect the offspring for a lifetime.

There has been minimal research on toxicant effects during the early transitions within the first trimester. By approximately the 10th gestational week of human development, all organs have begun to develop, although they may not be in their final locations. If exposure to pollutants occurs, the pollutants could disseminate more readily and diversely throughout the fetus than they could in a neonate or adolescent because innate protective barriers (e.g., skin, blood brain barrier, and gut blood barrier) have not fully formed and are leaky. Thus, cell expansions and differentiation within multiple organs are susceptible during prenatal development.

Throughout gestation, the fetus is reliant on nutrients and oxygen passed from the maternal system through the placenta to the fetus. Therefore, placental development is critical for fetal growth, and it is dependent on how well the embryo implanted into the uterine wall, which is dependent on maternal hormones and immune activities. Pollutants such as endocrine-disrupting chemicals (e.g., bisphenol A, phthalates, dichlorodiphenyltrichloroethane, and perfluorooctanoic acid) and chemicals inducing inflammation and immune alterations (e.g., metals such as arsenic, cadmium, and lead and alcohols) interfere with placental growth, and thus, the health of the fetus. Sensitivity to pollutants can differ due to sex because 15 percent of genes on the Xi (inactivated X) chromosome of female trophoblasts are not inactivated, giving females (XX) a double dose of enzymes over those of males (XY) to positively or negatively deal with stress. Pollutants are often thought of as chemicals that contaminate the air, water, or soil. However, pollutants affecting maternal-placental-fetal interactions that can modify prenatal or postnatal health can also be biological (toxins and pathogens) and even physical (e.g., noise and light).

The development of the fetus is dependent on prior and current maternal exposures to pollutants, diet, and physical/psychological stresses that affect the placenta's delivery of nutrients. The maternal supply of nutrients versus toxicants and the placental organization affecting this supply will determine how well the fetus develops and reaches full-term development. Pollutants are known to shorten the gestational period and lower the birth weight of the fetus due to intrauterine growth restriction. Prenatal exposure to single pollutants has been suggested to reduce fetal growth, and multiple combinations of pollutants or pollutants combined with physical or psychological stressors have been noted to worsen offspring health outcomes. Additionally, depending on genetic and environmental influences, some neonates born at lower size and weight due to environmental stressors have become overweight with high inflammatory conditions later in life, leading to cardiovascular disorders and type 2 diabetes.

Prenatal pollutant exposures affect long-term health because of early alteration of cells dispersing into organs undergoing development. For example, prenatal exposure to diesel exhaust particles has been suggested to modify the immune microglia cell in the brain, which influences neuronal connections and behaviors. Prenatal exposure to air pollutants, such as diesel exhaust and perchloroethylene, has been reported to be associated with brain functions and behavior. Myeloid progenitors disperse into tissues very early in embryonic development, and as for microglia in the brain, they may be integral to organogenesis in other organs. Thus, pollutants can alter as early as yolk sac derivations. In addition to innate early immune cells seeding into multiple organs affecting their development and later functions, pollutants can induce developmental immunotoxicological modifications that can have long-term consequences on autoimmune diseases, allergies, cancer, and susceptibilities to infections.

The recent Zika virus influence on brain development is evidence documenting the major differences of prenatal and adult exposures. Infected adults have relatively mild flu-like symptoms, whereas prenatal exposure can result in microcephaly or worse. It has been suggested that prenatal Zika pathology be referred to as a congenital Zika syndrome in that microcephaly is but one clinical sign of the disorder. A similar situation exists for congenital rubella syndrome, with prenatal infection leading to a number of different birth defects. Even without Zika-mediated microcephaly, a silent neurotoxicity (i.e., a neural abnormality not obvious at the time of birth) may be unmasked later in life with exposure to another stressor.

David A. Lawrence

See Also: Bisphenol A (BPA); Children's Environmental Health; Endocrine Disruptors; Environmental Toxicology; Heavy Metal Pollution; Phthalates; Zika Virus

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PUBLIC HEALTH SERVICE

The U.S. Public Health Service (PHS) is a federal agency within the Department of Health and Human Services charged with the central mission of protecting the health of the U.S. population. Today's PHS has its roots in the Marine Hospital Service, founded in 1798 to care for ill and disabled seamen. The official journal of the PHS, *Public Health Reports*, has been published since that year.

During the 19th century, the organization's mission expanded to include the public health of all Americans. Accordingly, in 1902, the name was changed to the Public Health and Marine Hospital Service. Major duties included quarantine and medical inspection of immigrants arriving at Ellis Island. In 1912, the name was shortened to the Public Health Service. With this new name came congressional legislation broadening PHS authority to investigate illnesses and address sanitation, water, and sewage. In addition to conducting public health research, the PHS tracked the spread of diseases and imposed quarantines to stem epidemics.

On July 3, 1944, President Franklin D. Roosevelt signed the Public Health Service Act. The act broadened the scope of PHS authority to make research grants-in-aid for any disease, to expand public health programs generally, and to specifically address tuberculosis. Additionally, it provided for the commissioning of nurses and specialists, such as entomologists, chemists, and zoologists. The act has been amended a number of times to address issues as disparate as family planning, cancer research, and health insurance.

Public Health Service doctor Ella Eulows (right) and laboratory assistant Sadie Carlin test antipneumococcal serum for potency, ca. 1920. Environmental health officers within the Public Health Service have a long history of disease and injury prevention, food safety, emergency preparedness, and public education. (National Archives)

The PHS is one of the uniformed services of the federal government. Officers hold rank and wear uniforms similar to those worn by U.S. Navy personnel. Through the PHS, more than 6,500 public health professionals hold duty stations within over 20 federal departments and agencies, where they respond to public health needs, provide leadership regarding public health practices, and advance public health science. The surgeon general, often called America's Doctor, oversees the PHS and educates the nation on public health matters. In recent years, major surgeon general initiatives have addressed HIV/AIDS, the dangers of tobacco use, and the psychological health of military service members and their families.

The health professionals who comprise the PHS represent a broad range of expertise, including physicians, dentists, nurses, clinical and rehabilitation therapists, pharmacists, dieticians, veterinarians, engineers, researchers, social scientists, allied clinical care providers, health educators, healthcare administrators, and environmental health experts. Among their myriad duties, environmental health officers in the PHS are concerned with epidemiological surveillance, disease prevention, radiological health, industrial hygiene, food safety, injury prevention and education, emergency preparedness, public health emergencies, and natural disasters.

Kathy Stolley

See Also: Disaster Preparedness and Response; Drinking Water Quality and Regulation; Environmental Epidemiology; Environmental Health Profession; Food Safety and Technology; Industrial Hygiene; Natural Disasters; Sewage Treatment and Disposal

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PUBLIC TRANSPORTATION AND ENVIRONMENTAL HEALTH

All over the world, communities in both urban and rural areas are expanding at impressive rates, especially in urban areas. It is expected that approximately two-thirds of the world's population will be living in urban areas by 2050. This is causing traditional infrastructures, especially related to transportation, to be stretched to their limits, resulting in increased delays and inefficiencies. For example, traffic congestion in 2014 caused U.S. drivers to waste more than 4 billion gallons (15 billion liters) of fuel and kept travelers stuck in traffic for nearly 7 billion extra hours. Additionally, the increased traffic congestion leads to deterioration in air quality, which adversely affects public health and the environment.

In addition to building new transportation infrastructure, increasing the use of rides with shared public transportation is being increasingly favored as an option for reducing traffic congestion. However, while public transportation ridership has been increasing, it is still not growing fast enough on average to effectively tackle the problem of congestion. The fundamental problem is uncertainty in the real-time schedule of public transportation services. Additionally, commuters become frustrated finding transportation options to and from the transit network.

Variations in travel and arrival times have been found to have a substantial impact on commuter satisfaction, and commuter tolerance to delays in bus schedules is quite low. To address this concern, some transit agencies have been integrating real-time sensors into public transit systems, and a number of approaches have been developed by academic researchers and commercial companies to process the sensor data. For instance, automatic vehicle location and passenger counter technology can provide real-time data (e.g., vehicle travel time, arrival and departure times, and passenger boarding counts), and these data can be used for traveler information displays, bus time prediction, and schedule planning optimization. The aim of these approaches is to provide real-time information to improve passenger experience and increase ridership. A direct benefit of increased ridership on public transportation is the reduced use of personal vehicles, and hence, reduction in both traffic congestion and vehicle pollution, with concomitant health benefits. Another solution is to use mobile device (e.g., smartphone) applications to provide travelers accurate, real-time information about potential travel options at the moment they are choosing how to get to where they need to go.

To alleviate the problem of first and last mile travel, a new market supported by connected applications and the shared economy has appeared. In this market, private ride-sharing companies, such as Uber and Lyft, have thrived. Recently, with the introduction of pooled services (e.g., uberPOOL and Lyft Line), these companies are helping bridge a gap between required and available services. A number of transit agencies are also focusing on shared rides, realizing that it is important to take the whole mobility problem into consideration, with the goal of reducing solo car trips. Over the long term, this will lead to reduced vehicle pollution, improved air quality, and lower healthcare costs.

Abhishek Dubey

See also: Air Pollution; Ambient Air Quality; Asthma; Automobile and Truck Emissions and Controls; Climate Change and Human Health; Green Space in Urban Environments; Hybrid and Electric Automobiles, Health Benefits from

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QUIET, BENEFITS OF

Time spent in quiet environments can be relaxing and restorative, and quiet homes and neighborhoods are highly valued. Quiet areas offer respite from distraction and stress, resulting in an improved mood and a better ability to concentrate. Understanding the value of quiet, manufacturers have developed quieter household appliances, aircraft technology, cars, lawn machinery, and even quieter pavement. "Buy quiet" initiatives encourage the use and purchase of quiet equipment as well as the design and manufacture of quiet products and tools to protect industrial workers and others.

Research typically examines the negative health impacts of noise rather than the positive impacts of quiet. However, a significant body of research focuses on the acoustic environment—the soundscape—and frames sound in neutral terms. This research examines quiet as an amenity in one framework and as benefiting health and well-being in another. Access to quiet may also be considered in studies looking at the restorative value of natural and green areas. Sometimes the health benefits of quiet—or silence—are found by accident. A 2006 study measured cardiac and respiratory responses to the various musical styles, tempo, and structure of 12 musicians and 12 nonmusicians. During the two minutes of silence intended as a pause between segments, researchers observed greater evidence of relaxation in subjects compared to their status during musical segments or at baseline.

Investing in Quieter Choices

Approximately 26 million Americans are affected by high-frequency hearing loss, and more than 45 million Americans suffer from tinnitus, a condition involving a sensation of ringing or other sounds in the ears. Both of these conditions are typically caused by noise exposure. Because hearing loss is usually cumulative, it is often associated with aging, but noise-induced hearing loss is preventable and does not have to be an inevitable part of aging. Investing in quieter choices can result in better hearing as we age and greater enjoyment of the sounds around us. Suggestions for protecting your hearing include limiting your exposure to sounds measuring 70 dBA and above, wearing hearing protection during loud activities, limiting the use of portable audio devices, and keeping the volume down when using such devices.

Structured quiet time in a hospital environment results in patients spending more time asleep or at rest, which is integral to the healing process. Nursing staff report that scheduled quiet time provides an opportunity to catch up on paperwork and offers relief from feeling rushed. Many hospitals feature sanctuaries or meditation rooms where patients, visitors, and staff can benefit from a few minutes alone in a quiet place. In residential buildings with high traffic noise exposure, bedrooms facing away from the street allow people to fall asleep more easily and to awaken less frequently, which can be especially important for people who are sensitive to noise.

In settings where environmental noise is unavoidable, people with access to a natural setting or green space close to home report an improved sense of physical and psychological well-being as well as the ability to recover from stress and feel restored. In some areas, traffic noise may still intrude upon green spaces and natural settings. Urban dwellers with access to this type of area might find an early morning visit to be sufficiently quiet to provide some tranquility before the start of a busy day. Residents in noisy areas with access to quiet courtyards often enjoy an improvement in quality of life that is significant enough to mitigate the annoyance and disruption caused by noise. Acousticians recommend that urban planners consider public health lessons learned from studying "quiet side" bedrooms and quiet courtyards that are shielded from traffic noise. However, they warn that the introduction of quiet side aspects will not completely mitigate the effects of building in noisy areas.

Sound is measured with sound level meters, and the unit of measurement is a decibel, or dB. The human ear is most responsive to frequencies between 500 hertz and 8 kilohertz, and higher and lower sounds are not heard as well. Frequency weighting in sound measurement allows sound level meters to "hear" frequencies in a way similar to the human ear. The most common weighting used is A-weighting, which is most similar to the human ear.

Quiet places are rarely devoid of any sound (see Table 15). A relatively quiet soundscape may include natural sounds and have an average sound level below 50 dBA. In quiet rural settings, there is a region—referred to as a "listening radius"—within which one hears faint sounds from distant homes. This provides a sense of community and reduces feelings of isolation. In noisy rural settings, residents may feel compelled to close windows to reduce noise indoors. Because of this, they lose a subtle but meaningful form of social connectedness.

Although many places and products are becoming quieter, noise is increasing in other ways, and the world just seems to be getting noisier. For example, national parks are increasingly grappling with anthropomorphic noise, from lock-signifying beeps and horn honks in automobile parking lots to helicopter tours circling overhead. The National Park Service provides educational material related to soundscape preservation, including ideas for minimizing your noise footprint in parks and suggestions for being a quiet neighbor. Additionally, the Centers for Disease Control and Prevention provides guidance about safe and unsafe noise levels,

Table 15. Average sound levels.

Sound	dB Level
Auditory threshold	0
Grand Canyon at night	10
Rustling leaves	20
Soft whisper	30
Wind blowing through trees	48
Normal conversation	55
Clothes dryer	60
Surf	70
Blender	80
Lawnmower	90
Drill	98
Rock concert	106
Jet plane taking off	130

Source: Noise Navigator Sound Level Database.

and public health advocates often address the deleterious effects of noise exposure by highlighting the benefits of access to quiet.

Jeanine Botta

See Also: Centers for Disease Control and Prevention; Green Space in Urban Environments; Noise Pollution

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RADIATION, IONIZING AND NONIONIZING

Radiation, which is energy in the form of electromagnetic waves or subatomic particles, is all around us. Radio waves, microwaves, and visible light are examples of radiation, as are X-rays and cosmic particles from outer space. Some radiation occurs naturally, for example, from minerals found in the ground, while other radiation is produced by medical diagnostic equipment and other types of machinery. Radiation exposure can also occur from accidents at nuclear power plants and from nuclear weapons. Radiation is a concern because exposure to some forms of radiation can cause serious health problems and even death. Pregnant women and children are particularly susceptible to radiation exposure.

There are two types of radiation: ionizing and nonionizing. Ionizing radiation is strong enough to dislodge electrons from their atomic orbits, causing the atom to become charged (i.e., ionized). Ionizing radiation can damage tissues, alter the DNA in genes, and sometimes cause cancer. (Because cancers are slow to develop, the effects of chronic exposure to ionizing radiation may not be apparent for 20 years or longer.) Exposure to high levels of ionizing radiation over a short period can cause radiation sickness and even death if there is significant damage to bone marrow, the gastrointestinal tract, or the central nervous system.

Leading Cause of Cancer Deaths

Lung cancer is the leading cause of cancer deaths in the United States among both men and women, accounting for over 150,000 deaths per year in recent years, or one-quarter of all cancer deaths. About 80 percent of lung cancers in men and 90 percent in women are attributed to cigarette smoking, and nonsmokers also have an increased risk of developing lung cancer if they are exposed to secondhand or thirdhand smoke. Lung cancer is also caused by exposure to radon gas (the second-leading cause of lung cancer), air pollution, and occupational exposure to substances such as asbestos, uranium, coke, and certain carcinogenic chemicals. Around two-thirds of all people diagnosed with lung cancer are age 65 or older, with an average diagnosis age of about 70. The five-year survival rate for people with lung cancer is only about 20 percent, and over 50 percent of people diagnosed with lung cancer die within a year. However, when lung cancer is detected early, before it has had time to spread to other organs, the survival rate is significantly improved.

The degree to which ionizing radiation causes adverse health effects depends on the type, strength, and duration of radiation and the organs exposed. The types of ionizing radiation include:

- Alpha Particles: Consisting of two protons and two neutrons from the nucleus of an atom and resulting from the decay of heavy radioactive elements, such as uranium, radium, and polonium. Alpha particles cannot penetrate the skin, but if ingested or inhaled, can severely damage cells and DNA.
- Beta Particles: Small, fast-moving particles emitted by unstable atoms, such as tritium, strontium-90, and carbon-14. Beta particles can penetrate the skin, causing burns, but they are much more dangerous if ingested or inhaled.
- Gamma Rays: Packets of energy called photons that can penetrate the human body, damaging cells and DNA. Gamma rays are so powerful that several inches of lead or several feet of concrete are needed to stop them.
- X-rays: Similar to gamma rays but lower energy and less penetrating. X-rays can occur naturally or be produced by machinery, such as medical diagnostic equipment. Medical X-rays represent the largest source of human created (i.e., nonnatural) radiation exposure.
- Neutrons: Usually resulting from nuclear fission processes, neutrons are the only type of radiation that can make other materials radioactive. Neutrons can travel long distances but can be blocked by concrete or water.

Radioactive decay occurs when radioactive elements called radionuclides release energy in the form of ionizing radiation. As this process of decay occurs, the radionuclide is transformed into a different atom called a decay product. The rate at which decay occurs is called the half-life, which is the time required for half of the radioactive atom to decay. Half-lives can be as short as a few seconds or as long as hundreds or millions of years.

In contrast to ionizing radiation, nonionizing radiation is not powerful enough to dislodge electrons. Nonionizing radiation excites atoms (i.e., causes them to move around and vibrate), resulting in an increase in temperature, for example, in the way a microwave oven thaws a frozen dinner or warms leftovers. The background levels of nonionizing radiation that are always present are generally harmless. However, there is some controversy about whether long-term exposure to some nonionizing radiation sources, including cell phones and high-power transmission lines, represents a health risk. Occupation exposure to high levels of nonionizing radiation (e.g., laser light and high-intensity radio waves and microwaves) can also lead to adverse health effects.

All radiation travels through empty space at the same speed of about 186,000 miles per second (3.0×108 meters per second), but radiation types differ according to their wavelength (which is inversely proportional to frequency) and energy. Ionizing radiation has a shorter wavelength than nonionizing radiation, which means that there is a higher frequency of waves passing a point in space over a given time frame. In contrast, nonionizing radiation has a longer wavelength and lower frequency. Higher frequency waves can impart more energy, which explains why exposure to ionizing radiation represents a greater health risk.

Most of the radiation we receive comes from background sources, for example, cosmic radiation from outer space and naturally occurring radioactive minerals (e.g., uranium and thorium) found in the soil and water and even trace amounts in our bodies. Radon, a radioactive gas that forms naturally from the decay of radioactive elements found in soil and rock, is the second leading cause of lung cancer in the United States. A large fraction of our radiation exposure also comes from medical diagnostic equipment using X-rays and from radiation therapy for treating cancer. Accidental nuclear power plant releases, such as occurred at Chernobyl and Fukushima, can also result in radiation exposure.

Radiation levels are characterized in four different ways (common units followed by SI units):

- Radioactivity: the amount of ionizing radiation coming from a material (i.e., the number of atoms decaying over a given period), measured as the curie (Ci) and becquerel (Bq).
- Exposure: the amount of radiation that travels through the air, measured as the roentgen (R) and coulomb per kilogram (C/kg).
- Absorbed dose: the amount of radiation actually absorbed by an object or person, measured as the radiation absorbed dose (rad) and gray (Gy).
- Dose equivalent (or effective dose): takes into account both the amount of radiation absorbed and the health effects of that type of radiation. The dose equivalent is same as the absorbed dose for beta and gamma radiation, but it is larger than the absorbed dose for alpha and neutron types of radiation, which cause more severe health effects. Dose equivalent is measured as the roentgen equivalent man (rem) and sievert (Sv).

The physical size and weight of a material has little to do with the amount of radiation it emits. For example, a pound of uranium-238 has about 0.00015 curies of radioactivity, whereas a pound of cobalt-60 has about 518,000 curies of radioactivity.

Richard Crume

See Also: Cancer Risk from Environmental Exposure; Chernobyl Incident; Electric Power Generation, Health Implications of; Fukushima Daiichi Incident; Nuclear Safety; Radiation Sickness; Radon

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RADIATION SICKNESS

Radiation sickness (also known as acute radiation sickness and acute radiation syndrome) is a serious and even fatal condition that occurs when people are exposed to a large amount of radiation over a relatively short period. Such exposure is rare and usually caused by an accident at a nuclear power plant or some other industrial facility using radioactive materials. The very small levels of radiation received from common medical diagnostic equipment, for example, a radiograph used to examine a broken bone, are not nearly high enough to cause radiation sickness.

Preparing for a Nuclear Power Plant Incident

Nearly 3 million Americans live within three miles of a nuclear power plant. What would you do if there were an incident at a nearby plant resulting in the release of radiation? Are you prepared? Fortunately, state and local governments, the federal government, and the electric utilities that own nuclear power plants all have emergency response plans for the possibility of a nuclear power plant incident. Additionally, there are steps you can take as an individual to be prepared. For example, you should have an emergency supply kit that contains all the items you will need (including medical prescriptions and supplies and important documents) in case of evacuation. Additionally, you should develop a family emergency plan that includes information on what to do, how to contact family members, and where to meet during an emergency. Knowing the local evacuation routes is also a good idea. Finally, become familiar with the following emergency notification terms so that you will better understand the seriousness of a situation and know what actions to take:

- Notification of Unusual Event: A small problem has occurred at the plant. No radiation leak is expected. No action on your part will be necessary.
- Alert: A small problem has occurred, and small amounts of radiation could leak inside the plant. This will not affect you, and no action is required.
- Site Area Emergency: Area sirens may be sounded. Listen to your radio or television for safety information.
- General Emergency: Radiation could leak outside the plant and off the plant site. The sirens will sound. Tune to your local radio or television station for reports. Be prepared to follow instructions promptly.

You can learn more at the Department of Homeland Security's Ready website (ready.gov).

Radiation is energy in the form of waves or tiny particles that is released from atoms. When people are exposed to high levels of radiation (particularly X-rays and gamma rays), the skin and other organs can be damaged. The intestinal tract and the blood cell-producing cells of bone marrow are most vulnerable to radiation sickness. Additionally, having radiation sickness increases the risk of developing leukemia or some other form of cancer later in life. Children exposed to radiation from nuclear weapons (i.e., Japanese surviving the Hiroshima and Nagasaki attacks during World War II) and power plant accidents are particularly at increased risk of thyroid cancer.

How sick someone becomes depends on the amount of radiation (i.e., the dose) absorbed by their body. The dose of radiation one receives is measured using a unit called the gray, which is the amount of energy absorbed per unit mass of tissue. (1 gray = 1 joule per kilogram.) The symptoms of radiation sickness begin to appear with exposures approaching 1 gray, and doses greater than 10 gray can result in death (see Table 16).

Nausea and vomiting typically appear first (sometimes accompanied by headache, diarrhea, and fever), and the sooner these symptoms appear, the more likely the person has absorbed higher amounts of radiation. Following the initial symptoms, there may be a brief period when no new symptoms appear, followed by the onset of new symptoms that may be more serious (e.g., loss of appetite, fatigue, dizziness, and even seizures and coma). Symptoms may appear within minutes or days after exposure, and they may come and go. With high doses, damage to the skin may be apparent, including swelling, itching, redness, and

Table 16. Symptoms of radiation sickness.

Symptom	**Mild Exposure (1–2 Gray)**	**Moderate Exposure (2–6 Gray)**	**Severe Exposure (6–9 Gray)**	**Very Severe Exposure (≥ 10 Gray)**
Nausea and vomiting	Within 6 hours	Within 2 hours	Within 1 hour	Within 10 minutes
Diarrhea	–	Within 8 hours	Within 3 hours	Within 1 hour
Headache	–	Within 24 hours	Within 4 hours	Within 2 hours
Fever	–	Within 3 hours	Within 1 hour	Within 1 hour
Dizziness and disorientation	–	–	Within 1 week	Immediate
Weakness and fatigue	Within four weeks	Within one to four weeks	Within one week	Immediate
Hair loss, bloody vomit and stools, infections, poor wound healing, and low blood pressure	–	Within one to four weeks	Within one week	Immediate

Source: Mayo Clinic.

even blisters and ulcers. Skin damage may appear within a few hours of exposure or be delayed several days. When death occurs, the cause is typically due to the destruction of bone marrow, which results in infections and internal bleeding.

The way radiation sickness is treated depends on the severity of exposure. The first step is often to remove any clothing that is contaminated with radioactive particles, and the body is washed with soap and water. Any injuries, including serious burns are treated, fevers and infections are addressed, hydration is maintained, and steps are taken to reduce symptoms and manage pain. Medications may be prescribed to counter the effects of radiation on bone marrow, and with severe bone marrow damage, blood transfusions may be needed.

Richard Crume

See Also: Cancer Risk from Environmental Exposure; Chernobyl Incident; Disaster Preparedness and Response; Emergency Planning and Community Right-to-Know Act; Fukushima Daiichi Incident; Nuclear Safety; Radiation, Ionizing and Nonionizing; Three Mile Island Incident

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RADIOACTIVE WASTES

Radioactive waste is waste material that poses a threat to human health due to ionizing radiation. This is the type of radiation that has sufficient energy to displace electrons or break molecular bonds when passing through certain materials, including living tissue. Radioactive waste is a dangerous health hazard because even moderate amounts of radiation exposure can cause cancer, and the waste can

Yucca Mountain—For and Against

The status of the proposed nuclear waste depository at Yucca Mountain, Nevada, remains uncertain due to vigorous opposition and escalating costs. The spent fuel rods at nuclear power facilities are highly radioactive and must be disposed of with the utmost care. The Yucca Mountain site in Nevada is considered by many to be an ideal repository for radioactive waste because of its isolated desert location far away from population centers. Additionally, the wastes can be stored there securely 1,000 feet (305 meters) underground in a closed hydrologic basin, and the site is surrounded by federal lands. However, opponents to the Yucca Mountain project argue that the site is unsuitable given that it is a seismically active region with numerous earthquake faults and nearby volcanic cinder cones. Furthermore, they contend that there are interconnecting faults and fractures that could allow groundwater and radioactive materials to move rapidly through the site, potentially affecting the aquifer beneath and eventually being released to the environment. Finally, opponents are worried about accidents during transportation of large quantities of radioactive materials by rail. If ever approved, the cost to build a transport railroad line in Nevada alone could exceed $3 billion in today's dollars, and the funding required to actually construct and operate the site could reach $100 billion or more.

remain radioactive for tens of thousands of years. Exposure to a large amount of ionizing radiation over a short period (referred to as "acute" exposure) can cause radiation sickness and even death.

The most common form of highly radioactive waste in the United States originates at nuclear electric power plants. The nuclear material in the fuel rods at these plants is composed of either uranium or plutonium, and the disposal of spent fuel rods must be done with great care to avoid radiation exposure. Additionally, other dangerous forms of radioactive waste include uranium mill tailings and "transuranic waste," which is waste generated from the recycling of spent fuel materials or fabrication of nuclear weapons. Radioactive waste products are regulated by the U.S. Nuclear Regulatory Commission (NRC).

As nuclear fuel rods in reactors expend their fissile material, they become highly radioactive waste. Most spent fuel rods are stored in on-site pools, typically 40 feet (12 meters) deep, where the water helps contain the radiation as the rods cool. Because many reactor water pools have reached capacity, older fuel rods must be moved to dry storage, typically after 5 to 10 years. In dry storage, the spent fuel rods are surrounded by inert gas inside a closed steel cylinder called a cask. Each individual cask is encased in more steel, in concrete, or in other materials that can shield workers from radiation. Nationwide, about 78 percent of spent nuclear fuel rods are contained in pools, with the remaining 22 percent in dry casks.

In addition to spent fuel rods, other high-level radioactive wastes must also be disposed of in a manner that protects the public. For example, uranium mill tailings, a by-product of mining and extracting, are stored in special disposal cells licensed by the NRC. Furthermore, in all nuclear power generating facilities, the reactor cores heat water to drive a turbine, and this water at some of these facilities can become radioactive, as does the water used to cool spent fuel rods. Radioactive water is treated on-site until radiation is below federal limits and can be discharged locally.

Since the early 1980s, when the first nuclear plants began to accumulate large numbers of spent fuel rods, the United States has been trying to establish a permanent waste disposal location for this highly radioactive and dangerous material. Geologic burial deep below the earth's surface was determined to be the best option for disposal over several other possibilities. (One proposed disposal option was to shoot the radioactive waste into outer space!) In 1987, the federal government determined that Yucca Mountain in Nevada, about 90 miles northwest of Las Vegas, was a prime location for storing spent fuel rods. However, disagreeing with the assessment that disposal at Yucca Mountain was safe, this plan was strongly opposed by many local residents, environmental advocacy groups, and the state of Nevada. While Yucca Mountain is still a potential long-term site for storing these radioactive wastes, the issue is still being debated, and at present, there is no funding to continue the project. Earlier work was limited to constructing an exploratory rail tunnel, which is now closed.

There are currently no viable alternatives to Yucca Mountain that all interested parties agree on. A small amount of nuclear waste material is housed at the Waste Isolation Pilot Project outside Carlsbad, New Mexico, and some dry fuel rod casks are housed at a facility near Idaho Falls, Idaho, which is only meant as an interim solution. Two locations, one in Andrews County, Texas, and the other in Lea County, New Mexico, are under consideration for becoming interim storage sites. Some nuclear waste can be reprocessed to be used again as reactor fuel, and a number of European countries have reprocessing facilities for their nuclear power plants. These reprocessing facilities produce some radioactive waste themselves, but by reprocessing the waste into fuel, the total amount of radioactive material to be disposed of is reduced.

Not all radioactive waste is as dangerous as spent fuel rods. The U.S. Environmental Protection Agency (EPA) defines "low-activity" radioactive waste as having small enough concentrations of radionuclides that regulation for containment and disposal need not be as stringent. For example, certain medical, research laboratory, and industrial wastes are radioactive but at relatively low levels. Four sites in the United States are licensed to accept low-level radioactive waste, and in some cases, this waste may be allowed to decay until it is safe enough to dispose of in a regular landfill.

To date, the only major accident in the United States involving radioactive waste is the partial meltdown of the Unit No. 2 Reactor at the Three Mile Island nuclear power plant, near Middletown, Pennsylvania, in 1979. A series of mechanical and human errors resulted in coolant water leaking and exposing the fuel rods, causing half of the nuclear core to melt down over a short period. However, the containment building functioned as designed, preventing any radioactive contamination of the surrounding area. This incident prompted a number of regulatory changes to nuclear power facility design and safety.

Recently, radioactive wastewater from hydraulic fracturing operations has become an issue as newer drilling operations come into contact with soil and rock that contain various contaminants, including naturally radioactive materials. Because public wastewater treatment facilities are not designed to treat this type of wastewater discharge, the EPA has developed regulations to ensure this wastewater is not sent to publicly owned treatment works.

Aaron Dorman

See Also: Electric Power Generation, Health Implications of; Environmental Protection Agency; Hydraulic Fracturing; Nuclear Regulatory Commission; Nuclear Safety; Radiation, Ionizing and Nonionizing; Sewage Treatment and Disposal; Three Mile Island Incident

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RADON

Radon is a radioactive, colorless, tasteless, and odorless gas found naturally in rocks and soil, from which it can escape into buildings, homes, and the environment. Radon is the second-leading cause of lung cancer in the United States after smoking, and it is the leading cause of lung cancer among nonsmokers. Around 21,000 Americans die of radon-related lung cancer each year.

Testing for Radon

If you want to test for radon in your home or business, there are two types of monitors: passive and active. Passive monitors are inexpensive and easy to set up, and they do not require electricity. Active monitors require electric power, but they can provide hourly readings and an average for the entire test period. Information on testing for radon, including the types of testing devices and the ones most appropriate to your situation, can be obtained from your state radon office. Discounted test kits and helpful information are available through the National Radon Program Services office at Kansas State University (http://sosradon.org), and test kits are also available commercially, for example, at home improvement stores and through online retailers.

Radon can readily enter buildings from the ground through basements and crawl spaces, cracks and gaps in floors and walls, construction joints, exhaust fans, and gas appliances. Additionally, certain materials used in the construction of buildings can release radon, such as bricks and mortar, cinder blocks, concrete, gravel, sheet rock, and stone. Well water and groundwater containing radon can be additional sources of exposure when used in sinks and showers and certain home appliances. For example, the heating and agitation of the water in a dishwasher or washing machine can cause radon to become airborne, leading to inhalation exposure.

Radon levels are not uniform across the United States or even in localities. The U.S. Environmental Protection Agency (EPA) estimates that as many as 1 in 15 American homes have radon levels above the EPA-recommended action level of 4 pCi/L. Furthermore, the EPA cautions that levels below 4 pCi/L can still potentially pose adverse health effects. Thus, residents are advised to check radon levels in their homes and to take action to reduce radon exposure when elevated levels are found.

Elevated radon levels across the United States have prompted many states to enact programs to help schools, homeowners, and building owners mitigate the amount of radon in indoor air. The increase in shale gas extraction over the past decade has raised additional concerns in some states because the waste streams from hydraulic fracturing techniques may contain elevated radon concentrations.

Radon emits alpha particles that are deposited deep in the lungs, and lung cancer can result when radon is inhaled over long periods. Small cell carcinoma, adenocarcinoma, and squamous cell carcinoma can develop in response to long-term radon exposure. Some studies suggest that radon is also linked to a higher incidence of leukemia, lymphoma, and multiple myeloma. In addition, elevated indoor air exposure to radon can lead to nonmalignant respiratory diseases.

The only way to know if you are exposed to elevated radon levels is to have your home or building tested. Radon testing is relatively inexpensive, and the testing is easy to do. In cases where elevated levels are found, a certified radon mitigation specialist should be consulted. Many states require that people in the business of radon mitigation be certified, and requirements for testing and disclosure are also common.

There are several methods to mitigate radon in buildings. Mechanical radon reduction systems rely on suction techniques that draw radon away from the interior of the building. One common example of a radon reduction system is subslab suction (depressurization), which relies on inserting suction pipes into the bottom floor or concrete slab. The suction pipes are connected to a radon vent fan that discharges the radon to the outside air. Radon levels may also be lowered by improving basement or crawlspace ventilation, sealing cracks or spaces, pressurizing a room or building, and improving basement, crawlspace, or living space ventilation.

In new construction, improved techniques can mitigate radon exposure. For example, a layer of course gravel can be placed below the building foundation, thereby allowing the radon and other naturally occurring gases to move freely beneath the building but not enter the structure. Plastic sheeting or a vapor barrier can be installed on top of the gravel to further prevent radon gases from entering the building. A pipe installed vertically from the gravel layer through cavities in the building can help vent the radon away from the structure, and all openings can be sealed to keep radon from entering the building. Before embarking on radon mitigation project, be sure to consult with an expert to determine the best approach for your situation.

Elizabeth Ann Glass Geltman and Nichole LeClair

See Also: Cancer Risk from Environmental Exposure; Environmental Protection Agency; Hydraulic Fracturing; Indoor Environment; Radiation, Ionizing and Nonionizing

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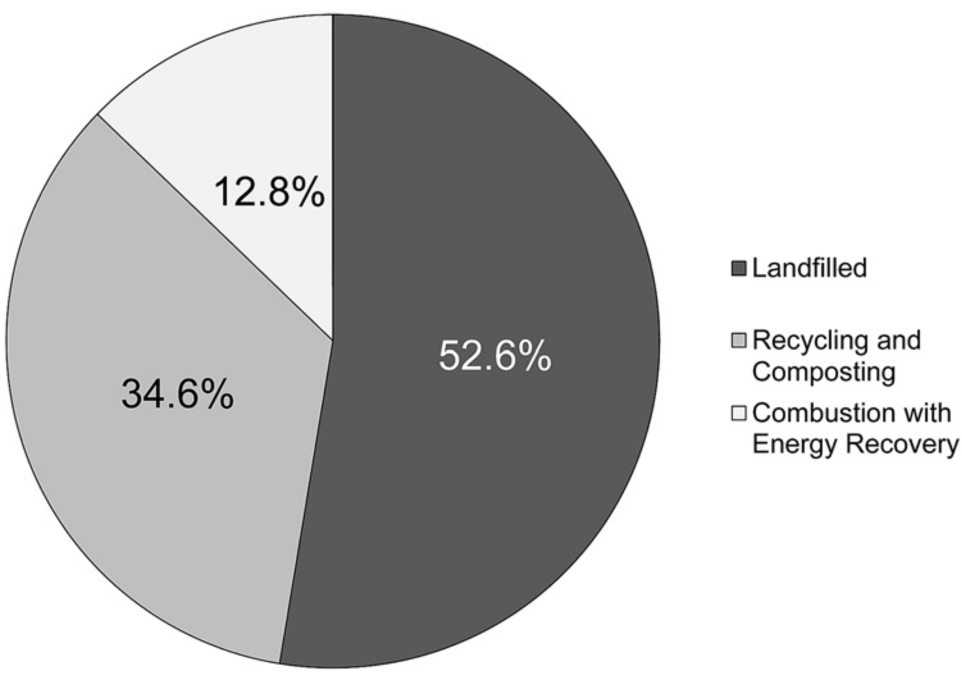
RECYCLING

Recycling has been an important part of maintaining a healthy environment since the early days of the Industrial Revolution. The first recycled paper plant, using discarded cotton and linen rags, was built at the Rittenhouse Mill near Philadelphia in 1690. As early as the Revolutionary War, it was realized that recycling was an essential method of recovering valuable materials that were in short supply. In recent times, supply shortages of some materials, combined with modern environmental consciousness and complex waste disposal requirements, have led to an increase in recycling for all kinds of waste materials.

The U.S. Environmental Protection Agency (EPA) defines "recycling" as "the process of collecting and processing materials that would otherwise be thrown away as trash and turning them into new products." The health benefits of recycling include the avoidance of any negative consequences that would have happened without the recycling process. This includes benefits not only from reducing the waste stream but also from reducing the need to find new resources, which can often be an intensive and environmentally destructive process.

Only about one-third of waste in the United States is recycled or composted (see the following figure), and although that rate has been going up, so has the total amount of garbage produced as well as per capita garbage generation. Also, recycling statistics do not account for trash like electronic waste that is either exported to other countries or stored unused in someone's basement or garage. There is also an increasing amount of discarded plastic material that has become part of



Management of municipal solid waste in the United States, 2014. (U.S. EPA, Advancing Sustainable Materials Management: 2014 Fact Sheet)

the large ocean garbage gyres and may not be accounted for in waste statistics. In the United States, the majority of garbage that is not recycled ends up in a landfill. Additionally, about 13 percent of U.S. garbage is incinerated with energy recovery. Under the Resource Conservation and Recovery Act, landfills cannot simply be holes in the ground where garbage collects and slowly disintegrates. Instead, they are lined with an impervious material like plastic or concrete and equipped to collect leachate (i.e., garbage that breaks down to a liquid form) and methane, a byproduct of anaerobic decomposition.

Several decades ago, there were over 7,500 active landfills in the United States. But since then, many have become filled to capacity and permanently closed, and now less than 2,000 landfills remain in operation. (The decreasing number of landfills is partially offset by an increase in size of remaining landfills.) The main hazards today of garbage disposal are impacts on climate change and disruptive land use. Many areas of the United States no longer have active landfills, and garbage is hauled long distances. For example, the garbage in New York City is transported to Ohio, Pennsylvania, or West Virginia for disposal. Therefore, the environmental effects of garbage must also include the pollution produced during transportation to disposal sites.

Although the odors near landfills can be noxious, the trace amounts of ammonia and hydrogen sulfide that typically cause the stinky smell are generally not high enough to impair human health. Over 90 percent of the gaseous output from landfills is methane or carbon dioxide, neither of which produces an

Packaged plastic trash ready to be recycled. Today about one-third of the municipal waste generated in the United States is recycled or composted. (Shutterstock)

odor or directly harms humans, although both are greenhouse gases contributing to climate change. An alternative to landfilling, waste incineration, effectively reduces the volume of wastes but can cause toxic air pollution, including dioxins and mercury.

The mining, extraction, processing, and manufacturing of new materials take a high toll on our health and environment, and the benefits of recycling are typically measured in terms of reducing these impacts. For example, the EPA reports that 89 million tons (81 metric tons) of municipal wastes were recycled or composted in 2014, equivalent to an annual reduction of 200 million tons (181 million metric tons) of carbon dioxide (equivalent) emissions, or the annual emissions from 38 million passenger cars. Recycling rates differ for different materials. For example, in the United States, 99 percent of lead-acid batteries and 90 percent of corrugated boxes are recycled successfully, but only 41 percent of tires, 33 percent of glass containers, and about 30 percent of plastic bottles and jars are recycled.

For some common materials, such as aluminum, recycling saves up to 95 percent of the energy required to mine and extract the same amount of new material, and the recycling of paper goods requires only half the energy needed for fresh pulp. Water conservation is another important benefit from recycling, where recovering 1 ton (0.9 metric ton) of paper is equivalent to saving 7,000 gallons (26,500 liters) of water. The most significant health benefit of recycling may come from efforts to reduce plastics in the environment. Plastics are difficult to break down and can persist in the environment for centuries, and plastic debris and chemical additives can easily enter the food chain. Heart disease and reproductive abnormalities have been linked to the presence of Bisphenol A (BPA), which is found in polycarbonate bottles and can linings. The U.S. Centers for Disease Control and Prevention estimates that at least trace amounts of BPA can be found in the bodies of over 90 percent of Americans.

Despite their intrinsic benefits, most recycling efforts leave something to be desired. Recycling plants themselves require energy input, and at present that nearly always comes in the form of nonrenewable fuels. Furthermore, when oil prices are low, recycled plastic may become more expensive than manufacturing new plastics. Quality can sometimes be an issue when a recycled material is not of the same quality as a newly made material and consumers find this objectionable.

Legislation on recycling varies by state, but some of the more effective practices include curbside recycle bins and small monetary incentives for returning glass and plastics. Also, there are efforts to limit certain kinds of packaging and toxic ingredients, for example, in the manufacture of BPA-free bottles.

Aaron Dorman

See Also: Bisphenol A (BPA); Carbon Dioxide and the Carbon Cycle; Dioxin Pollution; Electronic Waste Disposal; Environmental Protection Agency; Land Disposal of Waste Materials; Mercury Pollution; Municipal Solid Waste Management; Ocean Dumping and the Pacific Garbage Patch; Odor Pollution; Resource Conservation and Recovery Act; Three Rs of Waste Management; Waste Incineration

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REGIONAL HAZE POLLUTION

Many Americans travel to national parks to enjoy nature and take in the view, often of distant mountains or sunrise over the ocean. However, sometimes the view is obscured by white or brownish haze. Some haze is natural, but most is caused by air pollution present over a wide region. Some of the pollutants causing haze are associated with serious health conditions and environmental damage.

When sunlight strikes small pollution particles in the atmosphere, some of the light is absorbed by the particles and other light is scattered in all directions. This absorption and scattering of light reduces the visibility of distant objects and makes the sky appear hazy. In the eastern United States, haze often reduces the visibility to just 15 to 25 miles (24 to 40 kilometers), down from the 90-mile (145-kilometer) visibility expected on a perfectly clear day. In the western United States, where visibilities tend to be higher because humidity is lower and air pollution is less, haze often reduces visibility from 140 miles (225 kilometers) on a clear day to between 35 and 90 miles (56 and 145 kilometers). Reduced visibility is particularly bothersome to more than 300 million annual visitors to U.S. national parks, many of whom are hoping to escape urban smog and experience pristine conditions.

The small particles that cause haze can either be emitted directly into the atmosphere or form from gases (e.g., the formation of sulfate and nitrate particles from sulfur dioxide and nitrogen oxide gases). The sources of haze-forming particles and gases include coal-burning electric utility power plants, motor vehicles, and various manufacturing operations. These particles can also originate with natural events, such as forest fires and wind-entrained dust (e.g., the dust storms prevalent in the western United States). These pollutants can travel hundreds of miles, causing haze far away from the original sources of pollution.

Some of the haze-forming pollutants can also cause adverse health effects. For example, sulfur dioxide and nitrogen oxides can result in a variety of respiratory problems, including increased asthma symptoms, and elevated levels have been associated with an increase in emergency room and hospital admissions. The inhalation of small particles has been linked to increased respiratory illness, decreased lung function, and premature death. Small particles, such as the sulfate and nitrate particles common in haze, can also contribute to acid rain formation, which makes lakes and streams unsuitable for many aquatic species and can damage building and automobile surfaces.

While it is tempting to characterize haze and visibility in terms of how far we can see, it is actually much more complicated than that. For example, while admiring a distant mountain range, any haze that is present in the atmosphere may affect our perception of colors, forms, contrasts, and details. For some observers, this may be bothersome, whereas others may not even notice a perception difference. Furthermore, how we are affected by haze may depend on personality factors such as our interest in a particular view or what value we place on the object being observed. Time of day is also an important factor because our perception of haze is usually more acute during the early morning and late afternoon hours, when the sun is lower in the sky. The result is that haze is a controversial topic, often with unclear solutions. In the case of haze, beauty is truly in the eye of the beholder!

Richard Crume

See Also: Air Pollution; Asthma; Automobile and Truck Emissions and Controls; Electric Power Generation, Health Implications of; Fugitive Dust; Particulate Matter and Bioaerosols Pollution; Respiratory Disease and Air Pollution

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RENEWABLE ENERGY, HEALTH IMPLICATIONS OF

Fossil fuels, such as coal, oil, and gas, and nuclear power are used to produce much of the electricity the United States depends on. The transition from fossil fuels and nuclear power to renewable energy can greatly improve public health while helping to protect the environment. This transition is currently underway.

Greensburg Rebuilds with Renewable Energy

In 2007, Greensburg, Kansas, was mostly destroyed by a massive tornado—hardly a building was left standing throughout the town. Rather than rebuilding the city the way it was before the tornado, the residents viewed their misfortune as an opportunity to become a model for energy efficiency and renewable energy. This vision became a reality with the installation of a large wind farm and a number of smaller solar and biogas installations and with building codes designed to conserve energy. Green corridors and a walkable downtown were also part of the city's redevelopment plan. Today, the city is powered by 100 percent renewable energy.

Can Renewable Energy Make Us a Healthier Nation?

Technological innovations and volume sales have helped make renewable energy more affordable than ever.

An Interview with Carly Rixham

Executive Director, American Solar Energy Society

Carly Rixham is executive director of the American Solar Energy Society, the world's leading association of solar professionals and advocates. Rixham has a diverse background in solar power, biofuels, and wastewater management, and she has taught biology and ecology at the university and high school levels. As solar energy becomes more popular in the United States and throughout the world, Rixham is interested in promoting solar energy at the grassroots level and connecting science with the greater community of solar advocates.

By now, most people are familiar with the concepts of solar energy and a sustainable energy economy, but there has been little discussion in the press about how solar and sustainable energy benefit people's health. Can you comment on how replacing fossil fuel energy sources with innovative technologies, such as solar power, will help make us a healthier nation?

There are several ways in which solar and other renewable energy technologies improve public health. By replacing conventional fossil fuel-fired power plants, renewable energy is playing an increasing important role in the fight against climate change by cutting greenhouse gas emissions. We know that climate change will cause more severe heat waves and droughts, increase urban smog, and enhance the spread of diseases by ticks and mosquitoes. Thus, by replacing the sources of climate change gases, renewables help make the earth a healthier place to live. Fossil-fuel power plants also contribute significantly to air pollution in our major cities. Did you know that over 120 million Americans live in areas where federal air quality standards are exceeded? Again, clean renewable energy is obviously a better choice than fossil fuels!

Interest in renewable energy has been growing as evidence of climate change begins to emerge. Yet, proponents of traditional energy sources, like coal,

oil, natural gas, and nuclear power, argue that the required renewable energy infrastructure will take many more years to develop. Is there still time for renewable energy to play a major role in combating climate change?

Not replacing fossil fuel power plants with solar and other renewable energy sources is *not* an option. Technological innovations and volume sales have helped make renewable energy more affordable than ever. As proof of this, almost two-thirds of new electrical generation placed in service in the United States in 2015 comprised renewable energy—solar, wind, geothermal, biomass, and hydropower. That's an impressive accomplishment for an industry that some experts thought could not compete much longer with cheap coal and natural gas. While much must be accomplished to improve our power infrastructure and install sufficient renewable energy capacity, natural gas and possibly nuclear power can serve as a bridge, weaning us off of fossil fuels as we more fully develop renewable sources.

The American Solar Energy Society organizes the National Solar Tour, which provides an annual opportunity for Americans to tour innovative green homes and buildings and to see how solar energy can be used efficiently. These homes are not only environmentally friendly, but they also provide a healthy indoor environment. Do you see green buildings playing a complementary role with renewable energy in reducing the nation's dependence on fossil fuels and creating a healthy environment?

Reducing the energy consumption of buildings is essential to solving the climate change problem. This is because buildings in the United States account for almost 40 percent of total energy use and almost 70 percent of total electricity consumption. Because much of this energy comes from fossil fuel-powered power plants that are the leading source of climate changes gases, reducing building energy use can help fight climate change in a really big way. New buildings can be constructed so that they are much more energy efficient than in the past, and existing buildings can be retrofitted with energy-saving features. How we live and work in buildings makes a difference too. For example, simple actions like turning the lights out when we leave a room, washing clothes in warm water, and setting the thermostat back a few degrees in the winter can help a lot, especially if every American can be convinced to save energy. Passive solar houses that incorporate large south-facing windows and thermal mass for storing daytime heating can be especially effective in reducing heating costs in cold climates.

What is a good career path for a recent college or university graduate who is interested in addressing climate change and environmental pollution by promoting renewable energy and green buildings?

This is a tough question because there are so many fields someone might go into to develop and install renewable energy systems and promote green building practices—engineering, architecture, physics, materials science, and various trade professions, to name a few. The important thing is to find what you are good at and be the best you can be. Gaining practical experience through an internship or entry-level position is especially important.

For transportation fuels, ethanol (made from corn and other plant materials) and biodiesel (made from vegetable oils, animal fats, or recycled restaurant grease) are generally considered renewable energy. However, significant amounts of fossil fuels are used in growing the feedstock for these biofuels, refining and processing the feedstock, and transporting the feedstock and biofuels. In addition, combustion of biofuels in vehicles produces similar amounts of air pollution to fossil fuels. Thus, the health benefits of biofuels over fossil fuels may not be significant when the entire life cycle is taken into account.

Generating electricity from renewable sources rather than fossil fuels, however, does present the opportunity for significant public health improvements. The major sources of renewable energy include hydroelectric, wind, biomass (wood and waste), solar, and geothermal power. Table 17 lists the percent that each of these sources contributes to total electricity generation in the United States. While these percentages are currently small, wind and solar power, in particular, have experienced rapid growth, which is expected to continue well into the future. (Renewable energy makes up about 13 percent of total U.S. electricity generation. Nuclear power contributes 20 percent, coal 33 percent, natural gas 33 percent, and petroleum just 1 percent.)

Life cycle analysis demonstrates that renewable energy generally has substantial health benefits over fossil fuel and nuclear power sources. This is to be expected because renewables depend on clean, natural energy sources like sunlight and the

A solar energy generating facility in California's Mojave Desert. Renewable energy, including solar, wind, hydroelectric, biomass, and geothermal power, makes up only about 13 percent of U.S. energy production, but the percentage is growing every year. (iStockphoto.com)

Table 17. Contribution of renewable energy sources to total U.S. electricity generation in 2015.

Source	Contribution to Total U.S. Electricity Generation (Percentage)
Hydroelectric	6.0
Wind	4.6
Biomass wood	1.0
Solar	0.7
Biomass waste	0.4
Geothermal	0.4

wind. In contrast, the extraction, processing, and transportation of coal, oil, natural gas, and uranium (for nuclear fuel) produce copious amounts of air and water pollution and solid waste. Although concentrating solar power (CSP) facilities can cause some thermal pollution (i.e., the discharge of warm water into nearby lakes and streams), these facilities are rare, and the thermal pollution can be mitigated or eliminated through the use of technologies such as dry cooling.

Whereas renewable energy sources are generally clean, fossil-fuel and nuclear plants create large volumes of air, water, and solid waste pollution, including greenhouse gases, other common air pollutants, heavy metals, dioxins and furans, and high-level radioactive wastes. These pollutants cause adverse health consequences leading to thousands of premature deaths per year, tens of thousands of nonfatal illnesses, and resultant missed days at work and school. In 2015, reductions in sulfur dioxide and nitrogen oxides associated with the consumption of more wind power (at the expense of fossil fuels) saved $7.3 billion in public health costs.

In addition, fossil fuel and nuclear power plants are major sources of water use, second only to agriculture in many states. In comparison, wind and solar power facilities (except for some CSP plants) use practically no water. This leaves extra water for other purposes, such as agriculture, municipal uses, and maintaining healthy aquatic ecosystems.

Many misconceptions exist about renewable energy and its health implications. For example, claims have been made about the pollution that is created during the manufacturing of solar photovoltaic (PV) panels because of the amount of energy needed to make silicon, a basic building block of more than half of the PV panels manufactured today. These claims are based on out-of-date data that do not reflect the current manufacturing processes, which have become much more efficient in the past few years. Such claims also ignore that many silicon manufacturing facilities are now powered themselves by renewable energy and that fossil fuel and nuclear power plants also require energy-intense materials during manufacturing and construction (e.g., concrete and highly specialized metals). In addition, some solar PV panel manufacturers offer recycling programs for their products. Laws and regulations mandating the recycling of solar panels are not currently common but could be enacted in the future.

Misconceptions about health impacts from wind power largely focus on two issues: noise (caused by the wind turbine blades rotating through the air) and shadow flicker (a flickering on the ground as sunlight passes between the blades). While these issues can be annoying to some people, there is no credible evidence that wind turbines directly cause health (including mental health) problems or disease. Opposition to wind power also often focuses on bird deaths, although bird advocacy groups like the Audubon Society strongly support properly sited wind power facilities. Furthermore, many conservation biologists believe wind power's contribution to reducing greenhouse gases is important in the fight against climate change, which threatens wildlife on a global scale.

Switching to 100 percent renewable electricity through on-site generation or purchasing programs is already achievable, as evidenced by the hundreds of cities, states, countries, homes, and industries that have already achieved this level of renewables or have made serious commitments to do so in the future. Cities already achieving 100 percent renewable electricity include Aspen, Colorado; Georgetown, Texas; Burlington, Vermont; Kodiak, Alaska; and Greensburg, Kansas. Larger cities, such as Vancouver, Canada, and San Francisco, California, have committed to achieving 100 percent renewables in the next decade. Hawaii is on track to generate 100 percent of its electricity from renewable sources by 2045, and in Vermont, 75 percent of the electricity sold by its electric companies will come from renewables by 2032. The U.S. operations of technology giants Apple and Google are powered with 100 percent renewable energy.

Not only are solar, wind, and hydroelectric facilities nonpolluting, but they are often the lowest-cost source of electricity generation. For example, wind power is so inexpensive and plentiful in Texas that at times it has driven wholesale electricity rates into negative territory (i.e., electric generators have had to pay utilities to put their electricity on the grid). This has prompted some retail electric utilities, such as Amigo Energy in Texas, to offer free electricity at night when wind generation tends to be strongest and electricity demand lowest. Similarly, regulators in California and other states have chosen solar power plants over natural gas power plants, based on cost alone. While adequate long-distance transmission lines and electric storage continue presenting obstacles to renewable energy in some situations, the main obstacle to increased use of renewable energy is political inertia.

Robert Ukeiley

See Also: Climate Change and Human Health; Dioxin Pollution; Electric Power Generation, Health Implications of; Heavy Metal Pollution; Life Cycle Assessment; Noise Pollution; Nuclear Safety; Radioactive Wastes; Recycling

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REPRODUCTIVE HEALTH AND ENVIRONMENTAL EXPOSURES

Environmental pollutants interfere with reproductive function in experimental models, with corroborating evidence provided by observational human epidemiology studies. Synthetic, geogenic, and biogenic agents pollute air, water, and food from anthropogenic activities, including manufacturing and energy recovery, and these pollutants are also liberated by natural processes, such as volcanic eruptions and forest fires. Many pollutants alter endocrine function, changing gene expression and modifying cell communications, with resulting dysfunction. Additionally, pollutants can increase oxidative stress and inflammation, leading to tissue damage and death, and they can modify the acquired pattern of epigenetic molecules that bind to deoxyribonucleic acid (DNA) and regulate gene expression.

With the substantial growth of industry and manufacturing since World War II, exposure to toxic trace elements and synthetic organic compounds has become nearly ubiquitous. Toxic trace elements, such as arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg), are widespread contaminants of air, water, and food and have been shown to diminish semen quality, increase pregnancy loss and stillbirth, and foster developmental delays in offspring. Persistent organic pollutants (POPs), polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs), for instance, biomagnify in food chains, leading to dietary exposure through consumption of animal fats or ingestion of dust liberated from household furniture and carpeting. These agents accumulate over time and may interfere with estrogen and androgen (testosterone) signaling, raising risks for endometriosis, uterine fibroids, and infertility, and they may also impact intelligence and behavior in offspring.

Other, nonpersistent organic pollutants, such as bisphenol A (BPA), phthalate diesters, and paraben esters, tend to be rapidly metabolized and eliminated from the human body. Yet, populations are continually exposed to these pollutants through the use of consumer goods, personal care products, and pharmaceuticals, including ingestion from food and beverage packaging and containers, inhalation from air fresheners and building materials, and absorption from lotions and cosmetics. Nonpersistent organic compounds have been associated with a spectrum of adverse reproductive outcomes in animal and human research. BPA, for example, appears to be an ovarian toxicant and raises oxidative stress levels, whereas phthalates are implicated as testicular toxicants and may cause increased inflammation.

Various pollutants with suspected reproductive toxicity, including toxic trace elements, POPs, and nonpersistent organic pollutants, were detected in most blood and urine specimens collected from pregnant women during a 2003–2004 Centers for Disease Control and Prevention biomonitoring study. Many pollutants, including As, Cd, Pb, Hg, PCBs, PBDEs, BPA, phthalates, and parabens, cross the placenta, placing a developing fetus at risk. Even at low levels, fetal exposures within limited critical developmental windows (e.g., during gonadal differentiation starting around the seventh week of gestation) may lead to a spectrum of adverse effects that manifest after delivery or even in adulthood. The structural malformations, infertility, and reproductive cancers postulated by testicular and ovarian dysgenesis syndromes (i.e., defective development of the gonads) are examples of "fetal programming" impacts that may result from maternal pollutant exposure.

Despite growing evidence, the reproductive effects of low-level, background exposures to environmental pollutants experienced by most people remain controversial. Additional investigation, coupled with a precautionary approach to exposure, is recommended by many doctors and scientists.

Michael S. Bloom

See Also: Arsenic Pollution; Biomonitoring and Biomarkers; Bisphenol A (BPA); Centers for Disease Control and Prevention; Endocrine Disruptors; Environmental Epidemiology; Environmental Toxicology; Heavy Metal Pollution; Lead Poisoning Prevention; Mercury Pollution; Personal Care Products, Health Issues with; Pharmaceuticals in the Environment; Phthalates; Polychlorinated Biphenyls; Toxicogenomics

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RESOURCE CONSERVATION AND RECOVERY ACT

The Resource Conservation and Recovery Act (RCRA) was established in 1976 as a national waste management program that protects communities and resources from inappropriate waste disposal. The RCRA allows the U.S. Environmental Protection Agency (EPA) to control the creation, transportation, treatment, storage, and disposal of hazardous waste, and it also provides a structure for disposing of nonhazardous waste. Put into practice, the RCRA is a set of regulations, guidance, and policies developed by the EPA to safely manage and clean up both solid and hazardous waste and to encourage reuse and source reduction.

The RCRA is often described as cradle-to-grave legislation because it provides authority to control hazardous waste from when it is first generated to when it is ultimately disposed of and all the steps in between (e.g., moving the waste from one location to another and treating the waste to make it less hazardous or more stable). Amendments to the RCRA in 1984 addressed waste minimization, the phasing out of land disposal of hazardous waste, and corrective actions for releases. The 1986 amendments addressed environmental contamination problems specifically resulting from the storage of petroleum and other hazardous substances in underground tanks.

Examples of the impact the RCRA has had on the United States include (1) contamination prevention programs that reduce the potential for future Superfund sites that negatively affect communities; (2) programs that reward companies that adjust manufacturing processes to reduce waste and promote safe reuse of materials; and (3) improvements to the country's recycling infrastructure. These improvements have resulted in an increase to the municipal solid waste recycling/composting rate from 7 to 35 percent.

Hana Elliott

See Also: Composting, Health Benefits of; Environmental Protection Agency; Hazardous Waste Disposal; Recycling; Three Rs of Waste Management; Underground Storage Tanks, Health Concerns with

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RESPIRATORY DISEASE AND AIR POLLUTION

Air pollution has been recognized as a public health problem for several thousand years, adversely affecting human health and contributing to respiratory diseases. From early humans using fire for cooking and heating to the concentration of urban home chimneys and industry smokestacks, humankind has contributed significantly to air pollution. Over 2,500 years ago, the Greek physician Hippocrates (c. 460–c. 370 BCE), considered the father of medicine, described how health could be compromised by the quality of air.

Air pollution can be found in both outdoor and indoor environments and comes from both anthropogenic (human) and natural sources. Major air pollutants include emissions from automobiles and industries that burn fossil fuels and from natural events such as forest fires. Widespread air pollution can have a significant impact on climate change. For example, carbon dioxide, a by-product of fossil fuel combustion, contributes to global warming, which can affect air quality by increasing ground-level ozone and extending the length of the growing season for plants that produce allergens. This can lead to damaged lungs from ozone exposure and allergic reactions from pollens in the air.

Anthropogenic sources of outdoor air pollution are associated with mobile and stationary sources. Mobile sources include on-road vehicles such as cars, trucks, and buses and nonroad vehicles such as trains, ships, and planes. Pollution from these mobile sources involve the combustion of fossil fuels, causing gases to be emitted into the atmosphere from the engine exhaust. Stationary sources of anthropogenic pollution include facilities such as power plants, manufacturing operations, and oil refineries. These types of pollution sources can emit a variety of pollutants, including carbon monoxide, nitrogen oxides, particulate matter, sulfur dioxide, volatile organic compounds, and various toxic compounds. Many of these pollutants contribute to the smog common in many large cities. Natural sources of air pollution emit gases and particulate matter that can be dispersed over wide areas by the wind. This includes dust clouds, smoke and ash from forest fires and volcanic eruptions, and various types of allergens like ragweed pollen, animal dander, and mold.

Inhaling air pollution often results in irritation to the upper respiratory tract, breathing difficulties, allergic reactions, and eye irritation. Additionally, air pollution can trigger asthma attacks and lead to a general decline in lung function. Long-term exposure to some air pollutants, often termed "air toxics," can cause serious health issues, including cancer and cardiovascular problems. Older adults, children, and people with existing health conditions are particularly susceptible to air pollution. Because humans spend more than 90 percent of their time indoors, exposure to indoor pollutants can also be a serious problem. Sources of indoor pollution includes household chemicals, molds, dust mites, pests, environmental tobacco smoke, and lead paint dust, many of which are considered asthma triggers. Indoor air pollution has also been linked to sick building syndrome and Legionnaires' disease.

Recognizing the significant health and environmental problems associated with air pollution, the U.S. Congress passed the Clean Air Act in 1970, with major amendments in 1977 and 1990. This law regulated air emissions from mobile and stationary sources and authorized the U.S. Environmental Protection Agency (EPA) to develop national ambient air quality standards (NAAQS) that protect the health and welfare of the public, in addition to regulating toxic air pollutants. The EPA set primary NAAQS for carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide, and it set secondary standards for the same pollutants (except for carbon monoxide). Primary standards establish regulatory emission limits to protect public health, including the health of sensitive populations such as asthmatics, children, and the elderly. Secondary standards establish limits to protect the welfare of the public, including protections for crops, vegetation, visibility, animals, and buildings. The 1990 Clean Air Act Amendments incorporated provisions to address acid rain, urban air pollution, and toxic air emissions. The EPA established AirNow and the Air Quality Index to quickly inform the public about poor air quality days, potential adverse health effects, and actions to reduce exposure.

R. Christopher Rustin

See Also: AirNow and the Air Quality Index; Allergens in the Environment; Ambient Air Quality and Health; Asthma; Automobile and Truck Emissions and Controls; Cancer Risk from Environmental Exposure; Carbon Dioxide and the Carbon Cycle; Children's Environmental Health; Clean Air Act; Climate Change and Human Health; Crops and Vegetation, Air Pollution Damage to; Electric Power Generation, Health Implications of; Environmental Protection Agency; Fugitive Dust; Hazardous Air Pollutants; Indoor Environment; Lead Poisoning Prevention; Legionnaires' Disease; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Sick Building Syndrome; Tobacco Smoke, Secondhand and Thirdhand; Volatile Organic Compound Pollution

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RIVER BLINDNESS

River blindness, or Onchocerciasis, is an infection caused by the nematode *Onchocerca volvulus* that leads to skin disease and possible blindness. Most commonly found in sub-Saharan Africa, this disease has been estimated to have infected 37 million people worldwide. More than 99 percent of infections occur across 30 African countries. It is the second leading infectious cause of blindness, affecting 500,000 people throughout the world.

Black flies are the disease vector for *Onchocerca volvulus*, and humans are the only definitive host. Humans contract the disease when an infected black fly bites and deposits third-stage larvae into the skin. The larvae mature into adults over the next 6 to 12 months, after which the females start producing offspring called microfilariae. *Onchocerca volvulus* is a prolific reproducer and can make 1,000 to 3,000 microfilariae per day, leading to a total microfilaria load in heavily infected humans of more than 100 million. Once another black fly bites an infected person, microfilariae are transferred back to the fly, where they mature into infectious third-stage larvae over one to three weeks. This completes the infectious cycle.

Over their 3- to 15-year life span, female *Onchocerca volvulus* can grow to 20 inches (50.8 centimeters) long, and males typically grow to 5 inches (12.7 centimeters) long. The females burrow into subcutaneous and deeper muscle tissue and become encapsulated by fibrous tissue, forming hard nodules. The males move through subcutaneous, dermal, and ocular tissues as well as the lymphatic system.

As the worms die, they release antigens that activate the body's immune system, causing corneal inflammation and leading to anterior and posterior segment onchocercal eye disease as well as a variety of onchocercal skin diseases. Virtually no deaths are directly attributed to *Onchocerca volvulus* itself. However, infection reduces immunity and resistance to other diseases, which leads to an estimated reduction in life expectancy of 13 years.

The first signs of infection are intensely pruritic skin eruptions and rashes, followed by swelling of the lymph nodes. Patients may also complain of generalized symptoms like back and joint pain and weight loss. The first sign of ocular disease is the presence of microfilariae in the anterior segment of the eye on slit-lamp examination. With chronic exposure, corneal lesions occur, along with optic nerve atrophy, retinal death, and loss of the underlying choroid.

Diagnosis of the disease is primarily made via microscopic analysis of skin snip biopsies. Additionally, a more sensitive patch test has been developed as a noninvasive and cheaper alternative to skin snips and is widely used in endemic areas of Africa. Ultrasound may also be useful in identifying deeper nodules filled with adult worms.

Treatment for onchocerciasis is by a single dose of ivermectin repeated every 3 to 6 months until the patient is asymptomatic. There have also been very successful mass drug treatment programs in hyperendemic areas by the African Program for Onchocerciasis Control and the Onchocerciasis Elimination Program for the Americas. These programs rely on ivermectin dosing every 6 to 12 months for up to 10 to 16 years in symptomatic individuals.

Timothy J. Sutton

See Also: Environmental Toxicology; Infectious Diseases; Insect-Borne Diseases

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ROCKY MOUNTAIN SPOTTED FEVER

Rocky Mountain spotted fever (RMSF) is a serious, potentially fatal tick-borne disease caused by the intracellular bacterium *Rickettsii rickettsii*. It was first described in Idaho in 1906 by Howard Ricketts and is found natively throughout the United States, Canada, Mexico, Central America, and parts of South America. Historically, fatality rates were as high 65 to 80 percent, but today mortality ranges from about 0.3 to 3 percent in areas where the disease is established. RMSF is the most common rickettsial infection in the United States, with 4,470 cases of presumed infection in 2012 reported by the Centers for Disease Control and Prevention.

Rickettsii rickettsii gains entrance into its host through the saliva of a tick bite. The primary vector for infection in the United States is the American dog tick (*Dermacentor variabilis)* and Rocky Mountain wood tick (*Dermacentor andersoni*).

The bacteria quickly make their way into the intracellular space of local cells and begin replication in both the nucleus and cytoplasm. The bacteria then hijack host-cell filopodia for locomotion as well as stealing ATP and glutamine for energy. These adaptations allow the bacteria to move between cells at the incredible rate of over 3 inches (8 centimeters) per second!

The incubation period for infected patients to become symptomatic is 2 to 14 days after being bitten by the tick. The early symptoms of RMSF are nonspecific and include fever, headache, muscle and joint pain, nausea, abdominal pain, and overall flu-like symptoms. After a few days, a characteristic skin rash develops, which consists of red blotches that turn white when pressed and usually begin on the ankles and wrists and spread centrally. Over time, the red blotches form tiny bruises. *Rickettsii rickettsii* has no direct exotoxin to explain its morbidity and mortality. Instead, its tropism for vascular endothelial cells leads to direct vascular injury, which, when combined with host immune response, can lead to interstitial pneumonitis, myocarditis, and encephalitis.

When clinical symptoms are consistent with RMSF, the presence of the disease may be presumed by a medical professional, who may prescribe antibiotics and other treatments, even before a skin rash develops. Diagnosis is complicated because *Rickettsii rickettsii* is an obligate intracellular bacterium that cannot be cultured in most laboratories. Thus, serologic testing or skin biopsy staining is needed for definitive diagnosis.

Host factors influencing the severity of RMSF include (1) age 10 and younger or age 60 and older, (2) male gender, (3) glucose-6-phosphate dehydrogenase deficiency, (4) African-American, and (5) chronic alcohol abuse. Additionally, delay in treatment of five or more days after symptoms first appear is associated with an increased risk of mortality.

The virulence of *Rickettsii rickettsii* remains one of its most puzzling attributes. Historically, RMSF has had greater than 80 percent mortality in Bitteroot Valley, Montana, but only 3 percent mortality in the adjacent Snake River Valley. Bacterial isolates from both areas proved to be essentially identical. Thus, studies continue into the virulence of this bacterium.

The best prevention strategy is to avoid tick bites by wearing close-toed shoes, long-sleeve shirts, and long pants when out of doors. Additionally, wearing light colors can aid in identifying ticks on clothing. Using DEET bug spray on skin and permethrin-based bug repellents on clothing and gear is recommended.

Timothy J. Sutton

See Also: Environmental Toxicology; Infectious Diseases; Insect-Borne Diseases

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SAFE DRINKING WATER ACT

The Safe Drinking Water Act (SDWA) is a federal law enacted by the U.S. Congress in 1974 (with amendments in 1986 and in 1996) in response to serious concerns relating to the quality of the nation's drinking water. The rise of industry and agriculture in the middle of the 20th century led to an increase in chemicals and contaminants in drinking water sources in the United States. Several studies in the late 1960s revealed major problems at water treatment facilities and contaminants in drinking water across the country, and this ultimately prompted passage of the SDWA.

The SDWA directs the U.S. Environmental Protection Agency (EPA) to develop national, minimum health-based standards to ensure a safe drinking water supply for the American public. These standards are called the National Primary Drinking Water Regulations, and they apply to any public water system serving at least 25 people from any source (well or municipal water). Public water systems can be publicly or privately owned, but they must serve over 25 people to be covered by the SDWA. (Private wells that serve fewer than 25 people are not subject to the requirements of the SDWA). Commercial passenger services, such as passenger trains and airlines, are also subject to the SDWA if they meet the threshold of 25 users on average. More than 250 million Americans receive their water from public water systems subject to the SDWA.

The EPA's drinking water standards are aimed at contaminants that cause, or are likely to cause, adverse human health effects. The contaminants of concern may

The Water We Drink

The SDWA is a major contributor to human health, protecting our drinking water from contaminants that are natural or occur from human activities and making it easier for Americans to access information about the quality of their local drinking water. The United States arguably has the safest drinking water supply in the world, and the overwhelming majority of Americans get their water from supplies regulated by the act. Because what we pay for clean drinking water rarely covers the costs of preserving surface water quality and protecting groundwater from contamination, consumers are often misled into thinking that clean, safe drinking water is cheap and plentiful.

be naturally occurring (e.g., bacteria from animal waste) or result from human activities (e.g., industrial chemical waste). Even treatment chemicals used to purify water, including chlorine, can break down over time into other chemicals that pose a health hazard. For each identified contaminant, the EPA sets two limits: (1) a Maximum Contaminant Level Goal (MCLG), which represents the level of the contaminant below which there is no known human health risk; and (2) a Maximum Contaminant Level (MCL), which is as close as one can get to the MCLG, taking into account costs, benefits, detection ability, and best available treatment technologies. The MCLGs are nonenforceable goals that inform the MCLs, which are legally enforceable standards. The EPA has established MCLs for approximately 90 different contaminants.

The MCLs are established based on conservative estimates of risk of prolonged water consumption over a lifetime, such as a person drinking 2 liters (about 2 quarts) of water every day from the same source for 70 years. For example, the MCLG for arsenic is zero, whereas the MCL for arsenic is 0.010 milligrams per liter, or 10 parts per billion. Every six years the EPA must review each primary drinking water standard and determine if revisions are necessary to incorporate any new science, data, information, or advancements in analysis or treatment technologies.

Public water suppliers subject to the SDWA must routinely sample and analyze their water at specific locations and times to ensure compliance with the primary drinking water regulations. If a violation of any of these standards is confirmed, the supplier must provide notice (usually in the form of a letter sent by mail) to its customers, the state, and the EPA about the violation and potential health effects, given the contaminant and the extent of noncompliance.

The EPA sets the standards under the SDWA, but the states generally have primary responsibility for developing SDWA programs and enforcing the federal limits. States also must provide quarterly reports of any violations and other information to the EPA. These data from the states are stored in the Safe Drinking Water Information System, a database that helps the EPA monitor the success of the SDWA and serves to inform the public about the quality of its drinking water.

The SDWA originally focused on treatment technologies to remove contaminants, but later amendments broadened the focus to include the protection of drinking water sources, such as underground aquifers, rivers, lakes, and streams. Because the majority of community water systems in the United States obtain drinking water from underground sources, a major component of the SDWA is the Underground Injection Control (UIC) program. Injecting wastewater into deep underground wells for purposes of disposal has long been a practice used by agriculture, industry, and in some cases, cities. The SDWA, however, prohibits all underground injection of fluids unless done pursuant to a permit. The states can submit a UIC program to EPA and apply to become the primary enforcement authority (i.e., achieving "primacy" status) over their UIC program. Currently, 34 states have EPA-approved UIC programs, and the EPA shares enforcement authority or directly implements programs in the remaining states. State-run, EPA-approved UIC programs must meet the minimum federal standards established by the SDWA and the EPA. Whether by the EPA or a state with primacy, no permit for underground injection may be issued unless the state or the EPA determines that the underground injection "will not endanger drinking water sources."

It is well recognized that the number of water-related disease outbreaks has greatly decreased since the early 1900s. However, the EPA and the Centers for Disease Control and Prevention have recognized that many waterborne illnesses go unreported because they generally create symptoms similar to other illnesses or are not widespread and thus are not directly traceable to drinking water. Moreover, gathering data and statistics on waterborne diseases and reporting these data are voluntary efforts that not all states undertake. The largest waterborne disease outbreak in the United States occurred in 1993, when over 400,000 people became ill and 50 people died after drinking water contaminated with a parasite in the water supply of Milwaukee, Wisconsin.

In response to concerns regarding waterborne diseases, the EPA has implemented several programs aimed at reducing microbe and bacteria contamination. The Total Coliform Rule imposes additional monitoring and mitigation requirements (beyond the MCL for total coliform) for pathogens such as *E. coli* that are common to the feces of many animals, including humans. Additionally, the Surface Water Treatment Rule applies to water supply systems that use surface water, and the rule specifically targets reductions in viruses and giardia through treatment or filtration.

Surprisingly, what most people pay for their water rarely covers the costs of the protection, collection, treatment, and distribution of that water. While water rates may cover the expenses of operating a water utility, the additional costs of treatment to preserve surface water quality and to protect groundwater from contamination are not captured in consumer water bills. Some believe that this hidden subsidy shields consumers from an appreciation of the complex task of preserving and delivering healthful drinking water, and it reduces what otherwise would be public pressure on pollutant sources to better protect drinking water supplies.

The primary aim of the SDWA is to protect public health, and by that measure, it has been an important foundation in providing safe drinking water to nearly all Americans. The United States is one of the few countries in the world, if not the only country, where you can turn on a tap virtually anywhere across the entire nation and expect water safe for consumption. The SDWA not only sets minimum safety standards for contaminants in drinking water but also provides funding for research and programs to protect drinking water at its source. Together with the Clean Water Act, the SDWA is an important component to protecting the health and safety of the nation.

Leah A. Dundon and Richard S. Davis

See Also: Clean Water Act; Cyanobacteria Toxins; Drinking Water Quality and Regulation; Environmental Protection Agency; *Escherichia coli* (*E. coli*) Infection; Fluoridation of Water; Groundwater Pollution and Depletion; Industrial Effluents; Water Pollution; Waterborne Diseases

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SAFETY DATA SHEET

Safety Data Sheets (SDSs) are documents that contain information on specific hazardous chemicals or chemical mixtures. The primary purpose of these documents is to help protect human health and the environment by ensuring the proper use, storage, handling, and cleanup of hazardous chemicals. SDSs, formerly called Material Safety Data Sheets (MSDSs), have been required in the United States since 1985 for every hazardous chemical manufactured, imported, or used in the country. MSDSs were renamed SDSs in 2013 to better align the information available in the data sheets with international requirements and to facilitate international trade in chemicals.

The U.S. Occupational Safety and Health Administration (OSHA) defines hazardous chemicals or chemical mixtures as those that pose a physical or health hazard. A chemical presenting a physical hazard may be combustible, explosive, flammable, or unstable, whereas a chemical can be classified as a health hazard if there is evidence that it can cause adverse health effects, such as cancer, reproductive problems, skin or mucous membrane irritation, or other toxic effects involving the human body.

The information provided in SDSs include (1) the chemical composition of the product; (2) its physical and chemical properties (e.g., melting point, boiling point, pH, and solubility); (3) stability and reactivity; (4) toxicity and health effects; (5) proper uses and handling procedures (e.g., transport, storage, disposal, cleanup, and the use of protective equipment); (6) ecological information (e.g., ecotoxicity, persistence, bioaccumulation potential, and mobility); and (7) emergency phone numbers, first-aid protocols, and fire-fighting measures in the event of an accident.

Manufacturers or distributors of hazardous chemicals or chemical mixtures are required to prepare SDSs for their chemicals, and worksites are required to ensure that SDSs on hazardous chemicals used, manufactured, or warehoused at the worksite are readily available to workers. OSHA is responsible for ensuring worksites comply with the requirement to post SDS records at locations available to all workers.

Research to evaluate the information and data presented in SDSs has found inaccuracies or gaps in some SDSs. Manufacturers of hazardous chemicals can be subject to citations or even "failure to warn" lawsuits if any information or data in these documents are inaccurate or missing. Another potential problem with some SDSs is the difficulty some workers with limited formal education have in understanding the information and data. Efforts to improve the way information and data are presented in SDSs are ongoing.

Adrienne L. Katner

See Also: National Institute for Occupational Safety and Health; Occupational Safety and Health Administration; Persistent, Bioaccumulating, and Toxic Chemicals

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SCHISTOSOMIASIS

Schistosomiasis, also known as bilharzia or snail fever, is a waterborne parasitic infection. Caused by blood flukes (trematode worms), known as schistosomes, it is one of the most common parasitic diseases worldwide. The number of deaths due to schistosomiasis are difficult to pinpoint, but estimates range up to well over 200,000 per year.

Schistosomiasis is not found in the United States. However, it is endemic in more than 70 countries, affecting well over 200 million people. Schistosomiasis occurs in parts of Asia, the Middle East, South America, and the Caribbean, with the majority of cases occurring in Africa. It is considered a neglected tropical disease, which are diseases found primarily in tropical and subtropical locations, particularly areas with high rates of poverty and inadequate sanitation or access to clean water. These types of diseases cost billions of dollars in economic loses and untold human suffering. Migration and the movement of refugees from endemic areas, population growth patterns that tax environments and infrastructures, and the growth of tourism, including ecotourism, all contribute to the spread of infection.

Transmission occurs when an infected person's urine or feces contaminate fresh water with schistosoma eggs. The eggs hatch, becoming larvae that infect a particular kind of snail. The larvae multiply in the snails and are then released back into the water as parasites, which can penetrate the skin of people in contact with the water, for example, while bathing, doing laundry, fishing, fetching water, swimming, or caring for livestock. Inside the body, the parasites mature within the blood vessels, where they mate and produce thousands of eggs that can be excreted in the urine and feces, potentially perpetuating transmission.

There are two major forms of schistosomiasis. Urinary schistosomiasis mainly affects the urinary system and can lead to bladder cancer if the infection is long-term. It is also considered an HIV risk factor, particularly for women. Intestinal schistosomiasis can cause intestinal damage, hypertension of the abdominal blood vessels, and abdominal bleeding. The intestinal form of the disease also affects the liver, spleen, and lungs. Seizures, spinal cord inflammation, or paralysis can result in the rare cases when eggs migrate to the spinal cord or brain.

In children, a group especially at risk for contracting the disease, schistosomiasis can result in poor growth, malnutrition, cognitive impairment, and anemia. Early stage infections are often asymptomatic, with fever, chills, coughs, or muscle aches beginning within a month or two. The body's immune system reaction to the parasites causes scarring and other internal damage.

The anthelminthic drug, praziquantel, has been used for several decades to treat schistosomiasis. For maximum benefit and cost-efficiency, schistosomiasis treatment can simultaneously tackle several conditions, including river blindness and various kinds of intestinal worms. Development of a schistosomiasis vaccine is also underway. Health education campaigns emphasize the importance of not urinating or defecating in water and encourage people to take praziquantel when available. Environmental approaches to controlling schistosomiasis focus on establishing clean water and sanitation systems and vector control of snails.

Kathy Stolley

See Also: Drinking Water Quality and Regulation; Infectious Diseases; River Blindness; Sewage Treatment and Disposal; Waterborne Diseases

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SEA ICE, GLOBAL WARMING IMPLICATIONS FOR

Sea ice is found almost exclusively in the remote polar oceans, specifically, in the Arctic Ocean and around Antarctica. On average, sea ice makes up roughly 9.7 million square miles (25 million square kilometers) of the earth's surface (an area more than twice the size of Canada). Over the past century, due to the changing global climate, the amount of sea ice has been steadily decreasing at an alarming rate (e.g., 13.3 percent per decade over the past 30 years). By allowing global temperatures to rise, melting sea ice can indirectly affect human health by making heat waves and droughts worse and by increasing urban air pollution and the spread of disease.

Sea ice is ocean water that is frozen. Glaciers, icebergs, ice shelves, and ice sheets are different from sea ice because they are formed on land from precipitation. While the melting of glaciers and ice shelves poses significant issues, such as sea level rise and depleted freshwater sources, sea ice presents a different set of problems. Sea ice melts during the summer months and grows during the winter, and some areas of sea ice remain throughout the year, mainly in the Arctic Ocean. Arctic sea ice tends to be thicker and melt more slowly than Antarctic sea ice. This is because the Arctic Ocean is surrounded by land, which restricts the movement of ice and allows it to thicken during the winter months, whereas the sea ice surrounding Antarctica is exposed to open water, which allows more melting during the summer because the ice can more easily break away from the main ice pack. In contrast to Arctic sea ice, the extent of Antarctic sea ice has actually been increasing, by about 1.1 percent per decade. Scientists attribute this growth, which is relatively small compared with the rapid sea ice decrease in the Arctic Ocean, to a combination of winds and ocean circulation that have made the ice more compact and rigid and less susceptible to melting.

The Albedo of Sea Ice

Albedo is a scientific measure used to indicate how well a surface reflects sunlight. The albedo value of a surface can vary from 0 to 1. A value of 0 means that the surface is black and *absorbs* all incoming solar energy, whereas a value of 1 means that the surface is white and *reflects* all incoming solar energy back into space. Values between 0 and 1 indicate different gradations between black and white. Albedo is important in predicting how much the earth's climate may warm as a result of losing sea ice and other bright surfaces (e.g., glaciers, icebergs, ice shelves, ice sheets, and snow) that help regulate global temperatures by reflecting sunlight. Sea ice (with no snow cover) typically has an albedo of 0.5 to 0.7, indicating that sea ice reflects 50 to 70 percent of the incoming solar energy. The albedo of ocean water, in the absence of any ice, is 0.06, and the albedo of snow can be as high as 0.9.

The particular danger posed by the melting of sea ice involves the albedo effect, which describes the degree to which sunlight is reflected back into space—the more sunlight is reflected, the less the earth heats up, and conversely, with less sunlight reflected, the earth gets warmer. As the extent of sea ice declines, less sunlight is reflected into space, and the earth gets warmer. As the earth gets warmer, even more sea ice melts, even less sunlight is reflected, and the earth gets warmer still. This cycle of repeated warming and melting, described by scientists as a positive feedback loop, tends to accelerate the overall warming of the earth. Additionally, as the extent of sea ice has declined, its thickness has also decreased.

There are a number of ways melting of sea ice can affect human health. For example, many local indigenous communities, such as the Inuit (indigenous people of northern Canada and parts of Greenland and Alaska), depend on sea ice for hunting in the spring. If the sea ice melts too quickly, the hunting season is shortened as transportation becomes more difficult due to unsafe ice. As a result, indigenous communities that were once able to sustainably hunt are now forced to eat store-bought food to survive, and this has led to an increased prevalence of diabetes and obesity. Additionally, unemployment has reached up to 80 percent in some communities, forcing many residents to relocate to other towns.

Warming oceans and melting sea ice have also introduced new species and diseases. For example, there is a concern that the phocine distemper virus present in eastern Arctic seals will soon reach western Arctic seals because sea ice no longer presents the same physical barrier. Also, nonnative predators, like herons, have increased competition for already scarce resources.

On a global level, melting sea ice has the potential to disrupt the thermohaline circulation, which is a cycle of ocean currents that stabilize and regulate the earth's temperature. Warm ocean water travels from the equator around the African and European coasts north to the pole, where it then sinks as it cools. This cold water then travels back down the North American coast toward South America. When sea ice melts, it leaves a layer of fresh water on the surface because the fresh water is less dense than ocean water. This layer has the effect of slowing down the warm water moving north from the equator, thereby disrupting atmospheric temperatures and changing climate.

Anthony G. Papetti

See Also: Climate Change and Human Health; Drought and Desertification, Health Consequences of; Greenhouse Effect and Global Warming; Intergovernmental Panel on Climate Change

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SEPTEMBER 11 WORLD TRADE CENTER ATTACK

Tuesday, September 11, 2001—an unforgettable date in American history when terrorists flew two planes into the former World Trade Center (WTC) in New York City. A third plane flew into the Pentagon, and a fourth plane crashed in a field in Pennsylvania. In all, 2,977 people lost their lives that day. Local New York residents and rescue/recovery workers witnessed horrific events and experienced stress, fear, and uncertainty as many lost relatives, friends, and colleagues.

The collapse of the WTC towers exposed local people to many hazardous substances and complex chemical mixtures, including "WTC dust," which mainly consisted of inhalable particulate matter. The WTC dust and debris contained pulverized cement, gypsum, glass fibers, chrysotile asbestos, polycyclic aromatic hydrocarbons, polychlorinated biphenyls (PCBs), polychlorinated dioxins and furans, and metals. The dust was highly alkaline, which caused respiratory irritation and persistent upper airway disorders.

The earliest residential study conducted after the event found that affected-area residents reported more lower respiratory symptoms (LRS) and upper respiratory symptoms (URS) three months post–9/11 compared with control-area residents, and both LRS and URS in the affected areas were three times more persistent one year after 9/11. A pilot study indicated the possibility of an increase in bronchial hyperresponsiveness in exposed residents. Furthermore, in studies among first responders, LRS and URS were reported by nearly half of participants. Both respiratory and posttraumatic stress disorder (PTSD) symptoms were associated with being in the dust cloud, but smoke exposure may have had a greater impact than resuspended dust on LRS. "WTC cough" was a major complaint for both residents and responders, and chronic bronchitis was identified as a persistent problem five years post–9/11.

Regarding mental health, PTSD and depression in New York City after 9/11 were reported at twice the national baseline rate, and researchers found significantly higher rates of PTSD and depression among rescue workers than other workers. Significantly higher rates of PTSD and depression were also observed among lower Manhattan office workers. (Lower Manhattan is in the immediate area of the WTC attack.)

Birth outcomes have also been examined. Proximity to the WTC site after 9/11 did not indicate an increased risk of preterm birth or low birth weight. However, researchers found a 5.3 ounce (149 gram) reduction of birth weight in babies born to mothers within 2 miles (3.2 kilometers) of the WTC site and an increased risk of intrauterine growth restriction in the affected area. Studies examining umbilical cord blood samples did not show a clear relationship between 9/11 exposures and birth outcomes.

While respiratory hospitalizations immediately increased post–9/11, delayed increases in cardiovascular and cerebrovascular admissions after 9/11 also occurred. An analysis using New York City emergency department data found that 790 people with injuries sought medical care within 48 hours post–9/11. Inhalation and ocular injuries were the most common causes. In addition, prevalence of gastroesophageal reflux symptoms was elevated among firefighters and WTC rescue workers and within the WTC Health Registry (a registry used to track the health effects of the disaster), and these symptoms were more prevalent in those who arrived at the WTC site within 48 hours. By examining the WTF Health Registry, an increase in comorbidity (the presence of two or more health conditions) of depression was found among one-third of those with PTSD post–9/11.

Concern about medium- and long-term effects of the 9/11 disaster continues to this day. While a follow-up study showed a decline in symptoms approximately two to four years post–9/11, there still remained a higher rate of persistent symptoms among affected-area residents. Residents with multiple sources of 9/11 exposures were at the greatest health risk at follow-up, and psychological stress, dust/odors, and moisture were all important contributors. Among 3,271 workers who evacuated the WTC towers, 15 percent still had probable PTSD two to three years after 9/11. More importantly, the prevalence of PTSD in the WTC Health Registry

Aftermath of the World Trade Center terrorist attack on September 11, 2001. Many first responders, office workers, and visitors died, and survivors suffered from respiratory disease, posttraumatic stress disorder, and depression. (U.S. Department of Defense)

remained high (19 percent) five to six years after 9/11, with the highest prevalence noted among rescue and recovery workers. Late-emerging health problems may include cancers with long latency periods and premature death.

In conclusion, the most commonly reported health effects in the aftermath of this horrific event were respiratory and mental health consequences, with substantial short- and medium-term effects. Comparing residential with occupational exposures, adverse health effects were slightly higher in responders than residents.

Shao Lin

See Also: Asbestos; Dioxin Pollution; Heavy Metal Pollution; Occupational Safety and Health; Particulate Matter and Bioaerosols Pollution; Polychlorinated Biphenyls; Polycyclic Aromatic Hydrocarbons; Respiratory Disease and Air Pollution

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SEVESO DIOXIN INCIDENT

On July 10, 1976, a reactor in a chemical plant near Seveso, Italy, exploded, sending a plume of tetrachlorodibenzo-p-dioxin, known more simply as dioxin, into the air. Seveso is a small, middle-class town about 18 miles (29 kilometers) outside of Milan. Years later, studies indicated that more than 270,000 individuals were affected by the incident, either because they lived in nearby areas at the time of the exposure or were born in contaminated zones the decade following the incident.

Industrie Chimiche Media Societa Anonima (ICMESA), which was owned by Givaudin, a Swiss company, operated the Seveso plant. Givaudin manufactured perfumes and other cosmetic ingredients, and this particular plant developed a component of the bacteriostatic agent hexachlorophene, called trichlorophenol (TCP), which is used in soaps and disinfectants. In the early 1970s, 20 infants died after being treated with talcum powder consisting of large amounts of hexachlorophene, and the United States used an herbicide derivative of TCP, called Agent Orange, during the Vietnam War.

Although the plant was shut down during the incident, chemicals continued to react, increasing the temperature in the plant's reactor and causing dioxin to form. Soon after, the reactor exploded, sending contaminants into the air in a foggy cloud. Immediately after the incident, a worker fed water into the reactor's cooling system to prevent more gases from seeping into the air, and reports indicate the leak was contained in about 30 minutes. During that time, the cloud moved over the town of Seveso, spanning an area 4 miles (6.4 kilometers) long and one-third mile (one-half kilometer) wide. Residents reported the cloud's foul smell and white, foggy consistency, and people exposed to the cloud began coughing, experiencing burning eyes, and generally feeling ill.

The director of production for ICMESA, Paolo Paoletti, told residents they had been exposed to an aerosol mixture, noting that some toxic chemicals could have been included in the mix. The company advised residents of nearby towns to stay away from foods grown outdoors, but the police were unable to enforce the advisory due to insufficient information. On the night of the second day of the cloud, Seveso experienced a strong wind that dispersed the fog.

A local health inspector received information from the company that chlorinated phenol was the main ingredient in the cloud mixture and that no additional substances could be identified. A week later, workers at the plant went on strike, having suspicions that crucial information about the cloud had been hidden from the public. Later examinations found that there were high dioxin levels present in the soil, and 10 days after the incident, Paoletti was arrested and charged with causing the disaster.

During the second week following the incident, exclusion zones were created. Zone A residents were evacuated immediately. Zone B residents were allowed to continue living in their homes, but children and pregnant woman were evacuated each day to reduce their exposure. Later, Zone A was expanded and an additional Zone R was created, where residents would be monitored but not evacuated. Some reports suggest the dioxin distribution levels were so irregular throughout the area that the zone boundaries were arbitrarily drawn only to alleviate public concern. In the immediate aftermath, at least 30 people were hospitalized due to the incident, and over 200 cases of chloracne, a skin condition of pustules and sores, were reported.

In following years, studies indicated that exposure resulted in more cases of heart disease, chronic obstructive pulmonary disease, and diabetes, all conditions that stress from the disaster may have contributed to. Cases of gastrointestinal, lymphatic, and hematopoietic tissue cancer also increased, although they have not been directly linked to the dioxin exposure. Later studies found that exposed women were five times more likely to suffer from gallbladder cancer and multiple myeloma, a cancer of bone marrow, and exposed men were twice as likely to develop these cancers. Dioxin exposure is known to have a wide range of adverse effects on human health, including affecting the endocrine, immune, and central nervous systems and the development of fetal tissue.

The ICMESA plant was closed one month after the incident, and cleanup of the hazardous materials took about six years. In 1982, the most toxic chemicals remaining at the plant were put into 41 lead drums and transferred off-site for disposal. Later that year, the drums, which were being improperly stored in an abandoned warehouse outside of Paris, were sent to an incinerator in Switzerland for proper disposal.

The Seveso incident resulted in passage of the Seveso Directive by the European Union (then called the European Common Market), which led to more transparency and accountability in the chemical industry. The chemical companies involved in the incident financed the resettlement of families in Zone A, and they settled out of court around 7,000 individual lawsuits. In total, the estimated cleanup cost for the disaster was $162 million.

Mallory L. Daily

See Also: Air Pollution; Dioxin Pollution; Hazardous Air Pollutants; Hazardous Waste Disposal; Particulate Matter and Bioaerosols Pollution; Respiratory Disease and Air Pollution; Waste Incineration

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SEWAGE TREATMENT AND DISPOSAL

Since the beginning of human settlements, water has been essential for drinking, sanitation, and irrigation. As population centers have grown, so too has the need for more and more water for these same purposes. Adequate water resources, and the ability to remove and clean the water of impurities for repeated use, are essential to a healthy and vibrant society. Wastewater treatment is particularly important so that we can use rivers, streams, and lakes for fishing, swimming, and drinking water—these same waters often serve the dual purposes of supply *and* disposal.

It is common for communities to have a system of sewers and wastewater treatment plants to collect wastewater from homes, businesses, and industries and convey it to publicly owned treatment works (POTWs) for treatment before it is discharged to receiving water bodies or land, or in some cases, before it is reused. Prior to POTWs, the organic matter in collected waste was largely assimilated in the receiving stream, and consequently, waterways serving large population centers experienced frequent occurrences of low dissolved oxygen, fish kills, algal blooms, and bacterial contamination. Over time, the natural environment was having trouble keeping up with the increased amounts of discharges, and something had to be done. Thus, the POTW came into use.

Wastewater and sanitary engineers have harnessed, emulated, and expedited natural treatment processes in what is commonly termed “secondary treatment.” This involves the physical separation of solids heavy enough to settle out and a biological process that converts dissolved and suspended organic matter into biomass and carbon dioxide. Following secondary treatment, the converted biosolids are settled and retained/recirculated in the treatment plant (or extricated from the system), and the less potent treated wastewater is discharged. The biochemistry and operation of such processes, whether aerobic or anaerobic, is well understood and readily implemented. This type of system is the basis of the majority of POTWs across the United States. Note that POTWs must meet permitted levels of pollutants in the discharge prior to releasing it to the receiving body of water.

The strength of domestic sewage is often measured in terms of its oxygen-demanding characteristic, or more specifically, the biochemical oxygen demand. Organic waste is decomposed by bacteria, which use oxygen in the process of respiration to extract energy, grow, generate new biomass, and break down the organic matter. During the respiration process, carbon dioxide and water are generated (along with energy and biomass). As the organic matter passes through the treatment plant, care must be taken to ensure that the bacteria have an adequate supply of dissolved oxygen, a means for remaining in the treatment process (so they do not get discharged with the treated wastewater), and adequate nutrients (especially nitrogen, phosphorous, and trace elements) to sustain the bacterial process. As the biomass is grown to the optimal concentration, it must be settled out in a clarifier and some returned back into the process to repeat the cycle. Biomass that is not returned to the activated sludge basin to sustain the biodegradation becomes waste sludge, which is typically dewatered and pressed to remove excess moisture. The remaining sludge cake can normally be disposed of in a landfill or sometimes applied to land as a fertilizer.

An important feature and characteristic of the activated sludge system described previously is the growth, age, retention, and return of the biomass (i.e., the activated sludge). A gravity clarifier or quiescent zone is often used to allow the biomass to settle out, from where it is wasted or recirculated with the clarified supernatant discharged into the receiving stream. This process, however, can require a large area when dealing with large volumes or other design constraints. An alternate technique to retaining the activated biomass population is to provide a medium upon which it can grow, thus eliminating the need for a clarifier. Such attached growth systems can be implemented using packed vessels, rotating biocontactors, floating media, or other engineered substrates for an attachment surface. Yet another alternative is the membrane bioreactor, in which a semipermeable membrane is used for biomass retention.

A less sophisticated method of sewage treatment that may be suitable in some circumstances (e.g., highway rest stops and rural communities) is land treatment/application of the wastewater. This method involves the controlled application of wastewater directly to the land, where physical, chemical, and biological processes treat the wastewater as it passes across or through the soil. Land treatment systems may be designed as slow-rate, overland flow, or rapid-infiltration systems. It may be desirable to provide some treatment prior to land application. For example, in arid western states, pretreated municipal wastewater is regularly used to irrigate crops. Land treatment options are gaining popularity in the United States.

Another land treatment option that is becoming popular is the concept of a constructed wetland. Wetlands are areas where the water saturates the ground long enough each year to develop hydric soils and wetland vegetation. Thus, a constructed wetlands treatment system is where wastewater is treated by passing it through an intentionally designed wetland. Similar to the emulation of natural aerobic biodegradation in activated sludge systems, constructed wetland treatment uses enhanced natural physical, chemical, and biological wetland processes to treat domestic wastewater.

There is a growing concern about pharmaceuticals (i.e., prescription and non-prescription medications) and health and beauty care (HBC) products in wastewater. Modern-day medicines, shampoos, perfumes, and other exotic healthcare and beautification products are routinely being flushed into sewer systems and have recently been detected in wide-ranging samples of the nation's waters. For example, in a recent study of effluents from 50 large POTWs, trace amounts of hydrochlorothiazide and valsartan were found in every sample, and metoprolol, atenolol, and carbamazepine were found in over 90 percent of the samples. Other studies have found in surface waters endocrine disruptors, antibiotics (e.g., erythromycin), hormones (e.g., 17ß-estradiol and 17ß-ethinylestradiol), steroids (e.g., coprostanol), and over-the-counter medications such as ibuprofen and acetaminophen. And regarding HBC products, various studies have found parabens, synthetic fragrances, triclosan, triclocarban, and ultraviolet-filtering compounds in wastewater discharges. Conventional treatment plants often do not degrade or remove these constituents to a large degree. Just as industrial effluents with new and exotic constituents presented new challenges to industrial wastewater engineers in the 20th century, pharmaceuticals and HBC products promise to present the next big challenge for the 21st century.

John K. Borén

See Also: Bioremediation for Waste Treatment; Industrial Effluents; Land Disposal of Waste Materials; Municipal Solid Waste Management; Water Pollution

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SICK BUILDING SYNDROME

Sick building syndrome (SBS) describes the discomfort building occupants sometimes experience while inside the building. SBS is most common in office buildings, but it can also occur in apartments, schools, and other buildings with multiple occupants. To be considered SBS, health professionals typically look for symptoms among a group of occupants rather than one or two isolated cases.

Common SBS symptoms include headache, cough, dry and itchy skin, dizziness, nausea, loss of concentration, fatigue, odor sensitivity, and irritation of the eye, nose, or throat. The cause of these symptoms is often unknown, but because the symptoms typically subside, if not completely disappear, after occupants leave the building, the cause of the discomfort is assumed to be something inside. The symptoms may be limited to a specific room or area of the building, or they may be reported throughout the building, and they may or may not occur seasonally. (SBS is different from the condition known as building-related illness, which

Is Your Carpeting Toxic?

A surprising number of chemicals are used in carpeting. For example, there are chemicals in glues, dyes, backing materials, and flame retardants, and these chemicals are often volatile (i.e., they vaporize into the surrounding air). Some of these chemicals are capable of causing adverse reactions in sensitive individuals, including irritation, breathing difficulty, and even neurological symptoms. Additionally, some chemicals are believed to be carcinogenic. Fortunately, a number of carpets on the market today are specifically designed to minimize the release of toxic gases into the surrounding air. Environmentally conscious consumers may also be interested in carpets made of natural fibers and recycled materials.

covers diagnosable illnesses like Legionnaires' disease that can be directly attributed to specific agents in the building.)

Inadequate building ventilation is thought to contribute to many cases of SBS because without enough ventilation, air contaminants can increase to levels that adversely affect health. Air contaminants may originate inside the building, for example, from carpeting, wall paint, particle board, pesticides, office machines, air fresheners, dust mites, and even marking pens, or the air contaminants may be associated with outside air pollution and pollen drawn into the building by the ventilation system. Occupant health can also be affected by mold and other microbial contaminants, particularly when the contaminants build up in air-handling equipment and in water-damaged wallboard, ceiling tile, carpeting, and insulation. Odors, stagnant air, thermal gradients, high humidity, poor lighting, office noise, and inadequate sanitary and cleaning practices may also contribute to occupant discomfort.

Some examples of indoor air contaminants and their sources include the following:

- Acetic Acid: X-ray equipment, caulking compounds
- Formaldehyde: insulation, plywood, particle board, paneling, carpeting, fabric adhesives, tobacco smoke
- Inorganic Gases: window cleaners, acid drain cleaners, tobacco smoke, blueprint equipment, gas furnaces and appliances, engine exhausts. (Inorganic gas examples include ammonia, hydrogen sulfide, and sulfur dioxide.)
- Microbials: air-handling systems, cooling towers, humidifiers, water-damaged materials, plants, food and food products. (Microbials are microorganisms and other biological contaminants, including viruses, fungi, mold, bacteria, pollen, dander, and mites.)
- Nitrogen Oxides: gas furnaces and appliances, welding, engine exhausts, tobacco smoke
- Ozone: copy machines, electrostatic air cleaners, outside air
- Volatile Organic Compounds—paint, cleaning products and disinfectants, mothballs, glues, photocopiers, caulking materials, pesticides, cosmetics, and other personal products. (Volatile organic compound examples include trichloroethylene, benzene, toluene, methyl ethyl ketone, alcohols, and acrolein.)

Investigations of SBS complaints can be difficult because the symptoms are often subjective and nonspecific, and sometimes the symptoms are mistaken for other health conditions like asthma or the flu. In some cases, SBS may affect only a few individuals who are unusually sensitive to the offensive agents, and in other cases the entire workforce may be affected, causing the facility to be evacuated.

What can be done to remediate SBS? It is often difficult to identify the exact cause of the symptoms experienced by building occupants. Nevertheless, poor ventilation is suspected about half the time. Ventilation can be improved by adjusting or replacing mechanical systems, adding air treatment (e.g., carbon filters), locating air intakes away from potential air pollution sources (e.g., garages and roadways), regularly performing preventive maintenance (e.g., cleaning ducts and dampers and changing air filters), and ensuring temperature and humidity standards are consistently maintained. (Humidity should generally be below 60 percent to discourage microbial growth.) Standing water should be removed, for example, from humidifier reservoirs and drain pans, and any water-damaged materials should be replaced, including wallboard, ceiling tile, carpeting, and insulation. Carpeting and other materials that give off offensive gases can be replaced with more environmentally friendly materials, and nonporous surfaces can be cleaned with a disinfectant. Of course, cigarette smoking should always be banned indoors. You should consult with an indoor air quality professional to determine the steps most appropriate for your situation.

Occasionally a building occupant may exhibit hypersensitivity to something in the indoor environment that does not cause symptoms in other people. The occupant should be evaluated by a health professional, and if the problem persists despite all possible steps to remove what may be causing the symptoms, the occupant should be relocated to another part of the building where the symptoms do not occur.

While researchers believe SBS is mainly an air quality issue, research suggests that synergistic effects involving occupational stress may result in symptoms that otherwise may not be present. Thus, stress management programs might be considered along with other measures to address the problem. A number of conditions might lead to occupational stress, including tight deadlines, a noisy work environment, poor work area lighting and temperature control, eye strain and ergonomic problems from computer work, work/life balance issues, and communication problems with coworkers or supervisors.

Workers reporting SBS symptoms were once dismissed as complainers, but today these complaints are taken seriously as researchers find that even modern buildings can have indoor air quality problems. While significant advances in the manufacture of low-vapor carpets, wall paints, and other building materials have helped reduced the number of indoor air quality complaints, issues with microbial contaminants may be increasing. This could be related to the proliferation of energy-efficient buildings, where ventilation rates may not be ideal for discouraging the growth of molds, fungi, bacteria, and other biological contaminants.

Richard Crume

See Also: Air Pollution; Cancer Risk from Environmental Exposure; Environmental Toxicology; Formaldehyde; Hazardous Air Pollutants; Indoor Environment; Legionnaires' Disease; Mold and Dampness; Noise Pollution; Occupational Safety and Health; Odor Pollution; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Personal Care Products, Health Issues with; Pesticides and Herbicides; Quiet, Benefits of; Volatile Organic Compound Pollution

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SILICA

Silica is a chemical compound made of silicon and oxygen atoms, chemically known as silicon dioxide. It can exist in either a crystalline or noncrystalline (also called amorphous) state. The crystalline state is the primary cause of environmental concerns because it has long been recognized as an occupational inhalation hazard in several industries, where it has caused many disabilities and deaths. In contrast to the adverse health effects of inhalable silica, silica in the diet has been linked by some research to health benefits for bones, joints, collagen, and teeth.

Crystalline silica can occur in any of several forms, including quartz (the most common natural form), cristobalite, tridymite, and tripoli. These forms differ from each other in the arrangements of the tetrahedron structures that make up the crystals. The basic silica tetrahedron consists of one silicon atom surrounded by four oxygen atoms. Pure crystalline silica is also called free silica. When other elements are combined with silica, such as sodium, potassium, calcium, or magnesium, the compound is called a silicate. Among the many types of silicates are vermiculite, kaolin, talc, micas, and feldspar. Noncrystalline silica is found naturally in diatomaceous earth and other sediments and rocks as well as in synthetic materials such as silica gel.

According to the National Institute for Occupational Safety and Health (NIOSH), more than 2 million U.S. workers in the mining and construction industries are exposed to inhalable silica every year, and hundreds of these workers die annually from exposure to silica dust. Mining and quarrying activities involving sand, gravel, metal ore, and coal are the main sources of silica exposure. Increasingly, hydraulic fracturing is another major source. Construction activities that generate inhalable silica include both indoor and outdoor work, such as sandblasting and drilling, concrete mixing and pouring, and drywall installation.

Other industries where workers may be exposed to large amounts of inhalable silica are brick and clay, glass and ceramic, and metal manufacturing. The crushing and processing of raw materials, preparation of sand casts, and cleaning of residue are some of the manufacturing steps that generate silica dust. Silica is also used in the electronics, pharmaceutical, and food industries, although workers in those industries are generally exposed to little inhalable silica.

Outside of occupational exposures, the general public is at some risk of exposure to inhalable silica in the particulate matter of air pollution. This ambient air pollution is produced by various sources, including power plant emissions from the combustion of coal, airborne particles generated by vehicular traffic on paved and unpaved roads, tilling of soil in agriculture, and natural sources such as forest fires and wind erosion of soil. Children, the elderly, and individuals with weakened immune systems are most vulnerable to silica exposure.

The primary health hazards associated with silica are respiratory in nature. The tiny silica particles are inhaled into the respiratory tract and lungs, where they get carried into the deepest and smallest tissues—the alveoli—where oxygen is exchanged with the blood. Typical symptoms initially include respiratory irritation and dry coughing. However, during continued exposure over time, the silica particles can accumulate in the respiratory tract and lungs, causing severe inflammation that can lead to or aggravate other respiratory conditions, including bronchitis, emphysema, and chronic obstructive pulmonary disease.

The most common serious health problem caused by inhaling silica dust is silicosis, an acute or chronic inflammation of the lungs that is a type of pulmonary fibrosis. This condition, which is potentially fatal, may include bloody sputum production, shortness of breath, lung scarring, and reduced lung function. It may also lead to heart enlargement and damage as the heart pumps harder to compensate for the weakened pulmonary system.

In some cases, the silica particles are transported to the kidneys, lymph nodes, or other tissues of the body, resulting in renal failure or other serious problems outside the respiratory system. Still other possible diseases associated with silica inhalation include autoimmune disorders, such as rheumatoid arthritis and systemic lupus erythematosus, and lung cancer. The risk of severe disorders increases with the intensity and duration of exposure.

Numerous regulations and guidelines have been established by the U.S. government, as well as the governments of other nations, to minimize human exposure to inhalable silica. However, not all companies in the mining, construction, and other industries regularly perform surveillance of employee silica exposure to generate data sufficient for guideline compliance evaluation. Government researchers and regulators from NIOSH and the Occupational Safety and Health Administration (OSHA) sometimes detect unsafe worker exposure levels, in which case OSHA may issue a hazard alert to warn workers of the risk and to warn the company of the need to rectify the problem.

In 2016, OSHA enacted stricter rules for occupational exposure to silica, estimating that the rules will save more than 600 lives and prevent more than 900 cases of silicosis each year. Industries were given one to five years to comply with the new standards. While there are no federal standards for ambient air exposure to silica outside the workplace, several states have enacted such standards.

A. J. Smuskiewicz

See Also: Cancer Risk from Environmental Exposure; Fugitive Dust; Hydraulic Fracturing; Industrial Hygiene; National Institute for Occupational Safety and Health; Occupational Safety and Health; Occupational Safety and Health Administration; Particulate Matter and Bioaerosols Pollution; Respiratory Disease and Air Pollution

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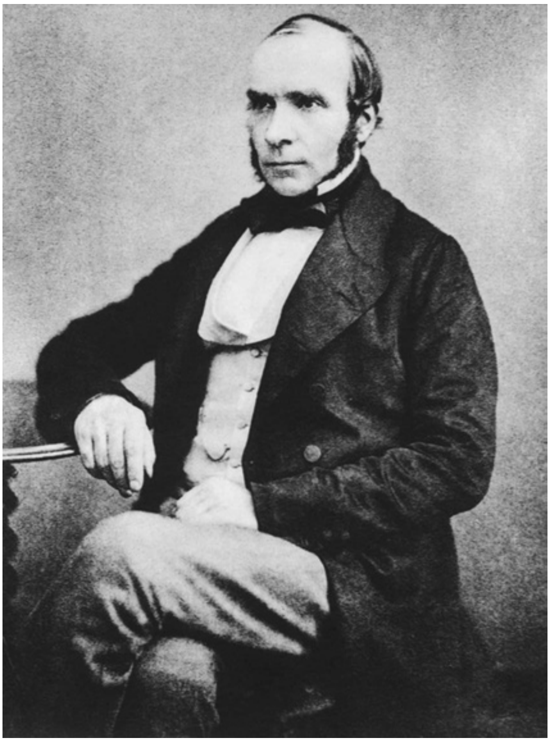
SNOW, JOHN

John Snow (1813–1858) was an English physician who did pioneering work spanning public health, anesthesia, intensive care medicine, and medical cartography. He is also hailed as a father of modern epidemiology for his scientific and systematic approach to mapping cholera transmission through contaminated water.

Born in York, England, on March 15, 1813, Snow was the oldest of nine children. As a young man, he became a vegetarian for some years, and he was also a teetotaler who advocated for the temperance movement. Snow's medical training began as an apprenticeship when he was 14. By age 23, when he went to London for formal medical education, Snow had apprenticed with three practitioners. He qualified as a surgeon-apothecary (a general practitioner) in 1838, and after additional study culminating at the University of London, he qualified as a physician in 1844. In 1850, Snow passed the exam to become a member of the elite Licentiate of the Royal College of Physicians of London. He practiced medicine in London's Soho neighborhood, developed a reputation as an excellent diagnostician, and was an active member of several professional organizations, including the Westminster Medical Society.

Snow became London's foremost anesthesiologist, making anesthesia safer by developing an inhaler to control the concentration of gases a surgical patient received. He also invented a device for resuscitating newborns. Snow regularly treated both poor and wealthy, famously administering chloroform to Queen Victoria for the births of both Prince Leopold and Princess Beatrice.

When cholera struck London, Snow conducted investigations that refuted the widely held miasmatic theory of cholera, which is the idea that the disease is spread by bad quality air, polluted by noxious odors from rotting organic matter. Snow disagreed with airborne theories, holding that the cause of cholera was a contagion passed by ingesting water contaminated by a cholera victim's bodily eliminations. The miasmatists (i.e., people who believed in miasmatic theory) advocated for sanitation reform projects that flushed sewage and trash away from homes and into waterways serving municipal water supplies. However, if Snow was correct, this approach actually spread disease such as cholera, which could be stopped with proper hygiene and sanitary water supplies.



John Snow, considered the father of modern epidemiology. Snow is recognized for his scientific and systematic approach to mapping cholera transmission through contaminated water. (National Library of Medicine)

Two consecutive cholera outbreaks afforded him the opportunity to conduct his "grand experiment," which involved comparing cholera deaths in households supplied by two different water companies. During the earlier epidemic, both companies had originally drawn water from the same polluted area of the Thames River. However, between outbreaks, one water company had changed its supply to a cleaner part of the river. Those customers showed a lower risk for cholera in the next epidemic. Snow combed available data on cholera and conducted his own investigations, including plotting a map of cholera deaths that led him to the public Broad Street water pump as the source of the outbreak. The pump handle was removed, and cholera cases quickly diminished.

Snow died of a stroke and kidney failure on June 16, 1858. It is speculated that Snow's propensity to experiment on himself with anesthetic agents having unknown health effects at the time may have contributed to his early demise. Within a decade of his death, there was another cholera outbreak in London. Drawing from Snow's work, the connection between contaminated water and disease outbreak was more firmly established for those who had remained skeptical. With improved knowledge and better engineering of water systems, large-scale cholera outbreaks in Britain were finally put to an end.

Kathy Stolley

See Also: Cholera; Drinking Water Quality and Regulation; Environmental Epidemiology; Sewage Treatment and Disposal; Waterborne Diseases

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SOCIOECONOMIC STATUS AND HEALTH

Socioeconomic status plays a major role in creating health disparities. Socioeconomic status refers to an individual's level of education and income as well as the occupation that person holds. Each of these three factors can impact various health outcomes. Generally, high socioeconomic status is associated with good health outcomes, and low socioeconomic status is associated with poor health outcomes. Health problems often associated with low socioeconomic status include heart disease, high blood pressure, diabetes, cancer, and low birth weight.

Although education, income, and occupation may be powerful determinants of an individual's overall health, they often do not create health outcomes directly. Instead, these factors underlie an individual's exposure to conditions and situations that have a more direct and immediate impact on health. A person's socioeconomic status is closely associated with their access to and quality of health care, their environmental exposure to harmful substances, and their health behaviors. These three factors combined account for approximately 80 percent of premature mortality, with 50 percent attributed to lifestyle and behavior, 20 percent attributed to environmental exposure, and 10 percent associated with health care.

Tobacco use is the single largest behavioral risk factor for premature death, and those with lower socioeconomic status are more likely to smoke. Those with less education and less income are also more likely to lead a sedentary lifestyle and eat a diet that is low in fresh produce and fiber. The same population may be less informed about how to lead a healthy lifestyle and may live in neighborhoods without recreational facilities (and where it may be unsafe to walk or play outdoors), with fewer stores selling healthy foods, and with more tobacco and alcohol advertising.

Socioeconomic status also impacts exposure to harmful environmental pollutants such as asbestos, mercury, lead, and industrial wastes. Those with lower socioeconomic status are more likely to live and work in unhealthy, contaminated environments. Poorer neighborhoods are more likely to be found in close proximity to highways, industrial business zones, and toxic waste sites because the land in these areas is less desirable and, thus, cheaper. Housing in these neighborhoods is also more likely to be of poorer quality. In the case of lead exposure, high levels of lead in the blood are six times more common in children and adults from poorer families when compared with children and adults from high-income families. (By comparison, middle-class children and adults showed a twofold increase in high blood lead levels.) Rates of childhood asthma are on the rise, and this is especially true in poor, urban neighborhoods. The severity of asthma symptoms also tends to be greater among children of low socioeconomic status.

The impact of an individual's social environment may be even more important than the physical surroundings. Those with low socioeconomic status are more likely to be isolated and not a part of a social network. Those who are socially isolated have increased rates of mortality—between 1.9 and 5 times greater than those who are more socially connected and engaged. The quality and patterns of social interaction can also impact health. For example, sexually transmitted diseases spread more rapidly within high-risk networks (e.g., those who are more likely to engage in unprotected sex with multiple partners), and these high-risk networks are often found in poorer areas.

Lastly, socioeconomic status also has a significant impact on healthcare access and quality. For instance, approximately 40 percent of individuals who did not graduate from high school do not have health insurance, compared to only 10 percent of college graduates. Among uninsured Americans, 60 percent come from low-income families. Uninsured individuals receive less medical care, including preventative screenings and treatment for diseases and conditions. It is important to note, however, that there are programs, such as Medicare, designed to provide health insurance coverage to low-income individuals and families. As such, when it comes to healthcare access and quality, the link between socioeconomic status and poor health outcomes is not as strong as it is for health behaviors and environmental exposure.

Jyotsna S. Jagai

See Also: Asthma; Environmental Justice; Vulnerable Populations, Environmental Threats to

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SOIL CONTAMINATION AND REMEDIATION

Soil is a natural body on the earth's surface composed of mineral and organic materials, water, and air. In the ecosystem, soil serves as a medium for plant growth, a regulator of water supplies, a recycler of raw materials, a habitat for organisms, and an engineering medium. Soils are said to be contaminated when they cannot perform one or more of these functions.

Soil contamination, a widespread problem in many parts of the world, is the result of the undesirable entry of chemicals into vulnerable ecosystems. These chemicals can be naturally occurring or manufactured by humans (i.e., xenobiotic). Regardless of origin, their undesirable entry into the environment is due to their production, use, and improper disposals during human activities, including agriculture, mining, manufacturing, medical practice, and military defense operations.

The most common contaminants in soil are petroleum hydrocarbons, polynuclear aromatic hydrocarbons (e.g., naphthalene and benzo(a)pyrene), solvents, pesticides, and lead and other heavy metals. Soil contamination can adversely affect human and ecosystem health. For example, human exposure to lead in soil can result in neurological impairment, and exposure to other chemicals is linked to cancers and congenital disorders. Infiltration of soil contaminants into groundwater aquifers can threaten the health of communities that depend on the aquifers for their water supplies. Because soil contaminants can pass into vegetation and enter food chains, the consumption of food crops grown in contaminated soil has become a major health risk in certain regions of the world.

Plants and soil microbes are equally impacted by soil contamination. For example, high levels of certain soil contaminants can be toxic to plant growth, and some contaminants can impair the abilities of soil microbes to conduct life-sustaining biological cycles.

The U.S. Environmental Protection Agency (EPA) is the major federal agency regulating soil contamination. Once EPA finds those responsible for contamination, it requires the contaminants to be cleaned up or the responsible party to pay the cost of cleanup. Cleaning contaminated soil, called soil remediation, involves removing contaminants and restoring the soil to its natural, pollution-free state. Scientists have studied a variety of treatment methods to remediate soil contamination. Depending on the type of contamination, the concentrations of the contaminants in the soil, and the available time frame and funding, different remediation methods have been used, including soil removal or washing, soil vapor extraction, thermal desorption, bioremediation or phytoremediation, and natural attenuation.

Soil removal and washing are simple methods for soil remediation. Soil removal can be used for contamination that covers a small area or is otherwise unresponsive to other in situ remediation technologies. Using buckets, drums, or roll-offs, the removed soil can be moved to landfills that accept contaminated soil or to treatment facilities that can clean contaminated soil, making it usable again. Soil washing, a process that uses surfactants and water to remove contaminants from the soil, involves either dissolving or suspending pollutants in the wash solution and separating the soil by particle size. Soil washing can be applied to soil contaminated with a wide variety of heavy metal, radionuclide, and organic contaminants. (The contaminated water must later be decontaminated.)

Vapor extraction is used to treat volatile and semivolatile organic contaminants in soil. This method uses a series of vacuum extraction wells placed throughout the contaminated zone, and a vacuum pump pulls air through the contaminated area. This method works well in permeable soil with a high sand content.

Thermal desorption is an efficient, environmentally beneficial process that uses heat to increase the volatility of contaminants so that they can be removed from the soil. This method typically consists of two main processes: (1) contaminated soil is heated to the boiling point of the contaminants and (2) the volatized contaminants are then captured and destroyed in a thermal oxidizer or condensed in a vapor recovery unit.

Bioremediation involves the use of living microorganisms, such as bacteria and fungi, to break down organic pollutants in the soil. This method is based on the common practice in microbiology of using microbes to break down organic compounds and other toxic materials in household and industrial wastes. Bioremediation has proved to be a very effective and inexpensive method to treat soils contaminated with toxic chemicals. This method can be used either in situ or ex situ (i.e., off-site). In situ bioremediation techniques are normally applied to soil that is lightly contaminated, difficult to remove, or has contaminants that are volatile. Ex situ bioremediation involves moving the contaminated soil to another location, where it can be processed using bioremediation.

If plants are used to remove contamination from the soil, the process is called phytoremediation. This is an emerging and proven strategy that may involve several processes broadly classified as (1) plant uptake and storage of metal contaminants that can then be harvested and recovered with a technique known as phytomining; (2) plant uptake and metabolizing of organic contaminants; and (3) interactions between soil microbes and plant root exudates that promote contaminant degradation, transformation, or stabilization, or a combination of these.

Many plant species have been used in phytoremediation, including shrubs, trees, flowers, and highly specialized species that can take up and tolerate toxic concentrations of elements (i.e., hyperaccumulators). Sometimes special planting techniques are applied to promote the various means by which contaminants can be removed or destroyed by plants or plant-microbe complexes.

Phytoremediation can be applied to both small and large areas, and compared with other soil decontamination methods, phytoremediation costs are much less and can be implemented with relatively little environmental disturbance. In addition, compared with landfilling, phytoremediation is considered a permanent solution to the cleanup and removal of many soil contaminants, including the most prevalent petroleum hydrocarbons resulting from leaking petroleum storage tanks.

Natural attenuation is a remedial method where contaminants naturally degrade without intervention. This method works well for organic contamination, such as fuels and solvents, which are readily degradable. To facilitate the breakdown of contaminants, microorganisms that feed on the contaminants may be added, or aerobic conditions can be created in the soil to increase microorganism activity. This is the most cost-effective soil remediation method, but it may not be satisfactory for high concentrations of certain contaminants, and routine monitoring is necessary to ensure that proper remediation is proceeding. Natural attenuation may be used in combination with other remedial methods, such as soil vapor extraction and excavation.

Dafeng Hui and E. Kudjo Dzantor

See Also: Bioremediation for Waste Treatment; Drinking Water Quality and Regulation; Ecosystems, Importance of; Environmental Protection Agency; Groundwater Pollution and Depletion; Hexavalent Chromium; Land Disposal of Waste Materials; Lead Poisoning Prevention; Oil Spills, Health Consequences of; Pesticides and Herbicides; Radioactive Wastes; Underground Storage Tanks, Health Concerns with

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STORMWATER RUNOFF

Stormwater runoff results when precipitation flows over the ground instead of infiltrating into the ground. Runoff may occur during a rain event or during snowmelt and can occur in a variety of environments, including urban, residential, agricultural, industrial, commercial, and construction areas. Stormwater can flow off paved streets, lawns, and rooftops, posing a threat to human health by contaminating water used for drinking and recreation.

Stormwater runoff contributes to what is known as nonpoint source pollution, which is different from point source pollution. Point source pollution, which is a single identifiable source of pollution discharge like a smokestack of a factory, is easy to treat because there is a single source of pollution. On the other hand,

Green Cities Are Seeing Green

Many cities have taken the initiative to reduce stormwater runoff from urban landscapes. For example, Philadelphia launched Green City, Clean Waters, which recreates living landscapes to keep water out of city sewers, promotes rain barrel use, and encourages architects and builders to include green roofs and landscaping in their designs. By employing a green approach to reduce stormwater pollution rather than relying on the traditional infrastructure, the Green City is saving an estimated $5.6 billion.

nonpoint source pollution, like stormwater runoff, is much more difficult to identify and treat because the pollution comes from multiple sources and directions. Consider the case of a farmer who spreads a chemical fertilizer on a plot of land just before a big rainstorm. If the rain is heavy enough, water will begin to drain in various directions, carrying the fertilizer with it. It will be difficult to predict where this chemical-laden runoff water will go, and consequently, cleanup will be complicated, if not impossible. Stormwater runoff can carry many different pollutants that can potentially affect human and environmental health.

The types of pollution carried with stormwater runoff depend on the environment in which the runoff is occurring. Urban environments typically have a large amount of stormwater runoff because there tends to be many impervious surfaces in a city and relatively little green space. (Impervious surfaces like concrete or asphalt prevent water from infiltrating into the ground below.) Cities also have considerable automobile and truck traffic, leading to oil and dust deposition on the streets, which can end up in stormwater runoff, as can litter on streets and sidewalks. If the stormwater runoff enters a combined sewer system, where sanitary water and stormwater are combined, there is the potential for a combined sewer overflow (CSO) event. CSOs result in untreated wastewater being released into water bodies that may provide drinking water or be used for recreation. Cities throughout the United States are working to minimize the number of CSO events, and reducing the amount of stormwater runoff from urban landscapes is an important factor in this mission.

Pollution in stormwater runoff is an issue not only with urban streets and sidewalks but also with residential lawns and parks, farms, commercial and industrial facilities, and construction sites. Residential lawns and parks can contribute to stormwater pollution when they are treated with fertilizers and pesticides. Farms and other agricultural operations are a particular problem when heavy amounts of fertilizer are applied and when pet and animal wastes are not appropriately managed. Commercial and industrial facilities may engage in practices that lead to grease and oil spills that will be picked up in stormwater runoff. Construction sites, which often disturb a large area of land, can lead to sediments running off into waterways.

There are various effects of pollutants occurring in stormwater runoff. According to the U.S. Environmental Protection Agency, sediment (sand, clay, or silt) is the most common pollutant in rivers, streams, lakes, and reservoirs. Sediment can cause water to become turbid (cloudy), clog fish gills, and prevent aquatic vegetation from growing. Sediment-rich runoff can also carry nutrients that trigger blue-green algae growth, which then releases cyanotoxins that are harmful to humans. Bacteria and pathogens, which may be present in runoff from land grazed by livestock, can make people extremely ill and have been linked to deaths in vulnerable populations, such as children, the elderly, and those lacking healthy immune systems. Pollutants found in stormwater runoff from agricultural lands may contain unhealthy levels of pesticides and fertilizers. Plastic bags and bottles, food wrappers, and other types of trash that end up on stormwater runoff can harm wildlife. Oils, paints, and soaps used for commercial and industrial purposes can make people sick and harm the environment.

With so many potential sources of harmful pollution in stormwater runoff, it is important to find ways to reduce the pollutant sources as well as the quantity of stormwater runoff. In urban environments, green infrastructure can help reduce runoff by mimicking the natural environment. Some examples of green infrastructure include green roofs (roofs covered with grasses and shrubs instead of an impervious material), permeable pavement (pavement that water can pass through), rain barrels and cisterns (systems that collect rainwater for use in gardens and landscaping), and vegetated swales (large vegetated areas where water is taken up by the plants). In agricultural areas, a vegetated buffer next to a water body can reduce stormwater runoff, as can the rotation of crops and animal grazing areas. Procedures should be in place at commercial and industrial areas that allow chemical spills to be cleaned up immediately. At construction sites, installing silt fences, using silt bags (e.g., at sewer openings), and applying mulch or hay to disturbed areas can help prevent sediments from be carried away with stormwater.

Elise C. Hunter

See Also: Combined Sewer Overflow; Cyanobacteria Toxins; Drinking Water Quality and Regulation; Environmental Protection Agency; Green Space in Urban Environments; Pesticides and Herbicides; Water Pollution; Watershed Management, Health Implications of; Wetlands and Healthy Waterways

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STRATOSPHERIC OZONE DEPLETION

Ozone is a naturally occurring molecule made up of three oxygen atoms. The molecules combine to form a stratified gaseous layer in the earth's upper atmosphere known as the stratosphere. This gaseous layer is called the ozonosphere. The ozonosphere sits roughly 9 to 22 miles (14 to 35 kilometers) above the earth's surface, with variations in its thickness based on the season and geographic location. (It is important not to confuse stratospheric ozone with ground-level ozone, which is a major component of smog in large cities and can cause respiratory distress and illness.)

The highest concentrations of ozone occur in the tropics at altitudes of 16 to 17 miles (26 to 27 kilometers) and toward the poles from 7 to 12 miles (11 to 19 kilometers). By encapsulating the planet Earth, the ozone layer protects the earth and hence plants, animals, and humans from the harmful effects of the sun's radiation. The ozone layer, which was discovered in 1913 by two French physicists—Charles Fabry (1867–1945) and Henri Buisson (1873–1944)—can absorb 97 to 99 percent of the ultraviolet (UV) radiation emitted by the sun. The UV rays, if left unchecked, can produce harmful effects on the earth and its habitation.

The ozone molecules of the ozonosphere have the ability to block solar radiation of wavelengths below 290 nanometers from reaching the ground surface. The ozone layer does so by absorbing UV rays, which are damaging to all living things on the earth. If the amount of UV radiation that strikes the earth's surface became truly excessive, the ground organic matter could be destroyed by the radiation, including plants and plankton/phytoplankton (small and microscopic organisms, such as protozoans, diatoms, eggs, and larvae). Phytoplankton acts as food and energy sources for other animals and humans. Phytoplankton productivity is limited to the upper layer of the water column, where there is sufficient sunlight, thus exposing them to increased UV radiation exposure. UV radiation has been noted to cause damage in the early developments of fish, shrimp, crab, amphibians, and other marine animals, resulting in the decreased capacity for natural reproductive processes and an impaired development of larvae.

Recent findings established that excessive exposure to UV radiation increases the chances of developing skin cancer and cataracts (thickening of the lens) in humans. For example, studies show that for every 1 percent decrease in the ozone protective layer, there is a 2 to 5 percent chance of people developing skin cancer. Other problems associated with ozone depletion include sunburns and depression of the immune system.

There are two regions in the world where ozone layer depletion has been apparent. Over Australia, where there is a 5 to 9 percent reduction in the thickness of the ozone layer, there has been an increase in human susceptibility to the effects of UV radiation during outdoor activities. Additionally, studies show there is a significant reduction of the ozone layer in the atmospheric regions over Antarctica, leading to the formation of "ozone holes" through which UV rays can strike the earth's surface. Ozone holes are often noticeable annually in Antarctica during the spring season (between September and November).

Some human-made gases, such as the chlorofluorocarbons (CFCs) used in spray can propellants, refrigerants, and cleaning agents, can survive for one to two years when released into the atmosphere. When CFCs reach the stratosphere, the UV radiation converts them to halogen atoms, which react with the ozone layer. The ongoing destruction of the ozone layer by the reactive products of CFCs results in ozone depletion and reduction in its ability to protect the earth's surface against UV rays. In 1987, the international community created the Montreal Protocol on Substances that Deplete the Ozone Layer. In this agreement and the subsequent Kigali amendment, 197 nations agreed to phase out the production and consumption of ozone-depleting substances, including CFCs and two other classes of ozone-depleting chemicals, hydrochlorofluorocarbons and hydrofluorocarbons. Recent studies indicate that this phaseout strategy is working—there has been a significant reduction in the holes in the ozone layer.

Ifeanyi Abuachi

See Also: Air Pollution; Chlorofluorocarbons; Environmental Protection Agency; Ultraviolet Radiation and the UV Index

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STYRENE

Styrene, consisting of a 2-carbon ethane molecule attached to a benzene ring, is used to make many consumer items, such as plastic packaging, consumer cups and plates, boats, shower stalls, automobile parts, corrosion resistant tanks, and synthetic rubber. Styrene is found outdoors primarily from vehicle exhausts and industrial emissions and indoors primarily from cigarette smoke and outgassing from consumer products, and it occurs naturally in foods such as strawberries, coffee, legumes, and spices. While its association with adverse health effects is controversial, some researchers believe styrene is a possible human carcinogen.

Styrene is consistently among the top 25 manufactured chemicals in the United States. Industrial manufacturing of styrene began just before World War II and has increased steadily since then. More than 12 billion pounds (5.4 billion kilograms) of styrene were manufactured in 2010, with over 10 million pounds (4.5 million kilograms) released to the atmosphere as fugitive emissions (i.e., escaping from various points in the manufacturing process without being captured). Just over 4,000 pounds (1,814 kilograms) of styrene were released into surface waters in 2008.

Reaction with light and microbial activity are the primary means of removing styrene from the environment. The half-life of styrene in air is between 2 and 17 hours. It is slightly soluble in water and volatizes quickly, with a half-life of about 6 hours in shallow water. However, the half-life can be more than 13 days in deeper water, and styrene can take up to 100 times longer to degrade in groundwater. Up to 16 weeks are required for 95 percent of styrene to degrade in soil, although it can persist for up to two years in some soils.

Humans readily absorb styrene through ingestion, inhalation, and to a lesser degree, skin absorption. The highest exposures occur in workplaces where styrene is manufactured or processed, in proximity to fugitive styrene sources, and through exposure to cigarette smoke. In general, occupational exposures are significantly higher than environmental exposures, and styrene exposure from smoking is almost 10 times higher than background exposures.

In the human body, styrene is metabolized to styrene-7,8-oxide, which is genotoxic (i.e., having the ability to damage genetic information within a cell). Most styrene is eliminated from the human body within hours, although some may remain in fatty tissues for a few days. According to the Centers for Disease Control and Prevention's latest National Health and Nutrition Examination Survey, 88 percent of Americans evaluated between 1988 and 1994 had styrene in their blood at concentrations up to 4 ug/L.

There are hundreds of peer-reviewed publications on the health effects of styrene, but they often reach different conclusions. The Styrene Information and Research Center, established in 1987 by styrene manufacturers, has raised more than 20 million dollars to study the effects of styrene on human health and the environment, and it has concluded that styrene is not carcinogenic. Furthermore, the American Conference of Governmental Industrial Hygienists finds that styrene is not classifiable as a human carcinogen. On the other hand, the National Toxicology Program at the National Institute of Environmental Health Sciences reports that styrene is reasonably anticipated to be a human carcinogen and, depending on dose, is associated with increased risk for leukemia, lymphoma, and all lymphohematopoietic cancers (i.e., cancers related to the production of lymphocytes and cells of the blood, bone marrow, lymph nodes, spleen, and thymus). Furthermore, the World Health Organization has classified styrene as a possible human carcinogen. Other research on the noncarcinogenic effects of styrene has found decreased balance, slowed reaction time, tiredness, and the sensation of feeling drunk at high-enough concentrations. Styrene can also be irritating to the nose and mouth.

Mary V. O'Reilly

See Also: Centers for Disease Control and Prevention; Indoor Environment; Integrated Risk Information System; National Institute of Environmental Health Sciences; National Toxicology Program; Occupational Safety and Health; Tobacco Smoke, Secondhand and Thirdhand; World Health Organization

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SUPERFUND ACT

In 1980, the U.S. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act, which came to be known as Superfund. The goal of Superfund was to address the health and environmental hazards presented by a large number of abandoned or uncontrolled waste sites containing hazardous materials. Under Superfund, a national program was established for emergency response, information collection and analysis, responsible party liability, and site cleanup. Additionally, a trust fund was created (i.e., a “Superfund”) to finance emergency response and cleanup operations.

Passage of the Superfund Act was preceded by several environmental disasters that caught the public’s attention and eventually demanded action by Congress. These disasters included (1) a large fire at a chemical waste treatment facility in New Jersey that resulted in six deaths; (2) a state of emergency at the Love Canal dump site in New York due to a dramatic increase in skin rashes, miscarriages,

Trucks loaded with debris contaminated with polychlorinated biphenyls at the Aerovox Mill Superfund site in New Bedford, Massachusetts. The Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) established a national program to address the large number of abandoned or uncontrolled waste sites across the United States containing hazardous materials. (Environmental Protection Agency)

and birth defects among local residents; and (3) another big fire in New Jersey, this time at a waste storage facility, causing schools to close and residents over a wide area to remain indoors.

There can be a wide variety of contaminants at Superfund sites, with varying degrees of toxicity. Four of the more common contaminants are lead, asbestos, dioxin, and radioactive waste materials. Some Superfund contaminants may present an immediate hazard, while other hazards may be more long-term, for example, in the case of carcinogens, which typically have long latency periods before cancer develops.

The health benefits from the Superfund program include a reduction of hazardous substances in communities, where sensitive groups like children, pregnant women, and older adults may be particularly vulnerable to exposure. Additionally, Superfund site cleanup helps protect habitats, farmland, and forests from environmental contamination. By restoring hazardous waste sites in urban areas, Superfund encourages economic growth in areas that might otherwise be subject to dumping of trash, vandalism, and trespassing. In this regard, many Superfund cleanup sites have become valuable local assets.

Over the years since passage of Superfund, several important developments related to hazardous waste site cleanup have occurred. These include:

1982: Establishing the Hazard Ranking System for evaluating the environmental hazards of a site
1983: Creating the National Priorities List to prioritize sites for cleanup using Superfund financing
1986: Passing the Superfund Amendments and Reauthorization Act (SARA) to, among other provisions, strengthen enforcement, increase state involvement, focus more on health issues, and encourage citizen participation
1986: Establishing under SARA the first emergency planning and community right-to-know law
1993: Beginning the Brownfields Initiative to redevelop abandoned or underused industrial and commercial sites where environmental contamination is a concern

The U.S. Environmental Protection Agency (EPA), the lead agency for implementing Superfund, typically responds to Superfund sites in one of two ways:

- Removal Actions: for emergency spills or releases requiring quick response
- Remedial Actions: for sites requiring long-term solutions and not presenting immediate threats to public health

Remedial actions often require substantial investigation and planning before cleanup can begin. Several of the most important steps involve conducting a preliminary assessment and site investigation, preparing a remedial investigation and feasibility study, issuing a record of decision, and developing a remedial design/remedial action plan.

Richard Crume

See Also: Asbestos; Brownfields; Dioxin Pollution; Emergency Planning and Community Right-to-Know Act; Environmental Protection Agency; Hazard Ranking System; Hazardous Waste Disposal; Lead Poisoning Prevention; Love Canal Incident

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SUSTAINABLE DEVELOPMENT AND HEALTH

In 1987, the United Nations defined "sustainable development" in the *Brundtland Report* as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This is understood to include improving and promoting both environmental and human health as well as economic development.

Health is a critical component of sustainable development, being both affected by and contributing to it. For example, poor health contributes to days lost from work and decreased productivity for adults as well as days missed in school for children, factors resulting in decreased economic development. Conversely, development can impact health when, for example, infrastructure such as roads improve, allowing more people to access health care. The connection between health and sustainable development can also be made clear by considering the costs to environmental protection and sustainability that are often associated with economic development. For example, expanding coal-fired energy production has resulted in air pollution in cities around the world, and extractive industries like mining have caused widespread water pollution. This pollution can expose populations to disease-causing environmental toxicants, such as heavy metals, polychlorinated biphenyls, and pesticides.

Some economic development activities themselves, like clearing forests for building roads, can also have negative environmental and human health impacts. For example, forest clearing introduces local populations to the forest edges, where they may be exposed to insects that are vectors of diseases like malaria, resulting in increased vector-borne disease transmission occurring locally or regionally. Also, the building of roads increases forest fragmentation, which negatively impacts biodiversity. We currently face land-use and land-cover changes, such as the development of monoculture agriculture (e.g., soy or palm oil plantations in tropical forest areas), that are degrading the environment and changing the climate globally. It is imperative that increased attention is paid to carrying out development activities in a more sustainable way than in the past so as to ensure the health of present and future generations.

Addressing global poverty is also key to addressing health. This was first considered at the 1972 Stockholm Convention (i.e., the UN Conference on Human Environment), which led to the founding of the UN Environment Programme. The 1992 Earth Summit in Rio de Janeiro marked the 20th anniversary of the Stockholm Convention, and it is where the Rio Declaration on the Environment and Development and a sustainable development plan called Agenda 21 were signed by 178 countries. These documents outline the ways populations can take control of development in their countries and their responsibilities to protect the environment in doing so. The Rio Declaration states in its 27 guiding principles that the only way to have lasting global economic development is to ensure that such development adheres to the principles of environmental protection.

In September 2000, world leaders adopted the UN Millennium Declaration, which describes a new global partnership to reduce extreme poverty and sets out a series of time-bound targets (with a deadline of 2015) that have become known as the Millennium Development Goals (MDGs). Three of the goals are specifically related to health: Reduce Child Mortality (Goal 4), Improve Maternal Health (Goal 5), and Combat HIV/AIDS, Malaria, and Other Diseases (Goal 6). Other MDGs also address health, such as Ensure Environmental Sustainability (Goal 7), which recognizes that poverty, environmental degradation, and poor health are inherently interlinked. The MDGs galvanized support for and awareness of development issues in low- and middle-income countries, and as such, great progress was made toward reducing poverty and disease globally. However, progress has varied across regions and especially within countries, where some of the most vulnerable populations (the most remote and the poorest) did not experience gains as significant as some less vulnerable populations. For example, Target 7.C of Goal 7 was to halve by 2015 (compared to a 1990 baseline) the proportion of people without sustainable access to safe drinking water. While globally there was a 62 percent reduction in the population without access to improved drinking water resources, thereby meeting this goal, the African and the Eastern Mediterranean regions only saw 38 and 39 percent reductions in this metric, respectively.

Building off of the MDGs, the United Nations introduced Sustainable Development Goals (SDGs) in 2015 to further the goals of the MDGs while addressing some of their limitations. The SDGs follow on the heels of the MDGs, with 17 goals and 169 targets within those goals to be achieved by 2030. These goals integrate the three dimensions of sustainable development (i.e., economic, social, and environmental) around the themes of people, planet, prosperity, peace, and partnership. Goal 3 is specifically directed at ensuring healthy lives and promoting well-being for all ages. The Goal 3 targets include the following:

- Reducing maternal mortality
- Ending preventable deaths for children under age five
- Ending global epidemics (including aids and malaria)
- Reducing noncommunicable diseases and substance abuse through prevention and treatment
- Promoting mental health and well-being

- Reducing deaths and injuries from road accidents
- Increasing family planning and sexual and reproductive healthcare services
- Achieving universal health coverage and medicine and vaccine access for all
- Reducing illness and deaths from environmental pollution
- Increasing tobacco control
- Supporting research and development for medicines and vaccines for diseases that primarily affect developing countries
- Increasing the sustainability of the health workforce in developing countries
- Strengthening all countries' capacities for implementing early warning systems for global health risks

Notably, there are many other health-related SDGs, such as those focused on labor and sustainability. This reflects a recognition that multisectoral policies that have co-benefits for human health, the environment, and economic development are central to promoting public health through sustainable development.

Beth J. Feingold

See Also: Communicable Diseases; Deforestation; Drinking Water Quality and Regulation; Electric Power Generation, Health Implications of; Green Space in Urban Environments; Pesticides and Herbicides; Polychlorinated Biphenyls; Renewable Energy, Health Implications of; United Nations Environmental Programme

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TERRY, LUTHER L.

Luther L. Terry, MD (1911–1985)—a physician and the ninth surgeon general of the United States (serving from 1961 to 1965)—is known for his groundbreaking work in warning the public about the dangers of tobacco use. Dr. Terry was charged by President Kennedy to head a committee of prominent scientists in preparing a 1964 report on tobacco use. The report found that smoking cigarettes contributed substantially to the country's death rate and that "appropriate remedial action" should be taken. Primarily as a result of this report, the percentage of Americans smoking dropped from 43 percent in 1964 to 23 percent in 2001. Dr. Terry was a former cigarette smoker himself, but he switched to a pipe before the report was issued.

During his tenure as surgeon general, Dr. Terry worked tirelessly to eliminate television tobacco advertising, to ensure that health warnings were placed on cigarette packaging and advertising, and to stop the sale of cigarettes to minors. His efforts led to the Federal Cigarette Labeling and Advertising Act of 1965, which required a warning label on each cigarette package.

Dr. Terry's passion for medicine began in Red Level, Alabama, where he helped his father, the town doctor, by working in his clinic and driving him around the countryside for emergency appointments. Dr. Terry earned his medical degree at Tulane University in 1935. After an internship at Hillman Hospital in Birmingham, Alabama, a residency at Cleveland (Ohio) Hospitals, and an internship at Washington University in St. Louis, Missouri, Dr. Terry became an associate professor of preventive medicine and public health at the University of Texas in Galveston in 1940. This is when his consciousness was raised about the disastrous impact of smoking.

The Leading Cause of Death and Disease

What is the leading preventable cause of death and disease in the United States? According to the U.S. Surgeon General's office, it is tobacco smoking. Tobacco smoke contains over 7,000 chemicals that can (1) damage DNA, blood vessels, and lungs; (2) cause blood vessel clotting, heart attacks and strokes, asthma attacks, emphysema, and chronic bronchitis; and (3) result in lung and other cancer. (One of every three cancer deaths in the United States is linked to smoking.) Additionally, the nicotine in tobacco smoke is addictive, which makes it hard to quit. There is no safe exposure to tobacco smoke, and even an occasional cigarette or exposure to secondhand smoke can be harmful. The surgeon general warns there is no safe cigarette.

Is It Safe to Be around Others Who Smoke?

When you breathe tobacco smoke from cigarettes, cigars, or pipes that other people are smoking and from the air they exhale (breathe out), you are breathing secondhand smoke. Similar to smoking, people exposed to secondhand smoke are at higher risk for heart disease, stroke, and lung cancer, and children are at particular risk for ear infections, asthma attacks, respiratory symptoms (e.g., shortness of breath), respiratory infections, and sudden infant death syndrome. Since 1964, about 2.5 million nonsmokers have died from health problems associated with secondhand smoke. There is no safe level of exposure to secondhand smoke, and even exposure of brief duration can be harmful.

Dr. Terry was called to active duty in the Public Health Service in 1942 and became the chief of medical service in 1943 at the U.S. Marine Hospital in Baltimore, Maryland. He was concurrently a teacher and researcher at Johns Hopkins University. In 1950, he became a researcher and later assistant director at the National Heart Institute, where his research focused on the causes and prevention of hypertension.

Luther Terry, MD, U.S. surgeon general from 1961 to 1965. Terry is best known for his groundbreaking work warning the public about the dangers of tobacco use. (National Library of Medicine)

After his tenure as surgeon general, Dr. Terry spent the rest of his career focusing on the dangers and prevention of diseases related to cigarette smoking. From 1967 to 1968, he was the chairman of the National Interagency Council on Smoking and Health. He later became vice president for medical affairs and a professor at the University of Pennsylvania, where he remained until retiring in 1982.

Later in his life, Dr. Terry spoke extensively on smoking in the workplace, emphasizing the dangers of secondhand smoke. He urged companies to take steps to ensure nonsmoking employees are not exposed to cigarette smoke. As a result, many American businesses banned smoking or allowed it only in designated areas.

Throughout his career, Dr. Terry was recognized with many honors, including 17 honorary degrees. The American Cancer Society established the Luther L. Terry Awards in conjunction with the World Conference on Tobacco or Health to recognize outstanding worldwide achievements in the field of tobacco control. In 1985, Dr. Terry was honored with a burial in Arlington National Cemetery.

Susan J. Montgomery

See Also: Asthma; Cancer Risk from Environmental Exposure; Indoor Environment; Public Health Service; Respiratory Disease and Air Pollution; Tobacco Smoke, Secondhand and Thirdhand

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TETANUS INFECTION

Tetanus (also called "lockjaw") is an infection caused by *Clostridium tetani*, a bacterium commonly found in soil, dust, and manure. Tetanus usually enters the body through cuts or puncture wounds caused by objects that carry the bacteria, and it has also been associated with burns, crush injuries, injuries with dead tissue, superficial wounds, surgical procedures, insect bites, dental infections, compound fractures, chronic sores and infections, and intravenous drug use. It does not spread from person to person, and tetanus infections are uncommon in the United States, with most cases occurring among unvaccinated people or adults who are not up to date on their 10-year booster shots.

A common symptom of tetanus is a tightening of the jaw muscles, making opening the mouth difficult (thus, the name "lockjaw"). Other symptoms include headache, sudden and involuntary muscle tightening (often in the stomach), painful muscle stiffness, difficulty swallowing, seizures, fever and sweating, high blood pressure, and fast heart rate. Complications may involve laryngospasm (contraction of the vocal cords), bone fracture, hospital-acquired infection, pulmonary embolism (blockage of the main artery of the lung or one of its branches), pneumonia, and breathing difficulty.

Tetanus has an incubation period that usually ranges from 3 to 21 days, with most infections occurring within 14 days. In some cases, depending on the type of wound, the incubation period may last several months. Because there are no laboratory tests to confirm the presence of tetanus, doctors must diagnose the disease based on symptoms. Tetanus is considered a medical emergency requiring hospitalization and immediate treatment.

The best way to prevent tetanus is to be fully immunized. The Centers for Disease Control and Prevention recommends tetanus vaccination for people of all ages and booster shots throughout life. People who have been infected do not develop immunity and can become infected again if not protected by vaccination. Often immediate care of wounds can help prevent an infection.

One early success of the tetanus vaccine was during World War II, when U.S. soldiers were at risk of infection because of wounds that could not be cleaned well on the battlefield. As a result of the military's vaccination program, only 12 soldiers were infected during the war, and half of them had not been vaccinated. In contrast, soldiers from other countries without vaccination programs were much more likely to develop tetanus. The vaccination of children began in the 1940s, and today only 40 to 60 cases of tetanus occur each year in the United States.

Richard Crume

See Also: Centers for Disease Control and Prevention; Communicable Diseases; Infectious Diseases

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THERMAL POLLUTION

Thermal pollution, like noise and light pollution, does not consist of toxic chemicals or foreign substances, as we traditionally associate with the term "pollution." In a broader sense, pollution can be seen as anything nonnative that is introduced into the environment that has an undesirable effect. Thermal pollution, the waste heat introduced into a body of water, often from an industrial process, fits this definition. Thermal pollution can adversely affect the ecology, including causing injury or death to fish, aquatic plants, and other organisms. Thermal pollution indirectly affects human health by reducing the supply of healthy fish and diminishing water quality for recreation.

The most common form of thermal pollution is where an industrial operation disposes of process water into a nearby body of water, such as a stream, river, or lake. An example is water used as coolant for heavy machinery. Coal-fired and nuclear electric power plants produce large quantities of wastewater and heated water (thermal pollution) from the power cycle and water treatment and pollution control systems. The Mississippi River is an example of a heavily trafficked waterway that receives intense thermal pollution from power plants. Less frequent causes of thermal pollution include runoff in urban areas, where water can be heated by pavement, and deforestation along shorelines, where the loss of shade can result in heating of water along the shore.

Thermal pollution is a problem for fish, aquatic plants, and other organisms because they can be sensitive to temperature changes and only survive within a restricted temperature range. If the temperature changes slowly, such as that which naturally occurs between seasons, fish and other aquatic organisms can adapt, but if the change is rapid, they may suffer thermal shock and die. Other consequences of thermal pollution include reduced reproduction rates, unhealthy offspring, and sometimes a dramatic shift in aquatic populations.

A dangerous consequence of thermal pollution is a reduction in the dissolved oxygen content of a body of water, causing fish and other organisms to suffocate. Another problem occurs when certain types of surface algae, which thrive in warm water, rapidly multiply and block the sunlight that other organisms depend on, resulting in decaying organic matter that can further reduce dissolved oxygen. And some types of algae, when too abundant, can release dangerous toxins into the water. Additionally, warmer water harbors more bacteria and pathogens that can be lethal to fish.

Thermal pollution can be mitigated by cooling the water before it enters a stream, river, or lake. For example, this could be accomplished with cooling towers, cooling ponds, and artificial lakes. These and other approaches are designed to address thermal pollution without disrupting the natural habitat.

Aaron Dorman

See Also: Deforestation; Electric Power Generation, Health Implications of; Light Pollution; Noise Pollution; Stormwater Runoff

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THREE MILE ISLAND INCIDENT

Three Mile Island, an island in the Susquehanna River of Pennsylvania, is home to the Three Mile Island nuclear power plant. On March 28, 1979, a cooling system malfunction in one of the plant's reactors led to 700,000 gallons (2.6 million liters) of radioactive water leaking into the facility. A smaller portion of this radioactive material was released into the atmosphere.

Public alarm was widespread in the days following the incident. The media reported the possibility of radioactive uranium melting from the base of the reactor into the earth's crust, a phenomenon referred to as the China syndrome, based on a fictional movie released earlier that month about a similar disaster. The media also reported that a hydrogen gas bubble was building inside the reactor that might cause it to explode, releasing radioactive waste into the atmosphere. Pregnant women and children within a five-mile radius were evacuated from their homes, and in surrounding communities, 140,000 people fled. About two weeks after the accident, once fears of further meltdowns were assuaged, people were encouraged to return to their homes.

President Jimmy Carter (1924–) created a 12-person commission to investigate the accident and its potential health effects. The report released by the commission noted that there were mechanical failures that led to the accident, but ultimately the operators of the reactor were to blame. However, the report also indicated that the operators were not sufficiently trained on standard operating procedures, and this was a fault of company leadership. Because of the lack of accountability, the commission recommended that the nuclear power industry create a way to maintain and regulate safety standards for its workers. In the year following the accident, the Institute of Nuclear Power Operations (INPO) was created to ensure proper training for operators working at nuclear power facilities. In 1985, INPO created the National Academy for Nuclear Training to oversee training programs at nuclear power plants.

The president's commission also found that the health effects from the incident were negligible due to speedy and effective containment of the radioactive material. Studies conducted from 1981 to 1991 by the Pennsylvania Department

The Debate over Nuclear Power

Although causing no deaths, the incident at Three Mile Island raised public skepticism in the United States about nuclear energy, and the Chernobyl and Fukushima Daiichi nuclear plant disasters added to the concern. Supporters of nuclear energy say it is the cleanest and most efficient way to transition away from fossil fuels because to generate electricity, no greenhouse gases are emitted. Opponents say the processes involved in creating nuclear energy are too dangerous, especially when plants are situated near communities, and the problem of long-term storage for spent fuel rods, which are highly radioactive, has not been resolved.

President Jimmy Carter visits the Three Mile Island nuclear plant after an accident in 1979. While there was no evidence of adverse health effects from the small release of radioactive material to the atmosphere, the incident caused the nation to reconsider the benefits and dangers of nuclear power. (National Archives)

of Health regarding infant mortality, hypothyroidism, cancer, and pregnancy also found no evidence of adverse health effects from the accident. In 1997, the Department of Health discontinued a study of 30,000 people living within 5 miles (8 kilometers) of Three Mile Island because they found no evidence of adverse health effects. More than a dozen independent studies have also found no evidence for negative health impacts. The average dose of radiation for people living within 10 miles (16 kilometers) of Three Mile Island is believed to be about the same as the radiation received during an X-ray.

Mallory L. Daily

See Also: Chernobyl Incident; Fukushima Daiichi Incident; Nuclear Regulatory Commission; Nuclear Safety; Radiation, Ionizing and Nonionizing; Radiation Sickness

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THREE Rs OF WASTE MANAGEMENT

The three Rs of waste management stand for "reduce," "reuse," and "recycle." All three are key to a sustainable future and to controlling the staggering amounts of garbage that have accumulated in the United States and other developed countries over the past century. Although there is no definitive origin for the "three Rs" as a slogan for environmentalism, its use coincides with the first Earth Day (April 22, 1970) and with the Resource Conservation and Recovery Act, which was enacted by the U.S. Congress that same year.

Reduce

Reducing consumption is necessary, not only to avoid the worst effects of climate change but also to maintain a healthy and sustainable biosphere. Every year, our society overshoots the biosphere's capacity for renewal. For example, in 2016, "earth overshoot day" was August 8, which means it took only 220 days to use up the quantity of resources that the biosphere could recover in one year. This calculation may actually underrepresent the amount of resources humanity is using because it does not account for nonrenewables, such as rare earth metals, which are used in many consumer products.

While waste management activities account for no more than 5 percent of greenhouse gas emissions in the United States, the entire life cycle of resource extraction through production of foods and consumer products accounts for a whopping 42 percent of greenhouse gases. Thus, the environmental benefits of recycling and other "green" waste management initiatives pale in comparison to what could be achieved if there was less consumption in the first place. Reducing consumption also helps address some of the health concerns associated with commercial and industrial operations that arise from air and water pollution. Additionally, there are other environmental benefits, such as reducing depletion of the earth's stratospheric ozone layer.

Reuse

Reusing products and materials reduces wastes and puts less strain on the global environment. One example is simply keeping products as long as possible before buying new ones. This approach is facilitated by companies that manufacture "quality" products lasting a long time. On the other hand, "planned obsolescence" causes products to be replaced sooner than necessary. (Planned obsolescence is a manufacturing and marketing strategy where products quickly become obsolete due to frequent design changes, unavailability of spare parts, and use of nondurable construction materials.) Unfortunately, raw material and labor costs are often such that it is cheaper to manufacture a new product than to fix an old one. This may change in the future as raw materials become scarcer and labor costs rise.

An emerging reuse success story involves reusable shopping bags (made of a durable fabric or plastic), which have become very popular with customers shopping at several large U.S. grocery store chains. This is an important step toward reducing waste in the United States, where over 1 billion disposable plastic grocery bags are discarded every week. Several large cities, such as Chicago and Los Angeles, have banned disposable plastic bags outright, while other cities (e.g., New York and Washington, D.C.) have resorted to regulatory measures, such as a bag fee, to encourage consumers to switch to reusable bags.

Recycle

Recycling helps keep valuable materials in circulation rather than discarded as waste. Most of what we consider recycling is actually "down-cycling," which means that the recycled materials lose their initial value but can still be used for other purposes. For example, many plastics can only be reprocessed into new plastics of lower quality, and the same is often true for certain metals and paper goods. Nevertheless, recycling helps extend the life cycle of raw materials and reduce the quantity of wastes going to landfills and incinerators.

Although recycling requires energy for collection, transportation to recycling centers, and reprocessing, the overall energy requirements are still often less than for extracting new raw materials. For example, the recycling of aluminum cans requires only 5 percent of the energy needed to mine new ore. It is sometimes less expensive to landfill certain renewable materials than to recycle them, although the long-term harm to the environment from the accumulation of garbage needs to be considered. According to the U.S. Environmental Protection Agency, the average person in the United States produces about 4.4 pounds (2.0 kilograms) of waste every day, and only about one-third of municipal waste is recycled.

The greatest gains to be made from recycling may involve packaging. Containers and packaging made from cardboard, paper, and plastic make up almost 30 percent of municipal solid waste, and often these materials are amenable to recycling programs. To reduce operational costs and promote sustainable operations, some manufacturers and online stores have switched to 100 percent recycled packaging for their products.

Aaron Dorman

See Also: Biosphere, Environmental Threats to; Earth Day; Environmental Protection Agency; Greenhouse Effect and Global Warming; Land Disposal of Waste Materials; Municipal Solid Waste Management; Recycling; Resource Conservation and Recovery Act; Stratospheric Ozone Depletion; Sustainable Development and Health

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THRESHOLD DOSE

In the fields of environmental toxicology and risk assessment, there are two common measures of acceptable dose and adverse effect for noncarcinogens. The *no observed adverse effect level* (NOAEL) is the highest dose at which no deleterious effects of a toxic chemical have been observed in toxicological experiments or epidemiologic studies. A related concept is the *lowest observed adverse effect level* (LOAEL), which is the lowest dose at which a toxic effect has been observed in toxicological experiments (possibly including epidemiological studies). The NOAEL and LOAEL have been used in chemical risk assessments as a starting point for deriving an acceptable level of exposure for humans. However, there are limitations to the NOAEL/LOAEL approach to informing safety standards, including the following:

- The NOAEL and LOAEL are fully dependent on the design of toxicological experiments, which may involve granular, discrete doses (e.g., four treatments of 5 parts per million [ppm], 10 ppm, 100 ppm, and 500 ppm). For example, imagine a newly synthesized chemical for which only a single toxicology experiment is available. If a NOAEL is observed at one concentration (e.g., 10 ppm) and a LOAEL is observed at the next highest concentration (e.g., 100 ppm), then there is a wide range of possible concentrations between 10 and 100 ppm where toxicity might occur. Using a NOAEL may lead to an unnecessarily conservative exposure recommendation, whereas a LOAEL may lead to an inadequately protective recommendation.
- A NOAEL/LOAEL summary uses only two data points from the entire toxicological literature on a chemical, although data from other relevant studies, if any, are considered in the process of deriving the final NOAEL and LOAEL. The dose-response information from other doses is ignored.
- The NOAEL and LOAEL are often defined using a toxicological model organism (e.g., a rodent) that is different from humans. Although a risk assessment uncertainty factor (e.g., dividing the NOAEL/LOAEL by a default value of 10 to account for interspecies differences in toxicokinetics and toxicodynamics) may be applied as a buffer, this uncertainty factor can be arbitrary and may be insufficient to protect human health.

The U.S. Environmental Protection Agency, the California Environmental Protection Agency, and other government health agencies have begun moving away from the NOAEL/LOAEL model to alternative approaches, such as the *benchmark dose* method, which estimates a defined biological response at a given dose by fitting a dose-response curve to toxicity data and drawing predictions from the curve. The benchmark dose method explicitly addresses the granularity limitation of the NOAEL and LOAEL and uses more of the information available from toxicological experiments. Nevertheless, it is still limited by interspecies extrapolations if the evidence being used to inform the risk assessment comes from nonhuman models. There also may be limitations to any model if the data it draws upon come from research that is undermined by reporting or study design biases. Another approach of policy interest is *physiologically based pharmacokinetic modeling*, which accounts for metabolic processes to estimate more human-relevant target-organ doses from external environmental exposures.

Matthew O. Gribble

See Also: Dose-Response Assessment; Environmental Epidemiology; Environmental Protection Agency; Environmental Toxicology; Integrated Risk Information System

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TOBACCO SMOKE, SECONDHAND AND THIRDHAND

Breathing someone else's tobacco smoke, referred to as involuntary or passive smoking, can be hazardous. This happens when tobacco smoke permeates an environment (e.g., at home or work) such that it is breathed by individuals other than the actual smoker. For nonsmokers, there is no safe level of exposure to tobacco smoke, which can cause various cancers and heart disease, aggravate asthmatic conditions, decrease pulmonary function, and impair blood circulation.

Secondhand Smoke and Cardiovascular Disease

Secondhand tobacco smoke increases the risk of coronary heart disease by about 30 percent. This noxious mixture of over 7,000 chemical compounds, including about 70 known carcinogens, has been recognized for some time as a cause of lung and other cancers. While the role of secondhand tobacco smoke as a cause of heart disease has been less well understood, the health effects of secondhand smoke are acknowledged to be greater than would be expected based solely on the risks associated with tobacco smoking and the relative amounts of smoke delivered to nonsmokers compared with smokers. Secondhand tobacco smoke is estimated to account for at least 35,000 deaths each year in the United States.

Secondhand tobacco smoke is a combination of smoke that comes from the burning end of a cigarette, cigar, or pipe (referred to as sidestream smoke) and the smoke that is exhaled from the lungs of a smoker (referred to as mainstream smoke). Sidestream smoke has higher concentrations of carcinogens, consists of smaller particulates, and is more toxic than mainstream smoke, which was partially filtered through its passage into the lungs of the smoker. The smaller particle size of sidestream smoke makes it easier for the harmful substances it contains, such as ammonia, arsenic, benzene, butane, cadmium, chromium, cyanide, formaldehyde, lead, nickel, and polonium, to make their way into the lungs and other body tissues of those exposed. The U.S. Environmental Protection Agency, National Toxicology Program, and International Agency for Research on Cancer (a branch of the World Health Organization) have all classified secondhand smoke as a known human carcinogen.

Thirdhand smoke consists of the residue that accumulates on surfaces exposed to tobacco smoke. This residual matter interacts with other common indoor pollutants, such as those routinely included in cleaning products, yielding a hazardous mixture that sticks to bedding, clothing, curtains, furniture, hair, skin, and other surfaces. When people interact with these surfaces, the toxic conglomeration can be inhaled, swallowed, or absorbed through contact with mucosal tissue, including the anus, eyelids, genitals, lips, and nostrils.

Individuals exposed to secondhand or thirdhand smoke are at greater risk for numerous health consequences compared to those who are not. If a pregnant woman is exposed to secondhand or thirdhand smoke, her baby is also exposed to the dangerous substances in these mixtures. Parents who smoked before or during pregnancy are more likely to have a child with hepatoblastoma (a rare liver cancer). Exposure causes lower respiratory tract infections in 150,000 to 300,000 children annually under 18 months of age, resulting in 7,500 to 15,000 hospitalizations every year. Other conditions linked to secondhand and thirdhand smoke exposure in children include asthma, cancers like leukemia, chronic obstructive pulmonary disease, sinus and nasal problems, and sudden infant death syndrome.

Furthermore, it is estimated that this exposure kills about 42,000 people from heart disease and 7,300 from lung cancer each year in the United States, where the added expenses associated with illnesses, medical care, and deaths are estimated at over $10 billion annually.

Considerable efforts have been directed at reducing or eliminating exposure to secondhand and thirdhand tobacco smoke. The U.S. surgeon general first addressed the harmful effects of environmental smoke in 1972, and numerous reports since have issued even stronger warnings. Community advocacy groups, such as the Group Against Smoking Pollution, have been organized to combat smoking in public. In contrast, beginning in the early 1990s, the tobacco industry has attempted to discredit the scientific research indicating that secondhand and thirdhand tobacco smoke exposure was harmful. In 1993, Vermont became the first state to ban smoking in restaurants. Currently, over 4,000 American municipalities have enacted similar laws restricting where individuals can smoke, and over 90 countries have passed laws and ordinances that limit smoking in public and work environments.

Victor B. Stolberg

See Also: Asthma; Cancer Risk from Environmental Exposure; Environmental Protection Agency; Indoor Environment; Particulate Matter and Bioaerosols Pollution; Respiratory Disease and Air Pollution; World Health Organization

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TORREY CANYON INCIDENT

The *Torrey Canyon*, a supertanker filled with crude oil, ran aground along the Cornish Peninsula of Great Britain on March 18, 1967. The resulting spill of nearly 100,000 tons (90,700 metric tons) of crude oil remains one of the largest oil spills in history, causing widespread ecologic damage that occurred as far away as Normandy, France, and presenting a health hazard for both marine life and humans that continues today.

The incident occurred because the captain of the *Torrey Canyon* decided to go through the Scilly Islands instead of around them to save time. The ship struck Pollard Rock in the Seven Stones reef, running aground and bursting 6 of its

18 tanks filled with crude oil, spilling 30,000 tons (27,200 metric tons) of oil into the sea. Eight days later, weather patterns and rough seas caused the release of another 30,000 tons (27,200 metric tons) of oil.

The government waited to take action on cleanup for 10 days while experts considered whether to syphon off the remaining oil. However, this was judged too dangerous because of explosion hazards. Attempts were then made to refloat the ship, which failed and resulted in the ship further breaking apart, spilling the remaining crude oil. The government then decided to address the issue by setting fire to the spilled oil. Subsequently, the Royal Air Force reportedly dropped 62,000 pounds (28,100 kilograms) of bombs, 5,200 gallons (19,700 liters) of petroleum, 11 high-powered rockets, and an undisclosed amount of napalm on the wreck and surrounding waters. This approach failed because rough seas quickly put out the fire.

The government was pressured to take immediate action by the Cornish coastal communities, whose beaches were a large source of tourist revenue. In response, the government arranged for the beaches and oil spill to be sprayed with 2 million gallons (7.6 million liters) of highly toxic oil dispersants. The dispersants turned out to be the worst possible choice, as not only did they contain toxic aromatic hydrocarbons, but the dispersants also converted the oil to a water-soluble form that

The oil tanker *Torrey Canyon* breaks apart after running aground on a reef off Land's End, England, in 1967. The subsequent oil spill contaminated vast areas of coastline and caused widespread ecological damage. (AP Photo)

was readily taken up by marine life. This toxic combination was responsible for the deaths of 15,000 seabirds, thousands of sea lions, innumerable fish, and other aquatic plant and animal life in open ocean. On shore, the dispersants destroyed lichens and other beach life, leaving the land toxic. Rapid recovery was recorded for the untreated shores, but ecological damage is still being reported 50 years later for the treated coastal areas.

The effects on the human population are more difficult to quantify, as little research has covered this aspect of the disaster. It is theorized by some researchers that the oil and contaminated plankton and other small marine organisms were eaten by successively larger predators, thereby concentrating the effects of the toxins. These predators were caught in large numbers by local fishermen and served to residents of the Cornish coastal communities. Research continues to identifying the health effects on the local population from this disastrous oil spill and equally disastrous cleanup.

Timothy J. Sutton

See Also: Deepwater Horizon Incident; *Exxon Valdez* Incident; International Environmental Law and Policy; Oil Spills, Health Consequences of; Persistent, Bioaccumulating, and Toxic Chemicals; Polycyclic Aromatic Hydrocarbons

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TOXIC SUBSTANCES AND DISEASE REGISTRY, AGENCY FOR

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal agency of the U.S. government housed within the U.S. Department of Health and Human Services. It was authorized by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and formally established in 1983. While the ATSDR is an independent agency, it works in close association with the U.S. Centers for Disease Control and Prevention (also known as the CDC) and is administered by the CDC director, who appoints the director of the ATSDR. (The ATSDR has a joint Office of the Director with the National Center for Environmental

Health, also under the CDC.) The ATSDR's mission is to "serve the public through responsive public health actions to promote healthy and safe environments and prevent harmful exposures."

The ATSDR's primary role is to evaluate the potential health effects of hazardous chemicals and sites. It serves in an advisory capacity to communities and other federal and state agencies, but it does not regulate industry, and it is not involved in the cleanup of sites. The agency conducts public health assessments for sites on the U.S. government's National Priority List (otherwise known as Superfund sites), which allow the ATSDR to evaluate whether specific Superfund sites pose human health risks. The agency also provides public health consultations for other hazardous sites. The ATSDR, or states receiving funding from the agency, can initiate consultations when requested by the public or other government agencies. Both assessments and consultations provide stakeholders with information about hazards and health risks, including recommendations for ways to reduce community exposure.

The ATSDR staff members also investigate hazardous releases that have occurred during emergency events. Not only do they provide on-the-ground support during emergencies, but they also conduct surveillance to track emergency-related chemical releases, exposures, and health effects. The agency has developed several health registries to document and track human exposures and health impacts from emergency events. One such registry is the World Trade Center Health Registry, which commenced shortly after the terrorist attacks of September 11, 2001. The registry now contains information on over 70,000 people who were affected by the collapse of the World Trade Center buildings. This registry has been used to study both the mental and physical impacts of the disaster.

Finally, the ATSDR is charged with conducting research into the health effects of specific hazards and preparing toxicological profiles of hazardous chemicals. The agency's online Toxic Substances Portal contains information on over 250 toxic chemicals, including physical and chemical properties, sources, routes of exposure, health effects, and medical management guidelines.

Adrienne L. Katner

See Also: Disaster Preparedness and Response; National Center for Environmental Assessment; September 11 World Trade Center Attack; Superfund Act

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TOXIC SUBSTANCES CONTROL ACT

The Toxic Substances Control Act (TSCA) (15 USC (C. 53) 2601–2692) is a law passed by the U.S. Congress allowing the federal government to identify and control both existing chemicals and those entering U.S. markets. The TSCA was signed into law on October 11, 1976, by former president Gerald Ford and is administered by the U.S. Environmental Protection Agency (EPA).

In the 1970s, policymakers, scientists, and healthcare professionals began to express concern over the risks that toxic substances pose to human health and the environment. Reports observed a significant increase in the number of new chemicals that were entering commercial markets each year, many with little or no information about toxicity. Worker-related chemical exposure scares in the late 1960s, combined with the increasing number of new chemicals, prompted government action in the early 1970s. President Richard Nixon formed the Council on Environmental Quality in 1971, which published an influential report leading to the eventual drafting and passing of the TSCA.

The intent of the new law was to give the EPA power to evaluate the safety of raw materials and authority to control chemical risks that were not addressed under previous statutes. For example, Section 4 of the TSCA gives the EPA the authority to require testing of chemicals produced in substantial quantities that may pose a significant risk to human health or the environment. Section 5 requires companies planning to manufacture or import a previously unregulated chemical to submit to the EPA a premanufacture notice that includes information on the identity, use, anticipated volume, hazard, and disposal of the chemical. Under Section 6, the EPA may ban or control the production of any new or existing chemical due to excessive risk to the environment or human health.

Section 8 requires the EPA to compile and maintain a published list of every manufactured or processed chemical as part of the TSCA Inventory. Upon passage of the TSCA, it was declared that all existing chemicals should be considered safe, and nearly 62,000 existing chemicals were grandfathered in. The inventory, originally published in 1979, has grown to include roughly 85,000 chemicals. Substances that are generally excluded from TSCA oversight include food, drugs, cosmetics, and pesticides.

Title I of the original statute established the core of the law, which directed the EPA to control risks related to polychlorinated biphenyls. Subsequently, there have been five titles added to the law that address specific concerns. Title II, which was added in 1986, takes aim at asbestos. Title III (1988) addresses radon, Title IV (1992) seeks to control lead, Title V (2007) addresses energy and environmental issues in schools, and Title VI was added in 2008 to control formaldehyde emissions from composite wood products.

Most recently, attempts have been made by the U.S. Congress to modernize the act. In 2009, President Obama issued the "Essential Principles for Reform of Chemicals Management Legislation," which was designed to help inform ways that Congress could reauthorize and make the TSCA more effective. In 2015, competing reform bills were proposed in both U.S. congressional chambers. The House of

Representatives passed the "TSCA Modernization Act of 2015" (H.R. 2576), and the Senate drafted the "Frank R. Lautenberg Chemical Safety for the 21st Century Act" (S. 697).

Anthony C. Holderied

See Also: Asbestos; Formaldehyde; National Toxicology Program; Persistent, Bioaccumulating, and Toxic Chemicals; Polychlorinated Biphenyls; Toxic Substances and Disease Registry, Agency for; Toxics Release Inventory

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TOXICOGENOMICS

Sensitivity to chemicals differs between people. Many factors, including social and psychological influences and other environmental exposures, affect how people respond when exposed. In addition to external factors, some of the differences influencing susceptibility may be innate. Toxicogenomics is the name given to genomic investigations into the innate component of susceptibility to toxic chemicals.

There are two main ways that biology can affect a chemical's toxicity: toxicokinetics, defined as the movement and transformation of toxic chemicals within the body, and toxicodynamics, the biological response to a chemical at the dose in the organ where toxicity occurs. Toxicokinetic processes determine the dose of the chemical in the organ where toxicity occurs and may differ according to genetics. For instance, genetic differences may lead to distinct versions of relevant transporters or metabolic enzymes with different affinities for a particular chemical, or relevant proteins may be present in different concentrations across individuals. In some cases, a person may have no functional copies of a particular protein; for example, the enzyme glutathione-S-transferase mu 1 (GSTM1), which can help to eliminate certain toxic chemicals, is nonfunctional in many people. Sometimes genes can also influence the intake of a chemical; for example, nicotinic receptor genes influencing addiction are important for cumulative tobacco exposures.

Genetics can also play an important role in toxicodynamics. For example, a person may have a different form of a receptor with higher affinity for a toxic chemical, and therefore, a lower concentration of the chemical may elicit a similar response to a higher dose in a person with a lower-affinity receptor.

Some exposures have a few genes that are known to be particularly important. For example, the *PON1* (serum paraoxonase/arylesterase 1) gene is particularly important for sensitivity to organophosphate pesticides, and the *AS3MT* (arsenic III methyltransferase) gene is particularly important for the response to arsenic. However, for most exposures we do not have a clear picture of the human response genetics.

There are two main approaches to studying genetics. The first approach has the goal of identifying genetic regions that have similar inheritance patterns to the phenotype of interest. This similar inheritance is called linkage, and studies aimed at observing it are called linkage studies. The second approach, called association, compares how individuals' frequency of genomic variants (i.e., their genotype at a specific locus) is associated with the phenotype of interest. The linkage approach is concerned with transmission; the association approach is concerned with burden. There are epidemiological and animal model examples of both approaches. In general, linkage approaches are more powerful to detect large effects from genetic variants that may be rare overall in the population, while association studies are more powerful to detect modest effects from common variants.

Both linkage and association testing may be done on the scale of the whole genome. The late 1990s and early 2000s saw a large number of genome-wide association scans (GWAS) for myriad outcomes. GWAS results are generally available in the GWAS Catalogue, a partnership between the National Human Genome Research Institute in the United States and the European Molecular Biology Laboratory/European Bioinformatics Institute. When genome-wide association scans are used to test for interactions with environmental exposures, this may be called a gene-environment-wide interaction study (GEWIS). Testing a very large number of hypotheses in a genome-wide screen increases the risk of false positive findings, and thus, a more stringent criterion for statistical significance is used to limit the number of false positives. As a result, the minimum sample sizes required for GEWIS can be enormous (on the order of several thousand people).

A complementary approach is to focus on specific genetic pathways hypothesized to be involved in the biological response to specific compounds. Use of prior information on the biology of the chemical can be much more efficient than conducting an "agnostic" genome-wide screen and therefore may be feasible in smaller sample sizes. Furthermore, pathway hypotheses have the advantage of being amenable to representation in models that can explicitly incorporate toxicokinetic processes.

Recently, the scope of the field has expanded from a focus on sequence variation to how gene expression can affect toxic chemical responses. "Epigenetics" refers to potentially inherited features of the genome that may affect gene expression. Much of the epidemiological research considering epigenetics to date has focused on DNA methylation differences between people. This is of interest because more methylated DNA is harder for polymerases to bind to and therefore tends to have lower gene expression. There is also research looking at copy number variation (differences in the numbers of copies of a gene present in a person's genome) and RNA expression as key dimensions of toxicogenomics.

There is also growing interest in moving beyond studying nuclear genomic DNA. One emerging area is mitochondrial DNA, which may be particularly relevant for chemical exposures where toxicity is mediated by reactive oxygen species. Another emerging area is the effect of microbial communities living within people on how toxic chemicals are processed. Studying genomic features of resident microbial communities is called meta-genomics. In the future, these other kinds of DNA may become more prominent in toxicogenomic investigations.

Matthew O. Gribble

See Also: Dose-Response Assessment; Environmental Epidemiology; Environmental Toxicology

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TOXICS RELEASE INVENTORY

The Toxics Release Inventory (TRI) is a data repository consisting of toxic chemical releases as well as waste reduction and pollution prevention activities reported by industrial and federal facilities in the United States. This repository is maintained by the U.S. Environmental Protection Agency (EPA) and is updated annually with data provided by facilities subject to TRI reporting requirements. This program allows citizens to identify areas where toxic chemicals have been emitted into the environment as well as the waste reduction and prevention strategies used to minimize this activity.

The TRI reporting program originated from the Emergency Planning and Community Right-to-Know Act (EPCRA) enacted in 1986. The primary objectives of EPCRA were the following: (1) enhance the efforts of state and local emergency planning organizations with actions directed at chemical emergencies; (2) provide a mechanism for notifying relevant authorities about emergency releases of chemicals; and (3) increase the body of available data on toxic and hazardous chemicals, which will be used to address community concerns. Section 313 of EPCRA requires the EPA and the states to collect annual data on releases and transfers of certain toxic chemicals from applicable facilities and to make this data available through the TRI.

Facilities that meet the three applicability criteria below must report to the TRI program:

- Be classified as part of a specific industrial sector (note that federal facilities are required to report if they meet the employee and chemical use thresholds, regardless of their industry sector)
- Employ 10 or more full-time equivalent employees
- Manufacture or process greater than 25,000 pounds (11,340 kilograms) of a TRI-listed chemical or otherwise use greater than 10,000 pounds (4,536 kilograms) of a listed chemical in a given year (note that certain persistent, bioaccumulative, and toxic chemicals—PBTs—have lower reporting thresholds)

If a facility meets these criteria, it must submit a TRI Form R (known as the long form) for each TRI-listed chemical it manufactures, processes, or otherwise uses in quantities above the reporting threshold. Each TRI Form R must be submitted to both the EPA and the relevant division in the state in which the facility is located. Facilities may be eligible to submit a shorter version of a TRI form (Form A) if all of the following criteria are met:

- The chemical being reported is not considered a persistent, bioaccumulating, and toxic chemical
- The chemical has not been manufactured, processed, or otherwise used in excess of 1,000,000 pounds (453,592 kilograms)
- The total annual waste management (i.e., recycling, energy recovery, treatment, and disposal or other releases) of the chemical does not exceed 500 pounds (227 kilograms)

The deadline for submitting TRI forms for chemical releases and other related activity occurring in the previous calendar year is July 1.

The TRI program has improved the availability of data that can be accessed by the general public on sources of toxic releases in their communities. In recent years, the EPA and several other organizations have developed systems to enable users to understand the information in the TRI and use it for decision making. Examples include the following:

- TOXMAP: Available from the National Library of Medicine, this geographic information system helps users manipulate maps of the United States to analyze data from the EPA's TRI and Superfund programs.
- MapEcos.org: Developed by faculty and students at Dartmouth College, Duke University, and Harvard Business School, this system allows users to access an interactive map of the United States illustrating the most recent TRI data.
- RTKnet.org: Available from the Center for Effective Government, this system provides access to a variety of current EPA data, including data for the TRI. Queries allow users to download files with the raw data.
- Envirofacts: Available from the EPA website, this system allows queries to the underlying relational database produce downloadable text documents.

Richard F. Pandullo

See Also: Emergency Planning and Community Right-to-Know Act; Environmental Protection Agency; National Air Toxics Assessment; Pollution Prevention

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TRACHOMA

Also known by the names granular conjunctivitis, Egyptian ophthalmia, and blinding trachoma, trachoma is the leading cause of infectious blindness. Blindness caused by trachoma is irreversible, and trachoma is the primary cause for the blindness or visual impairment of 1.9 million people. Trachoma is considered a public health problem in approximately 42 countries in Africa, Asia, Central America, and South America. While trachoma is not as prevalent in the United States as in to other countries, it is still present.

Chlamydia trachomatis is the organism responsible for causing trachoma as well as some genital tract infections. Serotypes A, B, Ba, and C are the primary causes of trachoma, while serotypes D through K cause urinary and genital tract infections. This disease is spread by direct contact with secretions from the eye, nose, and throat of infected individuals, but it can also be spread via fomites, such as handkerchiefs, towels, or washcloths contaminated with these secretions.

Trachoma appears to have two phases: an active, inflammatory trachoma and a cicatricial portion of the disease, in which scarring from the active phase causes the eyelid to turn inward, resulting in light sensitivity and ocular damage. Active trachoma is most commonly seen in young children up to nine years old, whereas the cicatricial disease and blindness are most often observed in adults.

The World Health Organization (WHO) has developed another categorization system for trachoma, termed the simplified WHO trachoma grading system. This classification helps determine the intervention required for the disease (see Table 18). The WHO and its partners in world health medicine endorse the surgery, antibiotics, facial cleanliness, and environmental improvement ("SAFE") strategy for trachoma control.

It is recommended that a good light and at least 2.5-times magnification be used to examine the eye when looking for inflammation, discharge, loss of eyelashes, rubbing on the cornea, and corneal opacity. The upper lid should also be everted to visualize the upper tarsal conjunctiva for evidence of follicles, inflammation, or scarring. If an eye has a grade of TT or CO in the WHO grading system, then there is a high propensity for blindness, and this observation should prompt ophthalmologic evaluation and surgical intervention.

If the cause of eye inflammation and discharge is in question, then there are laboratory tests available to test for *C. trachomatis*, such as immunofluorescent cytology, polymerase chain reaction, Giemsa cytology, and bacterial culture. Trachoma is often confused with eye irritation from viruses, chemicals, allergies, hypersensitivity to makeup, or infection by another bacterial organism, like *Streptococcus pneumoniae*, *Staphylococcus aureus*, and *Bartonella henselae*.

Table 18. Simplified trachoma grading system.

Classification	Description	Treatment
Trachomatous inflammation, follicular (TF)	Five or more follicles of > 0.5 mm on the upper tarsal conjunctiva	Antibiotic therapy and ocular hygiene
Trachomatous inflammation, intense (TI)	Papillary hypertrophy and inflammatory thickening of the upper tarsal conjunctiva, obscuring more than half the deep tarsal vessels	Antibiotic therapy and ocular hygiene
Trachomatous conjunctival scarring (TS)	Grossly visible scars on the tarsal conjunctiva	Ophthalmologic evaluation, antibiotic therapy, and ocular hygiene
Trachomatous trichiasis (TT)	At least one ingrown eyelash touching the globe, or evidence of epilation (eyelash removal)	Surgical intervention
Corneal opacity (CO)	Corneal opacity blurring part of the pupil margin	Surgical intervention and lifetime antibiotics

Trachoma is typically treated with a single high dose of azithromycin by mouth or topical forms of tetracyclines or azithromycin directly on the eyelid. Oral tetracycline cannot be used on pregnant women due to risk of harm to the unborn child, but the topical medicine is safe during pregnancy. If the severity of the illness has surpassed antibiotic intervention, then surgical methods are necessary.

Howard W. MacLennan Jr.

See Also: Communicable Diseases; Infectious Diseases; World Health Organization

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U

ULTRAVIOLET RADIATION AND THE UV INDEX

The sun emits radiation over a wide range of wavelengths, including wavelengths corresponding to radio waves, microwaves, infrared radiation, visible light, X-rays, gamma rays, and ultraviolet (UV) radiation. UV radiation is a particular concern because overexposure can cause reddening of the skin (erythema), reduced vitamin D synthesis, skin cancer, cataracts, and suppression of the immune system. We become overexposed to UV radiation when we spend too much time outdoors and neglect to take appropriate precautions to protect ourselves from the sun. Additionally, air pollution can worsen our exposure by weakening the UV radiation shielding provided by the stratospheric ozone layer.

Protecting Yourself from Too Much UV Radiation

In addition to causing a sunburn, too much UV radiation can cause skin cancer and other serious problems. Here are some simple steps you can follow to avoid overexposure while outdoors:

- Limit the time you spend in the midday sun, especially during the hours from 10:00 A.M. to 4:00 P.M.
- Avoid getting a sunburn, which can significantly increase the risk of developing skin cancer. (You can get a sunburn even on a cloudy day!)
- Try to stay in the shade as much as possible while outside.
- Be careful near water, snow, and sand, which can reflect sunlight and increase the risk of sunburn.
- Only buy sunglasses that provide 100 percent UV protection against both UVA and UVB radiation.
- Wear wide-brimmed hats and tightly woven, loose-fitting clothing.
- Stay away from suntanning salons and tanning beds, which increase the risk of skin cancer and wrinkling.
- Always apply a broad spectrum sunscreen before going outside, and reapply frequently.

Additionally, it is a good idea to check the National Weather Service's UV Index before planning outdoor activities to be sure you are adequately protected. And examine your skin at least monthly, looking for abnormalities, such as moles that have changed size, color, or shape and sores that have not healed.

Our health depends on sunlight. In particular, sunlight helps our bodies produce vitamin D, which is essential for healthy bones and for regulating the immune and neuromuscular systems. However, sunlight can sometimes be too much of a good thing when it affects our health. Many of us grew up thinking there is nothing wrong with a nice tan after a weekend at the beach. In fact, tanning is how your body protects itself from harmful UV radiation, and if you are developing a tan or, worse, a sunburn, you have probably been out in the sun too long.

Among the serious health consequences of overexposure to UV radiation, skin cancer is perhaps the best known. Here are the facts about skin cancer:

- The most common cancer in the United States is skin cancer.
- One in five Americans will develop skin cancer in their lifetime, and one American dies from skin cancer every hour.
- Among several risk factors for skin cancer, exposure to UV radiation is the most preventable. (Genetic factors and immune system deficiencies also increase the risk of developing skin cancer.)
- Overexposure to UV radiation and frequent sunburns, especially during childhood, enhance the likelihood of developing melanoma, the most serious type of skin cancer. (Melanoma represents only about 3 percent of skin cancer cases, but it accounts for over 75 percent of deaths attributable to skin cancer.)

Excessive UV radiation exposure can also cause actinic keratoses, which are growths of skin on overexposed areas of the body (especially the face, hands, neck, and forearms) that are risk factors for later development of cancer. Premature aging of the skin can also occur, making the skin look old and wrinkled. As people get older, up to 90 percent of the skin changes, often attributed to the aging process, are actually caused by the sun and are preventable if precautions are taken to reduce UV radiation exposure.

There are three types of UV radiation: UVA (having a wavelength of 315 to 400 nanometers), UVB (280 to 315 nanometers), and UVC (100 to 280 nanometers). While most UVA radiation reaches the surface of the earth, the earth's stratospheric ozone layer can block much of the UVB radiation from reaching the earth's surface, especially where the layer is thicker. However, when air pollution causes a thinning of the stratospheric ozone layer, more UVB can pass through. The atmosphere is very effective in blocking UVC radiation, with little ever reaching the earth's surface. Of all of the UV radiation reaching the earth's surface, about 90 to 95 percent is UVA, and the remainder is UVB. Overexposure to both UVA and UVB can adversely affect human health.

The UV Index is a daily forecast by the U.S. National Weather Service of the amount of UV radiation expected to reach the earth's surface, based the sun's elevation, the amount of stratospheric ozone, and cloud cover. The higher the index value, the more likely skin and eye damage will occur over a shorter period of time (see Table 19). Thus, it is a useful tool for planning outdoor activities. In addition to the UV Index, the National Environmental Education Foundation's SunWise program provides resources for teaching children about sun safety, UV radiation, and stratospheric ozone.

Richard Crume

Table 19. UV Index scale.

UV Index	Category	Precautions
0 to 2	Low (Green)	A UV Index reading of 0 to 2 means low danger from the sun's UV rays for the average person. Wear sunglasses on bright days. If you burn easily, cover up and use broad spectrum SPF 30+ sunscreen. Watch out for bright surfaces, like sand, water, and snow, which reflect UV and increase exposure.
3 to 5	Moderate (Yellow)	A UV Index reading of 3 to 5 means moderate risk of harm from unprotected sun exposure. Stay in shade near midday when the sun is strongest. If outdoors, wear protective clothing, a wide-brimmed hat, and UV-blocking sunglasses. Generously apply broad spectrum SPF 30+ sunscreen every two hours, even on cloudy days, and after swimming or sweating. Watch out for bright surfaces, like sand, water, and snow, which reflect UV and increase exposure.
6 to 7	High (Orange)	A UV Index reading of 6 to 7 means high risk of harm from unprotected sun exposure. Protection against skin and eye damage is needed. Reduce time in the sun between 10 A.M. and 4 P.M. If outdoors, seek shade and wear protective clothing, a wide-brimmed hat, and UV-blocking sunglasses. Generously apply broad spectrum SPF 30+ sunscreen every two hours, even on cloudy days, and after swimming or sweating. Watch out for bright surfaces, like sand, water, and snow, which reflect UV and increase exposure.
8 to 10	Very High (Red)	A UV Index reading of 8 to 10 means very high risk of harm from unprotected sun exposure. Take extra precautions because unprotected skin and eyes will be damaged and can burn quickly. Minimize sun exposure between 10 A.M. and 4 P.M. If outdoors, seek shade and wear protective clothing, a wide-brimmed hat, and UV-blocking sunglasses. Generously apply broad spectrum SPF 30+ sunscreen every two hours, even on cloudy days, and after swimming or sweating. Watch out for bright surfaces, like sand, water, and snow, which reflect UV and increase exposure.
11 or More	Extreme (Purple)	A UV Index reading of 11 or more means extreme risk of harm from unprotected sun exposure. Take all precautions because unprotected skin and eyes can burn in minutes. Try to avoid sun exposure between 10 A.M. and 4 P.M. If outdoors, seek shade and wear protective clothing, a wide-brimmed hat, and UV-blocking sunglasses. Generously apply broad spectrum SPF 30+ sunscreen every two hours, even on cloudy days, and after swimming or sweating. Watch out for bright surfaces, like sand, water, and snow, which reflect UV and increase exposure.

Source: U.S. Environmental Protection Agency.

See Also: Air Pollution; Cancer Risk from Environmental Exposure; Environmental Protection Agency; Stratospheric Ozone Depletion

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UNDERGROUND STORAGE TANKS, HEALTH CONCERNS WITH

Underground storage tanks (USTs) exist throughout the country and contain a variety of materials (primarily liquids), such as gasoline, diesel, oils, other petroleum products, solvents, additives, cleaners, water, and used oil. Finely ground metals may also be present, particularly when storing used oil. Health effects related to USTs are caused both by the unique ways relatively common materials with known health effects can enter the environment and by human exposure to these materials through both air and water (respiration and ingestion).

When Underground Storage Tanks Leak

Virtually any liquid chemical can be stored within a UST. When chemicals leak from a UST system, they can migrate in the subsurface soil, groundwater, and air in many ways, leading to complex exposure pathways. Chemical migration can be influenced by many factors, such as soil type, soil layering, the presence of underground features (including rock layers and caves), air pressure, rainfall, groundwater, tides, earthquake faults, subsurface utilities, and past excavations and backfill. Thus, determining the environmental effects of underground storage tank leaks can be very difficult, requiring expert knowledge and experience.

There are several ways that UST systems can discharge chemicals into the environment. These include leakage from the UST itself (including the piping and pumps) and spills around the tank. Spills are most likely during the process of adding and removing the contents. When contaminants are released from a UST, they are generally pulled downward by gravity and, in the gaseous phase, expand outward. This path is influenced by the soil and subsurface features, creating an impacted area called the contaminant plume, which may extend to the groundwater. Chemicals lighter than water will pool on top of the water, while those denser than water will sink. Most chemicals will dissolve in the groundwater to some extent. Variations in the conditions of the release result in a distinctive contaminant plume for each release.

The materials stored within the tanks can cause health concerns. Virtually any liquid material can be stored in a UST, as long as the material is not reactive with the UST material itself. In addition, liquids in the tanks (such as a used oil tank) may contain metals and other finely ground and dissolved materials that will travel with the liquid in the event of a discharge into the environment. In practice, USTs typically contain chemicals such as petroleum hydrocarbons (e.g., gasoline and diesel), cleaning agents (e.g., chlorinated solvents), and waste materials (e.g., used oil). Many of these are considered volatile organic compounds and can be readily detected by smell. Some of the chemicals, such as benzene and methyl tert-butyl ether, are potential human carcinogens. The health effects are the same as exposure to the materials through other channels; however, the exposure pathways are unique. While leakage from surface and above-ground tanks can be quickly identified and addressed, USTs may leak for some time until the leak is discovered.

One well-documented release pathway to exposure is the contamination of groundwater through releases from USTs. Contaminants leaked into the subsurface can travel with the water when it is pumped for human use. The contaminants are often very dilute and remain hidden until the water is tested. Gasoline consists of chemicals with a distinctive odor, and some initial contamination issues related to USTs for gasoline were identified by petroleum odors in well water.

Vapor migration in the subsurface can also lead to human exposure to the contents of USTs. While gravity tends to pull liquids downward, chemicals may also be present in the gaseous state (depending on the chemical and the environmental conditions). In addition to the overall downward movement of liquid chemicals, gases will move laterally and may even move upward. Human exposure through respiration can occur in many situations, such as basements and crawl spaces, where the gas would move from the soil into a space with limited air circulation, and in buildings where the gas could enter through foundations.

Exposure can also occur when contaminated groundwater exits subsurface flow to surface flow. Chemicals from the UST leakage may travel with the groundwater as it enters the surface stream. If contaminants in the groundwater are dilute, they may not be noticed over contaminants that enter the surface water from stormwater runoff. With higher concentrations of chemicals in the groundwater, a discoloration, surface sheen, or biological growth may be observed where the groundwater meets the surface water.

Workers may be exposed to UST releases as they construct trenches, such as for storm drains, sanitary sewers, and other buried utilities, as well as during excavations on construction sites. When encountering subsurface contaminants, workers at the site are typically alerted to the contamination when they notice odors from the volatile organic compounds and other chemicals, by which time their skin, clothes, and equipment may already be contaminated with soil and groundwater containing the chemicals. When found, work is usually suspended in the area of the subsurface contamination, pending investigation and cleanup of the released materials.

In Southern California in the 1990s, the gasoline additive named MTBE was found in drinking water wells in the Santa Monica area, where there was no other indication of significant contamination in the water. Although MTBE had been found in other locations, its identification in the Santa Monica water wells triggered more extensive testing of water wells throughout the country, and MTBE was found in additional wells. Further research determined that the MTBE traveled through the subsurface faster than other commonly tested chemicals, and MTBE actually became an early indicator of a UST leak.

Another health-related factor that was illustrated by the MTBE leakage is that some chemicals, including petroleum hydrocarbons, may be susceptible to biodegradation upon release into the environment. While biodegradation can be useful in that it removes the chemical from the environment, it can also cause the creation of new chemicals that were not originally present in the chemicals released from the UST. In the case of the MTBE leakage, some of the MTBE biodegrades into tert-butyl alcohol, a skin irritant that may then biodegrade into other compounds.

Thomas B. Lawrence

See Also: Biodegradable Materials, Health Benefits of; Cancer Risk from Environmental Exposure; Groundwater Pollution and Depletion; Respiratory Disease and Air Pollution; Volatile Organic Compound Pollution

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UNEXPLODED ORDNANCE

Unexploded ordnance (often abbreviated UXO) is active military weaponry that did not detonate upon deployment. It includes aerial bombs, hand grenades, tank mines, artillery shells, and landmines. This type of military weaponry has been used since the American Civil War. Unexploded ordnance is found all over the world, and it is unknown how much unexploded ordnance remains. Every year, about 24,000 people die from unexploded ordnance and landmines.

Unexploded World War II bombs at a warehouse in Okinawa, Japan. Every year many people throughout the world die from unexploded ordnance, including aerial bombs, hand grenades, tank mines, artillery shells, and landmines. (AP Photo/Itsuo Inouye)

A legacy of World War II, unexploded aerial bombs are commonly found in the United Kingdom, Germany, France, Japan, and the Pacific Islands. UXO is often discovered during construction projects. In France and Belgium, farmers plowing their fields turn up artillery in what they call the "iron harvest." Japan also regularly uncovers and defuses bombs left over from World War II. Since 1972, Japanese military forces have disposed of 5,500 tons (5,000 metric tons) of ordnance, and the discovery of bombs is almost a daily occurrence in Germany. This results in frequent evacuations while bomb-disposal teams do their work. Buried artillery becomes more unstable and therefore more dangerous over time, and in France alone, more than 630 demining workers have died while removing mines. This represents a fatality rate of one worker per every 5,000 defused mines.

Countries that have experienced recent or frequent conflict are most affected by unexploded ordnance. For instance, during the Vietnam War (1955–1975), the United States dropped more than 2 million tons (1.8 metric tons) of artillery on Laos, making it the world's most heavily bombed country per capita. In the four decades since this war, 8,000 people have been killed and 12,000 wounded from UXO, many of them children who did not know what they were playing with. The United States currently spends $12 million every year to remove UXO in Laos. In addition, Lebanon, Angola, and Afghanistan are each littered with millions of landmines and bomblets (cluster bombs) left over from military conflicts. This type of unexploded ordnance is considered more dangerous than large bombs because it is more difficult to detect. Mines and bomblets make agricultural land unusable until the land is cleared.

In the United States, over 10 million acres of land formerly used for military practice may contain unexploded ordnance, and restoring this land will cost at least $14 billion, according to the U.S. Environmental Protection Agency. The United States often uses sophisticated electronic or geophysical techniques to detect UXO, techniques that are effective but expensive.

Since 1980, international law has required countries to remove "explosive remnants of war" once the conflict has ended. Because civilians are victims of remaining mines, the United Nations believes that "antipersonnel" mines (mines designed to injure people) should not be used in warfare. Additionally, some people believe that antipersonnel mines accomplish only limited military goals. In 1997, UN efforts led to an international treaty, the Anti-Personnel Mine Ban Convention. The United States has not signed the treaty, criticizing it for allowing antivehicle mines and cluster bombs, which remain live for many years after deployment. The UN is currently working to find and remove UXO, assist victims, and educate people living in affected areas.

Alisha K. Newton

See Also: Chemical Weapons Elimination; Environmental Protection Agency; International Environmental Law and Policy

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UNITED NATIONS ENVIRONMENTAL PROGRAMME

The United Nations Environmental Programme (UNEP) oversees environmental progress and concerns around the world. As an agency of the United Nations, it works primarily with member states to identify, research, and mitigate environmental issues, such as air and water pollution, waste disposal, and climate change. The main functions of the UNEP are policy development and analysis, coordination among member nations and nongovernmental agencies, and resource mobilization and outreach.

Are You Too Lazy to Save the World?

If so, the United Nations has published a list of things you can do from the comfort of your couch, including the following:

- Save electricity by turning off electronic devices and appliances when not in use, such as your computer.
- Stop paper bank statements, and pay your bills online.
- Use social media to share interesting stories about, for example, climate change or women's rights.
- Speak up about important issues, like voicing your support for international climate agreements.
- Stop using your printer, and instead, jot down ideas in a notebook or a digital Post-it note on your computer.
- Order products from companies having sustainable practices.
- Stay informed about local and national issues by watching the TV news, reviewing online articles, and even the old-fashioned way—reading a newspaper.

And when you finally get up from the couch, turn off the lights, TV, and computer. Let's get with it!

The UNEP was established in December 1972 in direct response to concerns among people and governments around the world about rising pollution levels. It is headquartered in Nairobi, Kenya, and is organized around six regional offices located in Bahrain, Kenya, Panama, Switzerland, Thailand, and the United States. A number of other program offices are located throughout the world, giving the UNEP a strong international presence.

In many ways, the UNEP functions similarly to other UN agencies in that it seeks to provide key support by partnering with local groups. This focus is seen within each of the organization's seven divisions—Communication, Corporate Services, Economy, Ecosystems, Law, Policy and Programme, and Science.

A major UN concern is that current lifestyles and priorities may not be sustainable into the future. As a result, member states have adopted the following 17 sustainability goals, which include environmental health objectives supported by UNEP: no poverty; zero hunger; good health and well-being; quality education; gender equality; clean water and sanitation; affordable and clean energy; decent work and economic growth; industry innovation and infrastructure; reduced inequalities; sustainable cities and communities; responsible consumption and production; climate action; life below water; life on land; peace, justice, and strong institutions; and partnerships for the goals.

While achieving these goals is certainly a daunting task, partnerships with member states and local organizations have been making significant progress in each of these areas. One example is a project to bring clean water to a primary school in Sierra Leone for the first time in a decade. This and similar projects have increased access to safe drinking water from 37 to 63 percent of the Sierra Leone population in the past 25 years. Another project in Montenegro is helping the country develop a carbon-neutral, climate-friendly tourism industry by working with businesses to adopt sustainable practices. A third project in Georgia is addressing rural poverty and food security through sustainable agriculture development.

Charles Daniel

See Also: Earth Charter; International Environmental Law and Policy; Sustainable Development and Health; United Nations Framework Convention on Climate Change

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UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

The United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty that provides the foundation for coordinating national responses to both the causes and effects of climate change. This treaty has been instrumental in facilitating and encouraging nations to reduce their greenhouse gas emissions. Ultimately, this is enormously important from a public health perspective because global climate change will cause and contribute to phenomena that pose serious public health risks, such as floods, heat waves, water shortages, and food shortages. Actions taken to reduce greenhouse gas emissions will reduce the likelihood and/or magnitude of such phenomena.

The UNFCCC was negotiated in 1992 and entered into force in 1994. Today, it has near-universal membership, with 197 countries having ratified the agreement. The primary objective of the UNFCCC is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." While the original convention did not specify what this level would be or how that might translate to specific emissions limitations for particular countries or sectors, it did provide the basis for an ongoing international dialogue to reach consensus on these issues.

One of the key elements of the original convention is the formal recognition that all countries should implement measures to mitigate and adapt to climate change, in accordance with their common but differentiated responsibilities and respective capacities. This means that developed country parties should take the lead in combating climate change and its adverse effects, both because they are primarily responsible for the problem and because they have the resources to address it. Developing countries are also expected to implement mitigation and adaptation measures, but the convention recognizes that their ability to effectively implement their commitments is contingent on the provision of financial and technical support from developed country parties.

The convention also requires all parties to monitor anthropogenic sources and sinks of greenhouse gas emissions and to periodically submit national emission inventories to the UNFCCC secretariat. These reports provide a basis for determining the respective contributions of countries to global climate change and for evaluating the adequacy of national efforts to reduce greenhouse gas emissions.

Finally, the convention creates a framework for implementation and elaboration on commitments. It outlines a process whereby the Conference of the Parties can hold periodic meetings and negotiate subsidiary agreements, and it establishes a secretariat that is responsible for administrative matters, such as the collection and publication of national emissions inventories.

The Conference of the Parties has convened every year since 1995 to discuss implementation of the UNFCCC and has elaborated on many important issues in the decisional documents published for each annual meeting. For example, in the Cancun Agreements (the decision document for the 2010 conference), the parties agreed that they must limit global warming to 2°C (about 4°F) to meet the original objective of the UNFCCC. Commitments related to financial and technical assistance have also been laid out in these decisions. Unfortunately, the terms of these decisions are not legally binding. They can, however, can lead to the adoption of legally binding domestic laws in willing countries.

The Conference of the Parties has also promulgated two subsidiary agreements. The first was the Kyoto Protocol, which was adopted in 1997 but did not go into force until 2005. It established legally binding emissions targets for some developed country parties as well as flexibility mechanisms that permitted emissions trading and offsets. The success of the Kyoto Protocol is a subject of debate—most countries met their targets and the sum of emissions from those countries fell significantly. However, major emitters like the United States and China did not participate in the program, and emissions from developing and emerging economies increased substantially. One major concern regarding the effectiveness of the Kyoto Protocol is that the overall increase in global emissions is likely the result of emissions leakage (which occurs when there is an increase in greenhouse gas emissions in one country as a result of emission reductions in another country). Much of the emissions growth in China and other emerging economies was driven by the production of goods and services that were exported to developed countries, including the Kyoto parties.

The second subsidiary agreement is the Paris Agreement, adopted in 2015. The Paris Agreement takes a very different approach from Kyoto: it establishes a framework wherein parties develop and periodically revise national plans for reducing greenhouse gas emissions (known as "nationally determined contributions"). The adequacy and implementation of these plans is then assessed during a global assessment. The agreement also contains provisions related to adaptation and financial and technical assistance. Unlike the Kyoto Protocol, the Paris Agreement is on track to achieve universal participation, likely due to the lack of any quantitative emissions limitations on participating countries.

It is not possible to estimate the specific impacts of the UNFCCC and its subsidiary agreements in terms of emissions reductions or health benefits. However, it is safe to say that the framework established by the UNFCCC has played a significant role in motivating and facilitating national-level responses to climate change and that these responses have led to meaningful reductions in greenhouse gas emissions and other co-pollutants.

Jessica Wentz

See Also: Climate Change and Human Health; Greenhouse Effect and Global Warming; Intergovernmental Panel on Climate Change; International Environmental Law and Policy; Sea Ice, Global Warming Implications for

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V

VOLATILE ORGANIC COMPOUND POLLUTION

Volatile organic compounds (VOCs) are carbon containing compounds (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate) that participate in atmospheric photochemical reactions, such as the formation of smog. VOCs can be emitted from a variety of sources, including car exhausts, gas stations, paint and printing shops, and many types of industrial operations, such as chemical manufacturing plants and refineries. VOCs typically enter the body through respiration (breathing) and can have significant effects on both short-term and long-term health. VOCs can cause headaches, nausea, and irritation of the eyes, nose, and throat. Beyond these immediate health risks, some VOCs are also thought to be mutagens (DNA-altering agents), and some may cause cancer.

VOCs can react with nitrogen to form ozone. Ozone is naturally found high in the earth's atmosphere, 10 to 50 miles (16 to 80 kilometers) above the earth's surface. This is the "good" ozone that provides a shield against harmful ultraviolet radiation produced by the sun. However, ozone can also be formed at ground level, where VOCs react with nitrogen oxides in the presence of sunlight. This ozone is a major component of urban smog. Human exposure to ozone can cause respiratory problems, lung damage, and exacerbation of other diseases. Children and the elderly are at most risk from ozone exposures. Children are more sensitive to the effects of ozone exposure because their lungs are still developing and they typically spend more time outside. Elderly people may be more prone to the negative effects of ozone because of preexisting conditions and weakened immune systems.

VOCs can be found both outside and inside. Building materials, such as new carpets or furniture, can release VOCs slowly, and the "new car smell" is from VOCs. Dry cleaning solutions, nail polish and its remover, degreasers, deodorizers, air fresheners, colognes, perfumes, and household cleaning products are all examples of substances that may give off VOCs. Some VOCs, such as benzene, toluene, and xylene, are more harmful than others. These chemicals can be found in gasoline, kerosene fuel oil, and other petroleum-based products. Acetone, isopropyl alcohol, and ethyl alcohol are VOCs found in some personal care products, and various adhesives emit the VOCs toluene, cyclohexane, and methyl ethyl ketone.

In workplaces where manufacturing occurs and the use of chemicals is commonplace, extra safeguards are needed to avoid exposure. Paint thinners, fabric cleaners, various adhesives, degreasers, plywood, and pesticides can all emit

VOCs. Frequency and time of exposure determine the effects of these compounds, some of which may cause debilitating diseases and even cancer. The Occupational Safety and Health Administration (OSHA) is responsible for rules addressing VOCs in the workplace.

Andrew P. Barefield

See Also: Air Pollution; Cancer Risk from Environmental Exposure; Indoor Environment; Occupational Safety and Health Administration; Ozone and Smog in the Urban Environment; Personal Care Products, Health Issues with

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VULNERABLE POPULATIONS, ENVIRONMENTAL THREATS TO

It is well established that people living in close proximity to environmental pollution from power plants, factories, and motor vehicles are at greater risk of adverse health effects. The risk can be ameliorated by reducing the quantity of pollution, making it less toxic, or reducing exposure by moving to a less polluted area. However, in the United States and throughout the world, a new type of environmental health threat is emerging—climate change—that is harder to avoid, particular for the most vulnerable populations.

Climate change has the potential to affect the health of Americans by causing more extreme heat and other weather-related events, degrading ambient air quality, spreading waterborne and insect-borne diseases, threatening food safety and security, and inundating low-lying areas by sea level rise. The extent to which these environmental threats will occur depends on U.S. and global actions to reduce greenhouse gases, and in particular, on a willingness to replace power plants that burn fossil fuels with clean, renewable energy alternatives. Many scientists believe that significant climate change effects are already being observed in many regions of the world, and without urgent worldwide efforts to cut greenhouse gases, these effects will only worsen.

As you might imagine, the populations most vulnerable to climate change are those that are most sensitive to environmental change, least able to afford good medical care and other public services, and unable to relocate their homes to less affected areas. This includes low-income and minority people; children and pregnant women; older adults; recent immigrants experiencing a language barrier; people with disabilities; and those with underlying diseases such as asthma, diabetes, cardiovascular and kidney disease, and chronic obstructive pulmonary disease. Indigenous populations may also suffer from loss of cultural identity, as sacred lands are disrupted by drought, flooding, and thawing of permafrost, and as ceremonial practices are altered by loss of relevant plant and animal species.

To illustrate the potential for vulnerable populations to suffer disproportionately from climate change, consider the effects of extreme heat events. In the United States, low-income, minority, immigrant, and homeless people often inhabit our largest cities, where unusually hot weather is made worse by the heat island effect. These groups of people may be less likely to have well-insulated and air-conditioned homes, access to cooling centers and other public shelters, and adequate healthcare services, and these factors have undoubtedly contributed to an observed increase in heat-related illnesses and deaths during heat waves in some low-income and immigrant populations. Furthermore, air quality made worse by extreme heat has resulted in increased hospital and emergency room admissions for asthma attacks, shortness of breath, and cardiovascular and respiratory system distress. Cases of premature death have also been reported during these air pollution episodes.

Climate change effects can be even worse when environmental, socioeconomic, and demographic factors combine to threaten health while allowing for fewer healthcare options. Under these circumstances, populations may suffer not only from physical conditions but also from mental health problems. These challenges, already present today, will only worsen as climate change becomes more entrenched, with fewer options for halting and reversing the trend. It is not difficult to imagine that at some point in the future, a sense of desperation may set in among vulnerable populations as climate change accelerates, with fewer options for adapting to or avoiding its effects.

As demographics change, the number of most vulnerable people may also be altered. For example, minorities are expected to become a majority of the U.S. population by around 2043, and the number of older adults (age 65 and older) will nearly double between the years 2015 and 2050 as the baby boomer generation ages. At the same time, the effects of climate change are expected to become more apparent and disruptive over the next two to three decades, placing a greater strain on the nation's ability to cope its most vulnerable populations.

Of course, climate change is not limited to the United States, and the effects could be most severe in the poorest countries, where malnutrition and illness may become more prevalent and crops may fail. As people in sub-Saharan Africa and other impoverished areas are increasingly displaced by expanding deserts, more frequent floods, rising sea levels, and spreading diseases like malaria, they may have no option but to become environmental refugees—fleeing their homelands for places less affected by the changing climate, potentially leading to political unrest as their numbers swell. The irony is that those potentially most affected by climate change—poor people often living in the low latitudes who already suffer from malnutrition and disease—are least responsible for causing the problem, which largely originates with energy use and industrial operations in the developed nations.

Richard Crume

See Also: Climate Change and Human Health; Environmental Justice; Environmental Refugee; Greenhouse Effect and Global Warming; Heat Island Effect in Urban Areas; Heat Waves

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WASTE INCINERATION

Incinerators, where garbage is burned in a closed furnace, were created toward the end of the 19th century in England and were called "destructors." The first incinerator in the United States was built on New York's Governors Island in 1885. This method of garbage disposal was prevalent throughout the 1930s and 1940s, until environmental concerns and the cheaper cost of landfilling wastes outweighed the advantages of waste incineration. New York City and Los Angeles, in particular, had major problems with smog associated with incinerators and other air pollution sources, with bans on residential incinerators enacted in those cities in 1957 and 1971, respectively.

There were attempts in the 1980s to significantly increase the number of U.S. waste incinerators, with the intent of deriving energy from these units to generate steam or electricity. However, nationwide protests and environmental activism helped stall or kill many of these projects, with the slogan, "Not in My Backyard" (also known by its acronym, NIMBY), emerging. Today, NIMBY has become shorthand for a community's fight against undesirable infrastructure. Nevertheless, waste incineration survived, and today a number of waste incinerators are operating in the United States.

Incinerators can be harmful to the environment in several ways. The by-products of burning waste include air pollutants, such as dioxin and mercury, that are hazardous to human health. Other air pollutants contribute to urban smog and regional haze and are associated with lung and heart disease and other health problems. Expensive air pollution control equipment is required on waste incinerators to reduce the amount of air pollution to levels prescribed by state and federal regulations. Incinerators also create a toxic ash that needs to be managed carefully to avoid contaminating nearby water resources.

A mass-burn incinerator involves depositing the garbage in a large combustion chamber supplied with excess air to ensure good combustion. At many of these incinerators, garbage is unloaded by trucks into bunkers and then deposited into the furnace by crane, or alternatively, the garbage flows from the trucks along a conveyor belt. Two forms of ash are produced from incinerating garbage, "bottom ash" and "fly ash." The former is waste materials that is not completely burned, while the latter is particulate matter in the exhaust gas. Most of the bottom ash, as well as the fly ash collected by pollution control devices, is stored on-site or sent to landfills.

At a waste-to-energy incinerator, heat from burning the garbage is used to produce steam and to drive a turbine to produce electricity. For typical waste-to-energy incinerators, a ton of burned garbage produces about 550 kilowatt hours of electricity.

Nationwide, energy from U.S. incinerators powers the equivalent of 2 million homes. The U.S. Environmental Protection Agency considers waste-to-energy facilities to be a type of renewable energy source because of the continuous, never-ending flow of garbage. There are currently about 80 waste-to-energy incinerators in the United States.

Countries in northern Europe, such as Germany and Denmark, have relied on large incinerators to burn about one-third of their trash, and these incinerators are equipped with powerful pollution control devices to prevent most of the air pollution from entering the atmosphere. In contrast, Denmark has installed smaller incinerators, a strategy that helps reduce local impacts, and because the incinerators are located closer to communities, they are able to provide heat to homes and businesses. European countries also have efficient waste recycling programs, with some countries recycling up to two-thirds of their wastes.

Despite the availability of efficient pollution control technology, support for waste incineration in the United States remains low due to environmental concerns and construction costs, and the landfilling of wastes is usually less expensive. From an environmental health perspective, whether incineration versus the landfilling of waste is preferable is a complicated question requiring careful, case-by-case analysis of greenhouse gas emissions, toxic air emissions and controls, potential contamination of water resources, ash disposal alternatives, waste composition, availability of recycling programs, proximity to urban areas, and energy recovery options. Regardless of which disposal method is preferred, most experts agree that the best approach for waste management is to "reduce, reuse, and recycle."

Aaron Dorman

See Also: Dioxin Pollution; Environmental Protection Agency; Land Disposal of Waste Materials; Municipal Solid Waste Management; Ozone and Smog in the Urban Environment; Particulate Matter and Bioaerosols Pollution; Regional Haze Pollution; Respiratory Disease and Air Pollution; Three Rs of Waste Management

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WATER CONSERVATION

Water conservation efforts aim to protect water resources for a sustainable future. In this context, water conservation refers specifically to freshwater resources. Water conservation includes how water resources are used and managed as well as how policies shape the use and management of water resources. Conservation of water resources is often closely associated with water-use efficiency, which is achieving the maximum productivity with minimal waste.

In a general sense, water conservation is related to environmental health because humans depend on clean water for various purposes, and many water conservation strategies change how humans use water. Using less water and creating less wastewater is usually considered an important water management strategy. However, some water conservation efforts have the potential to pose a public health threat if not carried out appropriately. For example, one method of water conservation is gray water recycling, which is the use of domestic wastewater (e.g., shower or laundry water) for a secondary purpose, such as watering a lawn. If the gray water used to water a lawn drains into a nearby creek, contamination of the creek with water used by humans could occur. Thus, we cannot take for granted that water conservation and water quality always go hand in hand.

Water supply is driven by what is referred to as water demand, which indicates how much water is needed. Water demand tends to increase with increasing population. While estimates vary, an average estimate of water use per person in the United States is about 100 gallons per day. As the population of a town or region increases, more water is required to satisfy the needs of more people. For example, the additional food consumed by an increasing population requires increased agricultural production, which tends to use large amounts of water. An increasing population also requires additional energy, which can also use water in large quantities, depending on the energy source. Because satisfying water demand depends on finite water resources, water conservation is one way to ensure that water is used efficiently and sustainably.

Water on the earth appears plentiful, covering about 70 percent of the earth's surface. However, almost all of the water on the earth is saltwater in the oceans, and only about 2.5 percent is freshwater suitable for humans use. Much of this freshwater is frozen in the icecaps of Greenland and Antarctica, and consequently, only about 1 percent of the water on the earth is easily accessible. This is why water is often referred to as a finite resource, which means the availability of water is limited and conservation may be needed to ensure an adequate supply.

This limited amount of the earth's freshwater is considered a vital resource that is essential for a variety of purposes, including human consumption, agricultural irrigation, energy production, sanitation and hygiene, and various industrial, commercial, and leisure activities. According to the U.S. Geological Survey, the top three uses of freshwater in the United States are thermoelectric power generation, irrigation, and public water supply. Realizing that water, a finite resource, has so many essential uses helps us put the importance of water conservation into perspective.

The top use of freshwater in the United States is for energy. This is often referred to as the water-energy nexus because water and energy are so intimately interconnected. It generally takes a large amount of water to produce energy, and a considerable amount of energy is needed to manage water resources. Water and wastewater utilities have programs in place to increase both energy and water efficiency.

Irrigation is the second most demanding sector for water. Several advances in irrigation practices have helped reduce the amount of water needed to achieve the same crop yield on farms. For example, converting from high-pressure to low-pressure irrigation systems has made a significant difference in water use. Additionally, watering at the appropriate time of day can reduce water that is lost to evaporation. There are many other good examples of how water has been conserved in agricultural irrigation practices.

At the residential level, water-efficient appliances, such as washing machines that use less water and low-flow toilets, can conserve water. Behavioral changes can aid in water conservation too, such as taking shorter showers or turning off water flow while lathering the soap in your hands or brushing your teeth. While estimates vary, research suggests that outdoor water use accounts for over half of residential water use. Effective outdoor water conservation measures include limiting lawn watering and planting native crops that are adapted to a region's natural precipitation patterns.

Urban areas are increasingly optimistic about implementing water conservation strategies. As urban populations increase, water demands are growing, and the supply infrastructure may not always be adequate. Consequently, most major cities in the United States have launched water conservation programs. For example, New York City has implemented several programs, including a Water Demand Management Plan, Municipal Water Efficiency Program, Residential Water Efficiency Program, and Upstate Water Conservation Program. Urban water conservation plans are often targeted to save water and energy, with the added advantage that consumers may spend less on their water bills.

One important uncertainty in planning for future water demands and the potential impact of water conservation involves the growing threat of climate change. There is overwhelming consensus in the scientific community that global warming will affect future climate patterns, including more severe droughts and flooding, which will ultimately impact water supplies. Many cities are incorporating water conservation into their water management plans to counter the potential effects of climate change.

A large number of city, state, and federal programs exist to achieve water conservation goals. Two notable examples are the WaterSense program, run by the U.S. Environmental Protection Agency (EPA), and the Energy Star program, which is a joint venture between the EPA and the U.S. Department of Energy. A number of organizations have formed to advocate for water efficiency, conservation, and education, such as the Alliance for Water Efficiency. Additionally, ongoing academic research aims to evaluate and improve water conservation efforts.

Elise C. Hunter

See Also: Drinking Water Quality and Regulation; Drought and Desertification, Health Consequences of; Energy Star; Environmental Protection Agency; Intensive Farming Practices and Health; Municipal Solid Waste Management; Safe Drinking Water Act; Water Reuse and Recycling

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WATER POLLUTION

Safe and clean water is essential to human and environmental health. Water pollution is the contamination of waterbodies by chemical, physical, or disease-causing substances. According to World Health Organization (WHO), water pollution is considered a leading cause of death and disease worldwide. Water pollution also impacts the health of aquatic organisms, disrupts food chains, and destroys ecosystems.

Water pollution comes from a variety of sources, although most instances are a result of human intervention. Point-source water pollution refers to contamination

Arsenic in Bangladesh

The geological composition of aquifers can cause leaching of toxic elements into drinking water supplies. The main elements of concern are arsenic, fluoride, selenium, chromium, and uranium. In Bangladesh, arsenic-contaminated groundwater affects between 35 and 77 million people. Arsenicosis, or arsenic poisoning, symptoms can include skin problems and lesions, high blood pressure, and cancers of the bladder, kidney, and lungs. Approximately 1 in 100 people who drink arsenic-contaminated water (0.05 milligrams of arsenic per liter or greater) for a long period may eventually die from arsenic-related cancers.

originating from a single, identifiable source, such as a pipe or oil spill. Point-source pollutants typically are found near business, industry, agricultural, or urban sources. About 30 percent of the globally accessible freshwater is used by industry and municipalities. After processing, factories and sewage treatment plants discharge point-source wastewater, or effluents, directly into streams and rivers. In many parts of the world, these wastewaters are still untreated or else undergo treatment that does not effectively remove the majority of the pollutants.

When water pollution comes from many sources, it is considered nonpoint-source pollution. These diffuse pollutants often are associated with runoff from agricultural or urban areas. As stormwater flows over surfaces like pastures, parking lots, and lawns, it picks up chemicals and pollutants. This untreated water then flows directly into waterbodies. Large amounts of stormwater runoff can make small concentrations of pollutants, like fertilizer, sediment, and trash, a serious problem. All types of waterbodies, including lakes, streams, oceans, and groundwater, are susceptible to point-source and nonpoint-source pollution. Management and prevention of pollution is highly dependent on source type as well as the type of pollution.

Pollutants can be classified according to their chemical, physical, or disease-causing contaminants. Regardless of whether chemicals are naturally occurring or introduced by human interference, their concentrations and toxicities determine the degree of contamination and health hazard. Some chemical pollutants cause acute illnesses, while others damage human health (and the health of other organisms) over long periods, and some man-made chemical pollutants can be dangerous to human health even at low concentrations.

Common chemical pollutants include nutrients (nitrogen and phosphorus) from agricultural runoff, heavy metals from mining activities, toxic synthetic organics from pesticides, and radioactive waste. The sources and impacts of these common pollutants are reasonably well understood, but designing sustainable treatment technologies for them remains a challenge. For example, nutrients enter the environment from a wide range of human activities (agriculture, stormwater, wastewater, and residential runoff) that are difficult to pinpoint and reduce. High nutrient concentrations can lead to increased production of biomass, oxygen depletion, and toxic algal blooms.

Another source of chemical pollutants is gold mining by chemical extraction using mercury amalgamation (the process of merging gold and mercury for easier recovery of the precious metal). About 13 million miners in 55 countries increasingly practice this mining approach. During the process, waste mercury is discharged into the environment, including surface water, where it biomagnifies and then presents a health risk to indigenous populations. (Biomagnification is the increasing concentration of a substance in the tissues of organisms at successively higher levels in a food chain.) People are exposed to mercury by eating contaminated fish and wildlife that are at the top of aquatic food chains. When concentrations in humans are high enough, the mercury may act as a neurotoxin, causing harm to the brain and nervous system. Mercury exposure is especially dangerous to pregnant women and young children.

Persistent organic pollutants (POPs) are chemicals that are of great environmental concern. These chemicals persist for long periods and can bioaccumulate, passing from one species to the next through the food chain. Many of these toxic chemicals have proved beneficial in pest and disease control, crop production, and industrial manufacturing. These same chemicals, however, are believed to effect human health and the environment. For example, some of these chemicals are very similar to human hormones and are called endocrine disruptors, which may cause human developmental problems, deformations, and cancers. Well-known POPs, such as PCBs, DDT, and dioxins, are now highly regulated and are no longer produced in the United States.

Radioactive substances represent a small portion of chemical pollutants, although the associated health hazards could be significant. The degree of health concern is determined by the concentration of the contaminants, energy of the radiation being emitted, type of radiation, duration of exposure, and proximity of the contamination to the human body. Ingestion of radioactive contamination can cause cell death, genetic mutations, cancers, birth defects, and reproductive, immune, and endocrine system disorders. Radioactive contamination sources include nuclear power plants and research facilities, phosphate fertilizer, and naturally occurring nuclides in rocks and soil.

Unlike chemicals, physical pollutants alter the physical properties of the water, such as temperature and turbidity (water clarity or cloudiness). Thermal pollution changes the ambient water temperature and can be caused by the release coolant water by industrial facilities or by urban stormwater runoff. Elevated temperatures reduce dissolved oxygen concentrations, which can harm aquatic organism. As a result, food chains can be disrupted and biodiversity decreased. Excessive sediment, resulting from overintensive land-use practices, is considered the leading cause of pollution in rivers and streams in the United States, where sediment pollution causes approximately $16 billion in environmental damage annually. Sediment blocks sunlight, destroys habitat, and clogs fish gills, ultimately disrupting the natural food chain and altering water flow.

Disease-causing microorganisms, or pathogens, are often found in waters contaminated with human or animal feces. According to the WHO, 3.4 million people, mostly children, die from water-related diseases each year. High levels of pathogens may result from inadequate treatment of sewage discharge or poorly managed livestock. This is a common problem in developing countries, where many areas lack sanitation systems altogether. In Africa and Southeast Asia, cholera and typhoid fever are the primary causes of infant mortality. Although water-associated diseases are more prevalent in areas with inadequate sanitation, they are also a serious challenge in developed countries. Compiled data of disease outbreaks in the United States (1986–2000) indicate nearly 6,000 cases and 100 outbreaks associated with contaminated recreational water and over 400,000 cases and approximately 50 outbreaks caused by contaminated drinking water. Two common disease agents are *giardia lamblia* and *cryptosporidium*, both of which are parasitic, single-celled organisms common in the fecal material of many mammals.

The main cause of water pollution is improper management of water resources. The WHO as well as individual national governments have adopted strategies to manage water quality, with the goal of protecting and promoting human health. These agencies work to improve access to safe drinking water and sanitation and to encourage behavioral changes. It is estimated that over the years, better water management has provided 2.6 billion people access to an improved drinking-water source, although improved sources are not necessarily safe.

In the United States, water pollution reached crisis proportions by the early 1970s. This resulted in Congress passing the 1972 Clean Water Act, with the main objective "to restore and maintain the chemical, physical and biological integrity of the Nation's waters." The act requires regulation of point-source pollution through limitations set by the U.S. Environmental Protection Agency. Industrial, municipal, and other facilities must obtain a National Pollutant Discharge Elimination System permit to legally discharge pollutants into a waterbody. Additionally, under Section 303(d) of the act, states, territories, and authorized tribes are required to develop lists of impaired waters that are too polluted or degraded to provide acceptable water quality. The law requires jurisdictions to establish priority rankings for waters on these lists and develop Total Maximum Daily Loads (TMDL). A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards. The act was later expanded to include section 319, which aids jurisdictions in reducing nonpoint source pollution by granting money to support a wide range of nonpoint source management programs. To tackle drinking water quality, the Safe Drinking Water Act was passed in 1974 and stands as the principal federal law to ensure safe drinking water for the public by setting national health-based standards for both naturally occurring and man-made contaminants.

Remediating global water pollution requires an effective set of policies, technologies, and scientific advances. Water, unlike many other natural resources, does not have a substitute. Restoring and protecting the quality of water, therefore, is of highest priority. With more than one-third of the earth's accessible renewable freshwater used for agricultural, industrial, and domestic purposes, and with most of these activities leading to water contamination, water pollution will continue to be a major societal concern.

Chelsea N. Peters

See Also: Arsenic Pollution; Bioaccumulation of Environmental Contaminants; Clean Water Act; Combined Sewer Overflow; DDT Exposure; Deepwater Horizon Incident; Drinking Water Quality and Regulation; Great Lakes Pollution; Groundwater Pollution and Depletion; Mercury Pollution; National Estuary Program; National Pollution Discharge Elimination System; Oil Spills, Health Consequences of; Persistent, Bioaccumulating, and Toxic Chemicals; Pesticides and Herbicides; Polychlorinated Biphenyls; Radiation, Ionizing and Nonionizing; Radiation Sickness; Radioactive Wastes; Safe Drinking Water Act; Sewage Treatment and Disposal; Stormwater Runoff; Thermal Pollution; Waterborne Diseases; Watershed Management, Health Implications of; Wetlands and Healthy Waterways; World Health Organization

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WATER REUSE AND RECYCLING

Water is fundamental to life. Not only do humans need it to survive, but virtually every human activity requires water. For example, manufacturing facilities, power plants, oil and gas refineries, and agricultural operations all rely on water to produce the food we eat, the energy we rely on, and the products we buy. Agriculture alone accounts for approximately 80 percent of daily U.S. water consumption. Water reuse and recycling is essential to having a healthful and plentiful supply of water, particularly as water uses continue to grow. ("Recycling" and "reuse" are generally considered synonymous terms.)

Increasing population, especially in arid regions, and growing threats of severe drought due to climate change have boosted the demand for freshwater and made water conservation efforts more urgent. Finding ways to safely and effectively reuse wastewater increases the supply of freshwater and may also improve water quality, protecting the environment and human health and providing economic benefits.

Ensuring Future Clean Water Supplies

With worldwide population growth, particularly in urban areas, and climate change threatening more severe and prolonged droughts, public water supplies are becoming increasingly stressed. One solution to this problem involves the concept of direct potable reuse (DPR), where treated municipal wastewater meeting drinking water standards is introduced to a water treatment plant or channeled directly into a water distribution system. The technology is currently available, and many communities in the United States are beginning to explore the possibilities. (In 2013, Big Springs, Texas, became the first U.S. town to implement DPR.) Although overcoming the "yuck" factor may be a challenge, DPR could become commonplace in the future as water supplies become increasingly threatened.

Virtually any water that flows into a sewer or is discharged from an industrial facility can be reused. One example is sewage from our toilets that is channeled to a wastewater treatment plant, representing a potential source of reusable water for many cities. We already practice a form of wastewater reuse when upstream wastewater treatment plants discharge treated water to a river while downstream populations draw drinking water from that river. However, this type of unplanned reuse is not as efficient as planned projects to reuse water.

Currently, most planned water reuse projects involve using domestic wastewater for purposes other than drinking water. This includes water for irrigation, landscaping, and industrial uses. Because domestic wastewater typically contains only about 0.1 percent solid waste, the remaining 99.9 percent can be treated and safely reused. Recycled water often is treated only enough to satisfy the needs of its intended use, avoiding end users the cost of unnecessary further treatment.

One example of domestic wastewater reuse comes from Honolulu, Hawaii. The city has constructed a water reuse facility that filters and further treats effluent (the polluted discharge) from its wastewater treatment plant and then uses that water for golf course, agriculture, and landscaping irrigation and for industrial purposes. This results in decreased reliance on fresh drinking water supplies. Additionally, the treatment plant discharges less wastewater into the Pacific Ocean, resulting in a cleaner ocean environment.

Reuse of gray water has also become more popular and can have substantial environmental benefits. Gray water refers to water in offices or homes that has not come in contact with human or animal waste, for example, water from kitchen sinks, washing machines, and showers. This water can be safely reused on-site, with little or no additional treatment, for irrigating lawns and landscaping and flushing toilets, thereby reducing the amount of fresh drinking water typically used for these purposes.

Some areas are now considering direct potable reuse (DPR), where wastewater is treated with advanced technologies and then pumped directly into a drinking water treatment plant or supply system. Of course, the water must meet all drinking water quality standards before it is distributed to the drinking water system. DPR has been used successfully both internationally and in the United States. Although some people are concerned about drinking wastewater, it can be entirely safe to drink if properly treated and handled. The technologies associated with water reuse are sufficiently advanced such that regulatory authorities have recognized that safe, reliable drinking water can be produced from wastewater. However, cost can be a limiting factor for DPR.

Recycled water is also used to recharge underground aquifers (sources of underground drinking water) in a process known as indirect potable reuse. When underground sources of drinking water become depleted, injecting clean water into them can replenish the supply. In coastal areas, this can be especially important because saltwater can migrate into aquifers if there is insufficient freshwater to keep it out. For these purposes, recycled water is treated, typically to drinking water standards, and then injected into wells or placed in recharge ponds, where the treated water filters through soil before moving into the aquifer. This injected water can later be recovered from the aquifer for human consumption.

Many states, tribes, and other authorities have regulations addressing recycled water use and treatment, and the U.S. Environmental Protection Agency has developed comprehensive water reuse guidelines to support these regulations and facilitate further development of water reuse practices.

Leah A. Dundon and Richard S. Davis

See Also: Drinking Water Quality and Regulation; Drought and Desertification, Health Consequences of; Environmental Protection Agency; Groundwater Pollution and Depletion; Industrial Effluents; Recycling; Sewage Treatment and Disposal; Water Conservation

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WATERBORNE DISEASES

Water is essential for life on the earth. However, water can also be a source of illness when contaminated with pathogenic (disease-causing) organisms or toxic elements. A wide variety of waterborne diseases are caused when certain bacteria, protozoa, viruses, parasites, and metabolic toxins are present in water. These agents cause disease when they are ingested as contaminated water or food, come in contact with skin, or are inhaled as water vapor. The most common type of illness they cause is gastrointestinal diarrhea disorders. However, some waterborne agents may cause skin disease, ear, nose, and throat problems, respiratory disease, or neurological disorders. The severity of waterborne disease can range from mild to potentially fatal, depending on the particular disease agent, the level of exposure, and the ability of the person or animal to respond to the infection or toxin. The World Health Organization estimates that waterborne disease globally accounts for 1.5 million human deaths annually, with 58 percent of those due to unsafe water supply and lack of sanitation and hygiene. The importance of waterborne disease has grown in recent years due to several factors: more people are susceptible to

Sensitivity to Waterborne Pathogens

It is estimated that 20 to 25 percent of Americans are more susceptible to illness, including waterborne diseases, than the average population. This includes the elderly, the very young, those with chronic illness, and those with compromised immune systems from diseases (e.g., AIDS) or medical therapy (e.g., chemotherapy or organ transplants). These sensitive subpopulations are more likely to experience illness from exposure to low levels of waterborne pathogens that would not otherwise cause illness. This manifests in higher rates of disease, medical treatment, hospitalizations, and deaths among sensitive populations.

illnesses, diseases are spread more easily with rapid global commerce, the increasing virulence of microbes, and changing environmental conditions that favor more waterborne disease outbreaks.

People and animals can be exposed to different waterborne pathogens through a variety of contaminated water sources. These sources include contaminated treated drinking water; treated swimming pool or bathing water; untreated ambient waters in lakes, streams, and oceans; and exposure to contaminated industrial waters (e.g., cooling systems in buildings). The most common exposures occur from drinking water that is contaminated due to either the failure or absence of effective water treatment practices. In spite of strict water treatment requirements, there are still millions of cases of waterborne diseases each year of various etiologies (causes). The actual disease burden is not known since so many cases go unreported. However, U.S. federal agencies have been tracking significant waterborne disease outbreaks for several decades. Between 1971 and 2002, they reported on 764 waterborne disease outbreaks associated with drinking water. Of those outbreaks, 12 percent were caused by chemicals, 14 percent by bacteria, 19 percent by protozoa, and 8 percent by viruses. However, in nearly half of the outbreaks since 1971, they were not able to identify the cause and were simply labeled as unknown acute gastrointestinal illness. The undiagnosed cases are often thought to be viral in origin, but that is difficult to verify. Those 764 outbreaks resulted in over 575,000 cases of illness and 79 deaths. However, the actual incidence of waterborne disease is likely much higher due to lack of medical care and nonreporting. One study estimated that as many as 7 million people may fall ill each year from waterborne microbial infections, with up to 1,000 deaths per year in the United States.

Recreational water use is another significant source of waterborne illness. This can occur both in treated waterbodies, such as swimming pools and hot tubs, and in open ambient water in rivers, lakes, and oceans. Exposures in treated water are generally caused by inadequate water treatment or unsafe behaviors by users, such as fecal contamination of the pool. Exposures in natural water bodies are often associated with heavy rainfall events that raise the level of pathogen load in the water body through polluted stormwater runoff or failure of sewer lines or septic systems. In 2010, a rare natural event allowed researchers to study the rate of waterborne disease in triathlon swimmers in the oceans off Denmark and Norway. They compared the disease incidence in swimmers for the same triathlon race on two separate dates: one race following a major rainfall event and the other following a normal dry period. The rate of disease was 42 percent in the group that swam following the heavy rain and only 8 percent in the control group, for which rainfall did not precede the race. Infections in this study included *Campylobacter, Giardia lamblia*, and diarrhea-causing *Escherichia coli*. This and other studies have confirmed that there is risk to swimmers in contaminated freshwater or seawater.

Currently, more than 140 microorganisms have been recognized as waterborne pathogens able to cause disease from contaminated water sources. A variety of types of microorganisms, parasites, and toxins are capable of causing disease. The most common agents are protozoa, bacteria, and viruses. In addition, there are helminth parasites (worms), toxic algae, and other biotoxins that may also cause waterborne disease.

Protozoan parasites are single-celled organism that are frequently associated with diarrheal disease. They live in the intestinal tract of people and animals and are spread by fecal contamination. Their reproductive oocysts are resistant to conventional disinfectants used in water treatment and thus can persist in treated drinking water supplies. The two most common protozoa diagnosed are *Giardia* and *Cryptosporidium*, both of which have caused significant disease outbreaks in the United States.

- *Giardia* is a protozoan parasite and is the most common pathogen diagnosed in waterborne outbreaks. It can be found in water, soil, and food.
- C*ryptosporidium* (Crypto) is a single-celled protozoan parasite that infects people and animals. It can cause infection by ingestion or skin contact with water or soil.

Bacteria are the second most common cause of waterborne disease. As a group, they are more sensitive to water treatment practices and most often cause disease through direct fecal contamination or failure of a treatment system. Examples of these single-celled organisms and the illnesses they can cause include *Salmonella* (diarrhea and typhoid), *Shigella* (diarrhea), *Campylobacter* (diarrhea and nervous system disorders), *Vibrio cholera* (diarrhea and skin infections), *Escherichia coli* (pathogenic strains: diarrhea and hemorrhagic colitis), and *Legionella* (pneumonia and respiratory infections).

- *Escherichia coli* is a normal part of healthy intestinal bacterial flora. However, there are a number of pathogenic strains of *E. coli* that cause illnesses ranging from mild diarrhea to serious disease. The most virulent strain is *E. coli O157:H7*, which causes hemorrhagic colitis in its most severe form. The typical exposure is through contaminated food or water, especially from cattle, deer, sheep, and goats. It can be life-threatening in children and other susceptible individuals.
- *Salmonella* can cause serious, sometimes chronic diarrheal disease in people and animals, also known as typhoid fever.

- *Shigella* causes a disease called shigellosis, primarily in humans and other primates.
- *Campylobacter* causes a diarrheal illness and is mostly found in poultry, other animals, and people.
- *Vibrio cholera* is commonly associated with coastal marine waters and shellfish. It can also be transported in ship ballast water. Exposure occurs from ingesting contaminated water, eating raw shellfish, especially oysters, or entry through a wound in the skin. It causes cholera, which is resistant to antibiotics and can cause fever, chills, skin infections, and life-threatening septicemia.
- *Legionella* is associated with inhalation of contaminated water vapor from industrial sources, such as cooling systems in buildings. It causes two types of respiratory disease: Legionnaire's disease (severe pneumonia) and Pontiac disease (influenza-like disease).

Viral pathogens also frequently cause waterborne illnesses. Most of these viruses are in the enterovirus family (intestinal viruses), which colonize the intestinal tract and damage cells, causing inflammation, vomiting, and diarrhea. Some viruses can survive weeks or months in water and still cause disease. Viral infections in people are often self-limiting and of short duration, but they can be serious in sensitive individuals. More virulent viruses can also cause meningitis, myocarditis, respiratory disease, and nervous system disorders. Examples of the more common waterborne viral agents are hepatitis A (inflammation of the liver), Norovirus (diarrhea), Rotavirus (diarrhea, especially in children), plus astroviruses, adenoviruses, and other enteroviruses.

Biotoxins are another type of waterborne pathogen. They are most often associated with harmful algal blooms that occur with excessive nutrient water pollution and warmer, stagnant waters. Harmful algal blooms are becoming more frequent and disruptive, especially in the Great Lakes region and along the Florida coastlines. The biotoxins released from the thick algal mats pose a serious risk to people and aquatic life. They also disrupt use of source waters for drinking water treatment and have caused water shortages until eliminated from the area.

Helminth parasites are worms, such as trematodes (tapeworms) and cestodes (flukes), that infect people and animals. In many cases, these helminths have life cycle stages that involve an intermediate host animal, such as an aquatic snail or copepods, before they reach their final host in either people or other animals. They may exist free in the water for part of their life cycle and tend to be resistant to water treatment techniques. The diseases they cause vary with each agent, ranging from intestinal colonization to skin infections to invasion of nasal passages or eyes.

Many of these waterborne diseases are zoonotic disease agents, meaning that the disease can be transmitted between (or shared by) both animals and humans. The transmission potentially goes both ways for many bacteria, protozoa, viruses, and parasites. This means that wildlife, livestock, companion animals, and people share many of the same waterborne diseases. Examples of zoonotic waterborne parasites includes *Giardia, Cryptosporidium, Blastocystis, microsporidia*, *toxoplasma, Cyclospora*, amoeba, trematodes, cestodes, and others.

In rural communities, where open fields may be used to spread untreated livestock waste or biosolids from treated municipal sewage, this becomes a ready source for fecal contamination downstream during heavy rainfall events. Some outbreaks have occurred in cities where a major rainfall or spill from a manure lagoon has occurred in an upstream rural location. The largest outbreak in U.S. history occurred in the city of Milwaukee when an epidemic of *Cryptosporidium* protozoan parasites sickened over 400,000 people in the spring of 1993. The Milwaukee water source is Lake Michigan, and it was speculated that the water source in Milwaukee harbor was polluted by upstream cattle, slaughterhouses, or possibly human sewage. The waters of the Great Lakes continue to be at risk from various waterborne microorganisms and toxins, especially in light of increasingly warm waters and extreme rains sending excessive contamination of nutrients and fecal material into the lake ecosystem. Harmful algal blooms with exposure to algal toxins is another ongoing risk in the Great Lakes and other lakes around the country.

The factors that cause a waterborne disease outbreak involve much more than just the pathogen. When considering any waterborne disease, it is important to understand their full life cycle and the interrelationships with the ecosystem and organisms that are susceptible to their pathogenic effects. An outbreak happens as a result of complex interactions between weather conditions, water quality and quantity, presence or absence of treatment practices, occurrence of a pathogen, the immune competence of the patient, and the ultimate incidence of disease. Water quality is very closely associated with a variety of environmental conditions, including air and water temperature, extreme precipitation patterns (flood or drought), the land use of the watershed that drains to the source water, and the nature of contaminants carried by rainfall into streams, lakes, and reservoirs. Water temperature is a sensitive parameter, and many pathogens or toxic algae thrive in warmer waters while native aquatic species are often harmed by warmer waters with lower oxygen levels.

The strongest environmental influences on disease outbreaks are heavy rainfall events that result in large volumes of stormwater runoff flowing into lakes and streams. This runoff often carries heavy loads of pathogens and chemicals picked up across the landscape on its way to the body of water. A number of studies have shown a consistent correlation between heavy rainfall and outbreaks of waterborne disease. Intense rain and flooding reduces water quality in three main ways: direct contamination with fecal material from stormwater runoff into surface and groundwater sources, infiltration of contaminated runoff into drinking water lines due to aging infrastructure, and combined sewer overflow events that overwhelm the drainage system and send raw sewage directly into nearby rivers and streams. The high volumes of water and pathogens can temporarily overwhelm water treatment facilities and lead to contaminated finished drinking water.

Many studies have also documented an association between increased turbidity (cloudiness) of water sources and increased rates of pediatric illness. Higher turbidity levels can decrease the effectiveness of water purification methods and increase the pathogen load in the water supply. These associations with heavy rainfall and increased turbidity are of increasing importance with changing climate conditions. More frequent intense precipitation and flooding events are already occurring in every region, and that pattern is projected to increase in future decades. The combination of heavy rainfall, warmer waters, and increasing rates of land disturbance from farming or development is causing more erosion and turbidity. This, along with greater pathogen contamination, is setting the stage for higher rates of disease on a regular basis in the future. Understanding the environmental factors contributing to disease outbreaks is important for developing methods to predict and mitigate increased risks in the future.

The variety and complexity of different waterborne diseases make it difficult to identify simple prevention measures that benefit most of the causes of illness. General prevention methods primarily hinge on vigilant surveillance of bodies of water and disease incidence in the population. Beyond surveillance, it is important to take a system-wide approach to understanding the multifactorial nature of these disease outbreaks. These outbreaks take a serious toll on social and economic resources of society. A multidisciplinary "one health" approach may be beneficial to reducing adverse effects. Outbreaks occur when the conditions are right for ecological systems, weather conditions, water quality and quantity, animal health, human health, water treatment systems, and watershed conditions. Prevention efforts could be improved with a collaborative structure involving ecologists, public health agencies, veterinary health professionals, water utilities, agricultural agencies, stormwater managers, recreational leaders, and facility operators to work together to educate water users and optimize systems to protect human, animal, and ecological health.

Gwen Griffith

See Also: Cholera; Climate Change and Human Health; Drinking Water Quality and Regulation; *Escherichia coli* (*E. coli*) Infection; Infectious Diseases; Legionnaires' Disease; Norovirus Infection; Stormwater Runoff; Water Pollution; World Health Organization; Zoonotic Diseases

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WATERSHED MANAGEMENT, HEALTH IMPLICATIONS OF

Watershed management is the process of creating and implementing plans to protect watershed functions within the watershed boundary itself. The objective of watershed management is to sustain and enhance a watershed's ability to provide goods and services to the communities that depend on it. Using watersheds as basic organizing units allows effective management of mutually dependent interactions in a dynamic system. Healthy watersheds provide ecosystem, economic, and physical and mental health benefits, and the goods and services made possible by healthy watersheds are essential to social, environmental, and economic well-being.

Most natural resource problems are transboundary in nature, that is, they are intermunicipal, interstate, or international. Thus, there is rarely a single institution with legal jurisdiction over a natural resource. Natural resources, especially water, can cross recognized political boundaries, thereby creating situations where one jurisdiction's approach to resource management may not consider effects on neighboring jurisdictions. Watershed management addresses this problem by promoting a holistic, problem-solving approach that includes engagement with a variety of community stakeholders.

The U.S. Environmental Protection Agency (EPA) defines a watershed as a geographic area in which water drains to a common outlet, typically a point on a stream, lake, aquifer, estuary, or ocean. Watershed management is not limited to water supply, water quality, and water rights issues but extends to the overall planning and use of watersheds, including hydrological, geographical, geological, and biological aspects. Landowners, land-use agencies, stormwater management experts, environmental specialists, water-use surveyors, and communities all play an integral part in watershed management.

Watershed Management in New York City

New York City, the largest city in the United States, chose watershed protection over a more expensive filtration plant. The city was faced with an estimated $6 billion in capital costs and at least $300 million in annual operating and maintenance costs for the filtration plant. Instead, New York City opted to reduce its costs by negotiating a watershed protection program with state, federal, and environmental stakeholders, as well as with 70 watershed towns and villages. The program required a comprehensive watershed protection initiative in the Catskill-Delaware watershed, which supplies 90 percent of the New York City's drinking water.

Watershed management aims to regain healthy components of the landscape and ecosystem in disturbed watersheds. The health of a watershed can be defined by its landscape condition, biotic communities, ecological processes, water chemistry, and hydrologic and geomorphic processes. Together, these aspects support a healthy watershed.

There are many benefits to healthy watersheds. These benefits are called ecosystem services. Examples of these services include nutrient cycling, erosion control, increased biodiversity, soil formation, amelioration of air pollution, enhanced wildlife movement, water filtration, flood control, water storage, provisioning of food and timber, recreation, and finally, reduced vulnerability to invasive species, the effects of climate change, and other natural disasters. Watershed management seeks to sustainably protect and enhance these services in a sustainable manner within the watershed geographical boundary.

Healthy watersheds provide sufficient amounts of clean water required for aquatic ecosystems, habitat for fish and wildlife, drinking water, and recreation. This clean water has direct implications for the health and well-being of communities. For example, by preserving the ability of natural landscapes to filter pollutants, communities can reduce costs of drinking water treatment while ensuring a healthy drinking water supply. According to the National Resource Council, two-thirds of the U.S. population consumes water originating from forested lands. Precipitation in these areas infiltrates into the ground, where roots, soil, and sediments remove many of the impurities in the water. Through this process, toxins, excess nutrients, and sediments can be filtered before the water reaches a source of drinking water. A recent study found that about half of the variation in water treatment costs among municipalities could be explained by the area of forest cover in the water source area. Thus, a healthy watershed often means lower treatment costs as well as cleaner water.

Healthy watersheds can also help reduce vulnerability to climate change and natural disasters. Watersheds with sufficient natural land cover and soil resources can store significant amounts of carbon, helping to offset greenhouse gas emissions. Forest trees absorb carbon dioxide, ground-level ozone, carbon monoxide, and other greenhouse gases. It is estimated that the world's forests absorb as much as 30 percent of the annual global anthropogenic carbon dioxide emissions. Furthermore, intact floodplains and riparian zones are better adapted to changes in precipitation and floods. The EPA estimates that floods cause an average of \$8 billion in damage every year in the Unites States. And according to the National Oceanic Atmospheric Administration, floods also cause an average of 70–80 U.S. fatalities annually. Healthy watersheds reduce the area and impact of floods by preventing runoff from moving rapidly across the landscape, often storing excess water.

There are social and health benefits to living in healthy environments. Proximity to green space and nature encourages physical exercise and provides mental stress relief. Evidence suggests that workplaces with views of green space have employees who report fewer incidences of illness, and the positive influences of green space may extend beyond general health by influencing the degree of social interaction, level of mental fatigue, and number of opportunities for reflection. It is even thought that urban green space users have greater longevity. The World Health Organization defines "health" as being a state of complete physical, mental, and social well-being, not only the absence of disease. This key public health concept of well-being encompasses a wide array of biological, sociological, economic, environmental, and cultural factors, some of which are addressed by watershed management.

The EPA implemented its Healthy Watersheds Initiative as an integrated, systems-based approach to watershed protection. The initiative aims to meet the Clean Water Act Section 101(a) objective of restoring and maintaining the chemical, physical, and biological integrity of U.S. waters. Because the rate at which new waters are being listed for water quality impairments exceeds the pace at which these waters can be remediated, the initiative provides support for state watershed programs, integrates watershed policies into national programs, and increases public awareness through outreach programs.

Chelsea N. Peters

See Also: Clean Water Act; Deforestation; Drinking Water Quality and Regulation; Environmental Protection Agency; Green Space in Urban Environments; National Oceanic and Atmospheric Administration; Natural Disasters; Safe Drinking Water Act; Stormwater Runoff

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WEST NILE VIRUS

The West Nile virus (WNV) is a pathologic virus that is typically transmitted to people through the bites of mosquitoes. Mosquitoes also transmit WNV to, and cause illness in, other animals, most notably birds and horses. In addition to mosquito bites, the virus can be transmitted through blood transfusions, organ transplants, laboratory exposure, and mother-to-baby transmission during pregnancy, delivery, and breastfeeding.

Infection with WNV causes no symptoms in roughly 70 to 80 percent of people, according to the Centers for Disease Control and Prevention (CDC). However, one in five infected people will experience fever and other symptoms, such as headache, body ache, fatigue, vomiting, diarrhea, and rash. Most of those individuals fully recover within a few weeks. Such illness is known as nonneuroinvasive WNV disease.

In a small proportion of infected individuals—less than 1 percent—a severe and sometimes fatal neurologic illness can develop. Such illness is broadly classified as neuroinvasive WNV disease, though specific cases include such neurologic conditions as meningitis and encephalitis. Symptoms of these conditions may include disorientation, tremors, seizures, paralysis, and coma. Recovery from these conditions could require months, and some effects may be permanent. Death results in about 10 percent of cases of neuroinvasive WNV disease.

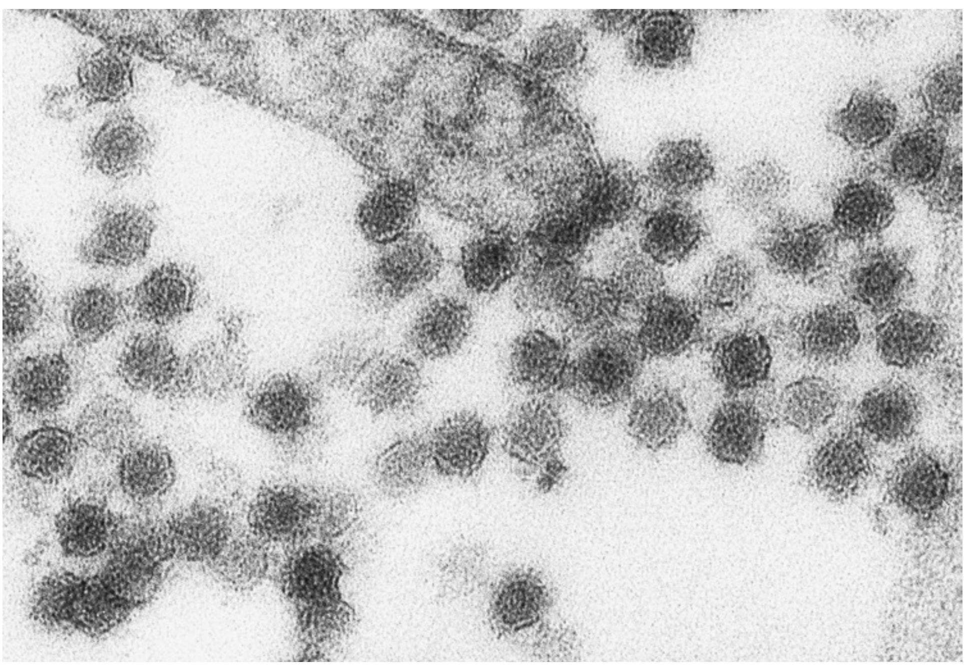

Image of the West Nile virus. The virus is most common throughout Africa, West Asia, and the Middle East, and it is typically transmitted by mosquito bites. (Centers for Disease Control and Prevention/Cynthia Goldsmith)

The prevalence of WNV disease varies from year to year. During 2016, the CDC received reports of 2,038 human cases of WNV disease throughout the United States. About 56 percent of those cases were neuroinvasive, and 44 percent were nonneuroinvasive. In the United States that year, 94 people died from WNV disease. From 1999 (the first year when WNV was detected in North America) to 2015, a total of 43,937 U.S. cases of WNV disease were reported to the CDC, including 1,911 deaths. Prevalence of the disease during that period was highest from:

- 2002 to 2008: ranging from a low of 1,356 cases with 44 deaths in 2008 to a high of 9,862 cases with 264 deaths in 2003.
- 2012 to 2015—ranging from a low of 2,175 cases with 146 deaths in 2015 to a high of 5,674 cases with 286 deaths in 2012.

Worldwide, WNV was first isolated in humans in 1937 in Uganda. Human cases of WNV disease continue to be most prevalent throughout Africa as well as in parts of the Middle East, West Asia, Europe, and Australia. Reliable global statistics on WNV disease prevalence are unavailable.

There are no effective medications to treat patients with WNV infection other than drugs to relieve the associated pain and reduce fever. Patients with severe WNV disease usually need to be hospitalized and receive such supportive treatment as intravenous fluids, prescription pain relievers, and nursing care.

A vaccine to prevent WNV infection is not yet available, although researchers around the world are working to develop one. The risk of contracting WNV can be minimized by covering the skin, including the arms and legs, with thick clothing to prevent mosquito bites and by spraying insect repellent over the skin. Windows and doors of homes should be kept closed or covered with screening to keep out mosquitoes during the warmer months.

A. J. Smuskiewicz

See Also: Centers for Disease Control and Prevention; Infectious Diseases; Insect-Borne Diseases; World Health Organization

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WETLANDS AND HEALTHY WATERWAYS

Wetland refers to an area of land that is frequently saturated with water. It is a unique ecosystem inundated by water where soils are dominated by anaerobic processes and plants are adapted to flooding or water-saturated soils. "Waterway" is a term used to describe a navigable body of water, such as a river, a canal, or another channel used by ships, boats, and small water vessels. Since wetlands and waterways provide habitat for wildlife, irrigation and drinking water, food, and other ecosystem services for humans, it is very important to ensure they remain productive and healthy.

Wetlands occur naturally in all countries and climatic zones, from the polar regions to the tropics. The largest wetlands include the Amazon River basin, the West Siberian Plain, and the Pantanal in South America. Wetlands can be either natural or artificial (constructed) and either permanent or temporary. The total area of wetlands in the world is about 33 percent larger than the United States, but massive losses of wetlands have occurred over the past decades worldwide, and the majority of remaining wetlands are degraded or under threat of degradation.

While the rate of wetland loss in North America is significant, the rate has slowed since the 1980s and remains low. However, a serious wetland loss problem exists in Asia. For example, the natural wetlands in China (3.8 percent of the terrestrial area) have suffered great losses and degradation, mainly due to severe population pressure and misguided policies over the past 50 years. In contrast, passage of the Clean Water Act of 1972 in the United States brought many improvements to surface water and removed much of the toxic and organic pollution going into wetlands and waterways.

There are four main kinds of wetlands: marsh, swamp, bog, and fen. The water in wetlands can be freshwater or saltwater. One unique characteristic of wetlands is the vegetation of aquatic plants that have adapted to the hydric soil (i.e., soil subject to saturation, flooding, or ponding such that anaerobic conditions have formed in the upper part of the soil.) Aquatic plants are essential for healthy wetland ecosystems because they reduce the amount of sediment in the water, remove nutrients, enhance pollutant breakdown, and provide food and shelter for invertebrates, frogs, reptiles, fish, and waterbirds.

Wetlands and waterways play an important role in the environment. Wetlands provide a wide variety of ecosystem services, such as (1) improving water quality by filtering sediment, nutrients, and pollutants; (2) reducing flood damage; (3) preventing shoreline erosion; (4) providing habitat for fish and wildlife; and (5) producing food, forest, and fuel products. Wetlands are considered one of the most biologically diverse and productive ecosystems, serving as home to a wide range of plant and animal life. Waterways provide resources for drinking, transportation, agricultural production, fisheries, flood control, and other services, including recreational and scenic values.

The multiple uses of wetlands and waterways have often led to significant changes in their structure and function, including alterations to catchment hydrology and sediment delivery, declining water quality, and loss of aquatic biodiversity. Pollution in the form of nutrients, such as nitrogen and phosphorus, and fine sediments can cause significant environmental problems. For example, nitrogen and phosphorus enhance the growth of algae and aquatic plants and, above certain levels, cause algae to grow very fast. Large algal blooms can eliminate the oxygen in a body of water, eventually killing most of the aquatic organisms, and the toxins produced by algal blooms can circumvent water treatment systems and directly threaten human health. If ingested or contacted, these toxins can cause skin irritation, stomach cramps, diarrhea, and even liver damage. Drinking water contaminated with bacteria may also lead to disease. This problem is greater in underdeveloped countries without water treatment systems but still sometimes occurs in developed countries.

Constructed wetlands have been widely used to improve water quality. These are artificial wetlands built to remove various types of pollutants, such as bacteria, nutrients (predominantly nitrogen and phosphorus), and metals present in wastewater and stormwater runoff. Constructed wetlands are designed to recreate the structure and function of natural wetlands that use natural processes involving wetland vegetation and soil and their associated microbial assemblages to improve water quality.

There are two types of constructed wetlands: surface-flow and subsurface-flow. Surface-flow constructed wetlands mimic natural environments and often have permanent standing water. In subsurface-flow wetlands, water passes laterally through a porous medium (usually sand and gravel) with a limited number of macrophyte species (i.e., plants visible to the naked eye). These systems often have no standing water. Constructed wetlands treat wastewater by filtration, settling, and bacterial decomposition, and the planted vegetation in constructed wetlands also plays a significant role in contaminant removal. In some cases, artificial wetlands provide additional benefits, such as groundwater recharge or habitat for waterfowl.

Assessing wetland health through monitoring is vital to their protection. This requires a strategic adaptive management plan that provides regular monitoring of a range of water quality parameters and other ecosystem attributes. Aspects of wetland and waterway health to be monitored include water quality and quantity (e.g., the concentrations of nutrients and pollutants in water), physical habitat (e.g., protective cover for fish, including woody debris), vegetation (e.g., types and productivity of species), physical parameters (e.g., the extent of erosion and sedimentation), and aquatic biology (e.g., the type and abundance of fish, invertebrates, phytoplankton macrophytes, exotic species, and algae). Effective management involves conservation and restoration of wetlands and their functions, including methods and approaches to protect wetland and aquatic resources, limit the pollution sources affecting waterways, and select and prioritize wetlands for restoration.

Dafeng Hui and Thomas D. Byl

See Also: Clean Water Act; Drinking Water Quality and Regulation; Ecosystems, Importance of; Stormwater Runoff; Water Pollution; Watershed Management, Health Implications of

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WOODSTOVE AIR POLLUTION

Emissions from residential wood heaters are an important air pollution problem and human health issue. Wood burning, even under ideal conditions, results in incomplete combustion during which the volatilized wood fuel condenses to form hazardous air pollution. Exposure to woodstove air pollution is widespread. Emissions from woodstoves and other wood heaters occur near ground level in residential communities across the country.

Unlike industrial stacks with sophisticated air pollution control devices and elevated emission release heights, millions of residential chimneys emit largely uncontrolled wood smoke relatively close to the ground and ultimately into homes and breathing spaces. Wintertime atmospheric inversions (dense cold air captured under warmer air) cause air pollution to be trapped close to the ground, where the fine (i.e., very small) wood smoke particles outdoors can readily enter homes and pollute indoor air. Consequently, even people living in homes without woodstoves or fireplaces are exposed to indoor air pollution from wood smoke if their neighbors burn wood. People in homes with woodstoves,

Wood Smoke: As American as Apple Pie?

For many people, wood smoke conjures up good memories and warm feelings of family time in front of the hearth and friends around a campfire. The truth is that the pleasant aroma of wood smoke belies its danger to human health and the environment. Wood smoke is a major contributor to particulate air pollution, especially in the winter. The serious health and environmental effects of particulate pollution are well studied and widely recognized. Wood smoke also contains carbon monoxide, nitrogen oxides, carcinogenic hazardous air pollutants, and climate change pollutants.

especially old, leaky woodstoves that emit some smoke into indoor air, are the most significantly exposed.

According to the U.S. Census Bureau's 2013 American Housing Survey, over 2 million U.S. residences burn wood as their primary heating fuel. However, it has been widely reported that there are approximately 12 million woodstoves being used in the United States as primary, secondary, or occasional heat sources. Moreover, the Hearth, Patio, and Barbecue Association estimates that more than half of all U.S. households have at least one fireplace or freestanding woodstove. The wood smoke emitted from these millions of chimneys across the country is a complex mixture of gases and fine particles composed largely of unburnt carbon and organic (carbon-containing) compounds. This mixture contains many different air pollutants that adversely affect human health and the environment, including fine particulate matter (PM), carbon monoxide, nitrogen oxides, toxic chemicals, and climate-change pollutants.

In the year 2011 alone, the U.S. Environmental Protection Agency (EPA) estimates that smoke from residential wood heaters and fireplaces contributed over 380,000 tons (345,000 metric tons) of fine PM throughout the country, mostly during the winter months. Wood smoke contains primarily $PM_{2.5}$, which is very small PM with an aerodynamic diameter of 2.5 microns or less. (A micron, also called a micrometer, is a unit of length equal to one-millionth of a meter.) These particles, which are less than 4 percent of the diameter of a human hair (much too small to be seen with the unaided human eye), are inhaled deeply into the smallest sections of human lungs. There they can remain lodged for long periods while contributing to respiratory diseases and structural damage. According to the EPA, exposure to PM, and in particular $PM_{2.5}$, has been linked by numerous scientific studies to health problems, including premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, and respiratory symptoms, such as irritation of the airways, coughing, and difficulty breathing.

Carbon monoxide in wood smoke decreases the blood's ability to carry oxygen to the brain, impairing thinking and reflexes and even leading to death. Carbon monoxide is also known to cause lower birth weights and increased deaths in newborns. Adverse health effects from nitrogen oxides include damage to the immune system by compromising the body's ability to fight respiratory infection. Those populations most susceptible to health effects resulting from inhaling wood smoke are infants and young children, the elderly, and anyone with existing heart or lung conditions or impairments, including smokers and ex-smokers.

The fine PM in wood smoke also carries into the lungs toxic chemicals classified by the EPA as hazardous air pollutants (HAPs). The EPA defines HAPs, also known as air toxics, as those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive problems and birth defects. HAPs in wood smoke, including acetaldehyde, acrolein, benzene, formaldehyde, and numerous polycyclic aromatic hydrocarbons, damage the respiratory tract, and many are known to cause cancer. In fact, according to the EPA's National Air Toxics Assessment published in December 2015, residential wood combustion in the United States accounts for nearly 50 percent of cancer risk from HAPs emitted by area sources. (Area sources are small air pollution emission sources like dry cleaners and auto body shops that individually do not account for much pollution but taken all together can be very significant in urban areas).

Beyond damaging human health, wood smoke also harms the environment. Reduced visibility (haze) is smoke's most obvious impact. Less obviously, the fine PM in wood smoke can be carried over very long distances before settling on the ground and water, where it can cause adverse environmental impacts, including acidification of lakes and streams. According to the EPA and numerous studies, PM deposition also changes the nutrient balance in watersheds and large river basins, leading to similar problems in coastal waters and the oceans. Additionally, soil nutrients can be depleted and forests and crops damaged, and ultimately, PM deposition can adversely affect the diversity of entire ecosystems. Finally, some pollutants in wood smoke, such as methane and black carbon, contribute to climate change.

Given the hazards of wood smoke, it is important to minimize woodstove emissions. The EPA has recognized this and first regulated PM emissions from some newly manufactured residential wood heaters in 1988. In May 2015, the agency promulgated updated PM emission limits for all newly manufactured residential wood heaters, which are to be phased in over five years, and even more stringent PM emission limits must be met starting in May 2020. The law does not apply to existing wood heaters in people's homes, but all new residential wood heaters for sale in the United States (including woodstoves, central wood furnaces, and indoor and outdoor wood boilers) must be certified to meet these PM limits. Furthermore, the PM level emitted by each wood heater model and the heater's energy efficiency (as measured by an EPA-required certification test) must be made available to the consumer on both the manufacturer's and the EPA's websites. To minimize woodstove air pollution, people should shop for the lowest emitting and most efficient wood heater and always use proper burn techniques, as discussed on the EPA's Burn Wise website.

Jill Warnasch Mozier

See Also: Air Pollution; Ambient Air Quality; Carbon Dioxide and the Carbon Cycle; Climate Change and Human Health; Environmental Protection Agency; Formaldehyde; Hazardous Air Pollutants; National Air Toxics Assessment; Particulate Matter and Bioaerosols Pollution; Polycyclic Aromatic Hydrocarbons; Regional Haze Pollution; Respiratory Disease and Air Pollution

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WORLD HEALTH ORGANIZATION

The World Health Organization (WHO) is an agency of the United Nations with a mission to advance international public health. Founded on April 7, 1948—now celebrated as World Health Day—the WHO provides leadership, surveillance, and technical support to countries around the world. This includes sharing expertise, logistical support, training, and directing research.

Headquartered in Geneva, Switzerland, the organization is made up of 194 member states. Representatives from these states form the World Health Assembly, which is the WHO's governing body. As an agency of the United Nations, it is administered through the Economic and Social Council. The member states are organized into six regions across the world, each with a regional office. These geographical groupings are the Americas, Africa, Southeast Asia, Europe, Eastern Mediterranean, and Western Pacific.

Using this global network, the WHO seeks to improve health among all people. It defines the concept of health broadly as a state of complete physical, mental, and social well-being and not just the absence of disease. Because many diseases and health conditions share environmental risk factors, the WHO's focus includes environmental health, which is prioritized to the needs of each region. According to WHO data, 23 percent of all deaths in the world (an estimated 13 million deaths) are attributed to unhealthy environments.

Current efforts include a focus on many environmental concerns, such as air quality, food and chemical safety, and vector control. The WHO is also a leader in water and sanitation, waste management, and climate change. For example, in response to the changing climate, the WHO provides information and technical support and advocates for science-informed public policy. While climate change affects all countries, it will be most severe for the poorest populations in developing nations. The WHO partners with groups in these nations to help raise awareness and build capacity for an effective response.

Water and sanitation remain key environmental concerns around the world. According to the WHO, almost 2 billion people worldwide get their drinking water from a contaminated source. Some diseases are directly linked to unsafe drinking water. In addition, scientists predict that in the future, half of the world's population will be living in areas where access to clean water is uncertain.

Further challenging the environment is unsustainable waste disposal. Sustainable waste management informed by science allows for safe disposal of a variety of waste materials, including chemical, solid, liquid, and hazardous wastes. As the global population increases, waste management is becoming a more pressing issue. The WHO works to find waste management solutions, especially in developing countries.

Charles Daniel

See Also: Climate Change and Human Health; Drinking Water Quality and Regulation; Hazardous Waste Disposal; Infectious Diseases; United Nations Environmental Programme; Waterborne Diseases

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Y

YELLOW FEVER

Yellow fever is a well-known viral infection found throughout the tropical regions of the world, such as sub-Saharan Africa and South America, that is regularly monitored by the World Health Organization (WHO) and the Centers for Disease Control and Prevention. It is a virus of the *Flaviviridae* family that is typically spread by mosquitoes biting monkeys and, when transmitted to humans, leads to a mosquito-borne viral hemorrhagic fever having a high fatality rate. Yellow fever is transmitted by the same "day-biting" mosquito, *Aedes aegypti*, that transmits the chikungunya and Zika viruses.

Historical disasters often lead to major developments in medicine. For example, the 1918 influenza pandemic that killed approximately 1 million people in the United States and more than 50 million worldwide led to research creating the influenza vaccine in 1938. Similarly, the yellow fever epidemic between 1817 and 1905 led to research into generating the yellow fever vaccine in 1936. Today, the yellow fever vaccine is recognized as being highly effective, safe, and inexpensive.

There is no treatment or antiviral therapy available for yellow fever once it is acquired, and only supportive and comfort measures are available (e.g., treating associated dehydration, liver and kidney failure, and bacterial infection). The chance

Yellow Fever in the United States

It is a little known fact that the United States was hit by a major yellow fever epidemic—way back in 1793. The epidemic struck Philadelphia, which was then the young nation's capital and home to many Revolutionary War figures and free African Americans. At the time, Thomas Jefferson wrote to James Madison that everyone who could leave the city was doing so. Those left behind were mostly poor with no place to escape to, and it is estimated that 5,000 people out of a population of 45,000 died. African Americans, who were thought to be immune to yellow fever, were asked to care for the sick. However, after several months, when African Americans began falling ill and dying at the same rate as whites, this theory was proven wrong. Dr. Jean Devèze, a French doctor who took over treatments at the local Bush Hill hospital, would become recognized as a world authority on yellow fever. Later, between 1817 and 1905, over 40,000 people may have died in New Orleans, which was built in a swampy area ideal for mosquito breeding. The city tried unsuccessfully to eradicate the disease by burning tar to purify the air and by firing cannons.

of survival is improved with modern intensive care medicine, although this level of care is generally not available in the areas most affected by the virus. Thus, the best treatment for yellow fever is prevention with the yellow fever vaccination, which is particularly important for travelers departing to endemic areas.

Due to the severity of the yellow fever illness and its recurring resurgence, including the 2016–2017 outbreak in a region of South America frequented by tourists, the WHO established the Eliminate Yellow Fever Epidemics (EYE) program in 2016 to control, if not eliminate, the disease. The EYE initiative incorporates three pillars: (1) preventing yellow fever in at-risk populations, (2) stopping international spread of the disease, and (3) containing outbreaks rapidly. Along with vaccinations, the EYE yellow fever strategy promotes resilient urban centers, urban readiness, and stronger international health regulations. The program identifies 27 countries in Africa and 13 in the Americas that are at highest risk, requiring large-scale vaccinations to ensure high levels of immunity.

Howard W. MacLennan Jr.

See Also: Centers for Disease Control and Prevention; Environmental Epidemiology; Infectious Diseases; Insect-Borne Diseases; World Health Organization

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Z

ZIKA VIRUS

Zika is a viral infection primarily spread by the bite of an infected *Aedes aegypti* mosquito. However, it can also be transmitted through sexual contact and blood transfusions. The main threat from Zika is that it can be passed from a pregnant woman to her fetus, causing an abnormal smallness of the child's brain at birth or developing within the first few years of life. Known as microcephaly, this condition can cause developmental delays, cognitive impairment, problems with coordination and balance, and seizures. Furthermore, doctors have observed other Zika-related problems among fetuses and in infants infected prior to birth, including eye defects, poor hearing, and impaired growth. And there is increasing evidence of a link between Zika and Guillain-Barré syndrome, a rare nervous system disorder.

Zika infections were initially reported for Americans returning to the United States after traveling to areas where Zika outbreaks have occurred. However, more recently there have been an increasing number of cases where the virus was acquired locally by individuals living in the United States who did not travel abroad. The virus was first discovered in 1947 at a virus research facility in Uganda's Zika forest. Since then, there may have been a number of Zika outbreaks that were not attributed to the Zika virus because its symptoms are similar to other viral diseases.

Many people infected with the Zika virus will have mild symptoms or no symptoms at all, and they may not be sick enough to be hospitalized. But for others, the symptoms may be more severe. Typical symptoms are fever, rash, joint pain, and conjunctivitis. Additionally, people may experience muscle pain and headache. These symptoms may last from several days to a week, and once infected, people may be protected from getting the infection again. Of course, if you believe you have an infection, you should see your doctor right away.

Zika infections can be diagnosed from a person's symptoms and travel history and confirmed with a blood or urine test. Because Zika symptoms are similar to other infectious diseases, a health professional may test for several different types of infections. Aside from treating the symptoms, there are no medicines or vaccines for the Zika virus, although several candidate vaccines are under development. Additionally, trials are under way for genetically modified *Aedes aegypti* mosquitoes whose offspring die before they can transmit the disease.

To avoid acquiring the Zika virus, the best approach is to prevent mosquito bites when in areas where the virus is believed to be present. Avoiding mosquitos is not always easy, but using insect repellent, wearing long-sleeve shirts and long pants, and eliminating standing water near your home can help. (When using an insect repellent, always follow the label instructions.) Use window and door screens to prevent mosquitoes from entering your home, and if you do not have air-conditioning and must open the windows to cool off at night, you can avoid mosquito bites by sleeping under a mosquito net. If you are pregnant, the Centers for Disease and Control and Prevention recommends that you do *not* travel to areas where ongoing Zika transmission by mosquito is occurring, and use condoms or do not have sexual contact if you are pregnant and your partner lives in or has traveled to a Zika-infected area.

Our understanding of the Zika virus is evolving, and it is important to stay informed about the latest research and developments. A good source of information for the latest updates is the CDC's Zika virus website.

Richard Crume

See Also: Centers for Disease Control and Prevention; Communicable Diseases; Infectious Diseases; Zoonotic Diseases

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ZOONOTIC DISEASES

Zoonotic diseases, or zoonoses, are infectious diseases that are transmissible under natural conditions from vertebrate animals to humans (see Table 20). Zoonotic diseases can be caused by viruses, bacteria, parasites, and fungi. These diseases are common, and it is estimated that 6 out of every 10 known infectious diseases in people are spread from animals. In addition, 3 out of every 4 emerging infectious diseases in people are transmitted from animals. Emerging infectious diseases are defined as those that are caused by apparently new agents or by known agents that occur in regions or species that did not previously appear to be affected by these known agents. The rise of emerging zoonotic infections is due to ecological changes resulting from agricultural practices, such as deforestation. It is speculated that climate change and overpopulation will result in more zoonotic diseases as the habitats of animals change, and they come into more frequent contact with humans.

Table 20. Examples of zoonotic diseases and associated animals.

Animal Type	Zoonotic Disease
Cats	Rabies, toxoplasmosis
Cattle	*Escherichia coli* O157:H7, cryptosporidiosis, bovine spongiform encephalopathy (mad cow disease)
Dogs	Rabies, leptospirosis, campylobacteriosis
Poultry	Influenza, salmonellosis
Swine	Influenza, trichinosis
Bats	Rabies
Rodents	Hantavirus, plague, tularemia

The definition of a zoonotic disease is broad and includes disease-causing pathogens that operate in a variety of ways. Some diseases maintain an infection cycle in an animal host that is independent from the disease the pathogen causes in humans. Others cause disease in both the human and animal hosts. There are several possible routes of transmission between animals and humans, including skin contact, bites or scratches, and direct inhalation or ingestion. People who are immunocompromised, children under five years of age, and pregnant women may be at increased risk of infection from zoonotic diseases.

The bubonic plague is an example of a zoonotic infection in which the disease-causing pathogen maintains an infection cycle in a host that is independent from humans. This disease is caused by the bacterium *Yersinia pestis*, which is transmitted by the bite of infected fleas from rodents. One natural reservoir for the plague is the ground squirrel, which is common throughout the United States. The bubonic plague begins with nonspecific symptoms, such as fever and chills, and progresses to infect the lymph nodes. In very rare cases, it can be transmitted by coming into contact with infected tissue or exposure to the cough of an infected human.

Rabies is an example of a disease that can infect both humans and animals. It is an acute and highly fatal zoonotic disease that affects the central nervous system. This disease is caused by a virus that is most often transmitted through saliva from the bites of infected animals. Worldwide, dog bites are the principal source of transmission of rabies to humans. In mammals, this disease results in encephalopathy and paralysis of the respiratory system. Symptoms at the early stages of the disease are nonspecific and include fever, headache, and malaise. As the disease progresses, it leads to hallucinations and paralysis, and death ensues within days. Treatment typically consists of a vaccine that must be administered as quickly as possible. Without treatment, this disease almost universally results in death.

Jyotsna S. Jagai

See Also: Bubonic Plague; Deforestation; Ebola Virus; *Escherichia coli* (*E. coli*) Infection; Infectious Diseases

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Appendix: Steps to Reducing Your Environmental Exposure

We are surrounded by toxic substances in the environment. They are in the air we breathe, in our drinking water and food, and even in consumer products like clothing. Fortunately, our exposure to most of these substances is so low that we have nothing to worry about. But for some toxic substances, particularly those having higher toxicities, exposure can sometimes cause illnesses and even death. We can never eliminate all toxic substances, but if we can reduce our exposure to those that are most egregious or avoid them all together, we stand a much better chance of living a long and healthy life.

The first step in reducing our environmental exposure is to know what substances we need to avoid. Unfortunately, this is not as simple as it sounds. While we have good information on many toxic chemicals and other substances in the environment, there are still many others we know little or nothing about. For example, an estimated 60,000 or more commercial chemicals on the market have never been safety tested, and roughly 2,000 new chemicals are introduced every year. Millions of Americans are exposed daily to these chemicals, many of which are contained in consumer products. Similarly, there are many other toxic substances in the environment we know little about. Often, we learn about these substances only after they have caused a problem.

This presents a dilemma: How do we reduce our exposure to toxic substances when we do not always know what substances to be concerned about? While we may never have certainty about what is toxic and what is not, there are some common-sense measures we can take to reduce our risk of injury and illness. Of course, everyone knows that eating healthy foods and exercising are essential to maintaining good health and building a strong immune system. And it goes without saying that smoking and substance abuse are bad ideas. But what more can we do?

The World Health Organization (WHO) estimates that environmental factors account for about a quarter of the global disease burden and about the same percentage of deaths from all causes. Many of these environmental factors are well understood, and we can take steps to reduce our exposure to these factors or avoid them all together. Here are some examples of the steps we can take:

- Air Quality: Over 120 million Americans live in areas where *air quality* does not meet federal health standards. Check the AirNow Air Quality Index in the morning, and if the air quality is poor, limit strenuous exercise and stay indoor as much as possible. (Visit airnow.gov for specific guidance.)

- Water Supply: If you are on a public *water supply* system, review the annual water quality testing report and consider filtering your water if any contaminant limits are exceeded. If you are on a private system, be sure to have your water tested regularly, particularly if there has been recent agricultural or industrial development in the neighborhood or if you live near a landfill or waste dump.
- Infectious Diseases: To prevent *infectious diseases* spread by ticks and mosquitos, use insect repellent and wear a long-sleeve shirt, long pants, and socks when in grassy and wooded areas. It is also a good idea to purchase flea and tick control products for your pets so that they stay healthy and do not bring fleas and ticks inside the house.
- Handwashing: Old-fashioned *handwashing* remains one of the best ways to keep you and others from getting sick, especially when preparing food, caring for someone who is sick, handling an animal, and using the toilet. It is easy to do it right: wet your hands, lather with soap, scrub your hands together for at least 20 seconds (as long as it takes to sing the "happy birthday" song twice), rinse with running water, and dry.
- Radon: *Radon* is the second leading cause of lung cancer in America (after smoking), resulting in an estimated 21,000 deaths annually. Have your home tested for radon, and if readings are high, hire a radon contractor to explore options for remediation.
- Shampoos, Detergents, and Cleaning Agents: It is a mistake to assume that the chemicals in our *shampoos, detergents*, and *cleaning agents* have been safety tested because often they have not. Consider using natural, nontoxic alternatives, which are better for your health and kinder to the environment too!
- Pesticides: When using commercial *pesticides* at home, be sure to carefully follow the directions to avoid exposure to you and your loved ones. Better yet, try pesticides made of natural, nontoxic substances, and seal any cracks in your floors, walls, and ceilings where the little critters can enter. Keeping the kitchen area clean also helps.
- Household Dust: Regular vacuuming of *household dust* can reduce indoor toxic substances and help prevent allergies and asthma attacks. Dusts have been found to include all sorts of dangerous substances, such as lead, pesticides, fire retardants, and various allergens. Because carpeting collects dust, consider replacing it with solid wood, cork, tile, or nonvinyl linoleum flooring.
- Home Heaters: Ensure your *fireplace, woodstove*, or *kerosene heater* meets safety codes and is well ventilated, and install several carbon monoxide monitors in your home. Do not burn treated lumber, which can give off toxic gases.
- Remodeling: If you are *remodeling an older home*, especially one built in the 1970s or earlier, it may contain asbestos in insulation, wiring, roof and siding shingles, and floor tile, and there could be lead in old plumbing and wall paint. Hire a qualified inspector or contractor to assess the hazards and discuss remediation options. Use paints and wood products that do not off-gas harmful chemicals.
- Contaminated Fish: Be cautious about eating *fish contaminated with mercury*, such as some kinds of tuna. This is especially important for young children and pregnant and breastfeeding women. Fish can be good for you, but consider eating lower on the food chain to avoid fish that have bioaccumulated high levels of heavy metals. (See seafood.edf.org for more information.)
- Bisphenol A: Consider using food packaging, beverage containers, and plastic dinnerware that are free of *Bisphenol A (BPA)*, watch out for the BPA-containing epoxy resins used in the protective linings of food cans, and never microwave polycarbonate

food containers. According to the Centers for Disease Control and Prevention (CDC) (cdc.gov/biomonitoring/bisphenola_factsheet.html), BPA is widespread in the human population, and while its human health effects at low environmental exposures are unknown, BPA has been shown to affect the reproductive systems of laboratory animals.

- Sunlight Exposure: If you spend time *out-of-doors* for work or recreation, apply a broad-spectrum sunscreen that protects against both UVA and UVB ultraviolet sunlight. Also, consider using an insect repellent and wearing a long-sleeve shirt, long pants, and socks when in grassy and wooded areas. (The Mayo Clinic presents additional sunscreen information here: mayoclinic.org/healthy-lifestyle/adult-health/in-depth/best-sunscreen/art-20045110.)
- Hearing Loss: *Hearing loss* is the third most common chronic health condition in the United States, where about 40 million Americans age 20 to 69 have noise-induced hearing loss. When mowing the lawn, using a noisy leaf blower, running a loud power saw, or attending a rock concert, be sure to wear ear protection.
- Exposures at Work: If you come into contact with *dust, fibers, chemical fumes, radiation, or biological agents* at work, wear the appropriate personal protective equipment, such as gloves, masks, coveralls, and respirators, and shower before leaving work so that you do not bring any contaminants home on your clothing.
- Medical Imaging: Avoid unnecessary *medical imaging tests* using ionizing radiation, such as X-rays, CT scans, and fluoroscopy. According to the CDC (cdc.gov/nceh/radiation/ionizing.htm), such tests can lead to a small increase in the likelihood of developing cancer later in life as well as skin reddening, hair loss, and possible allergic reactions associated with contrast dyes.
- Environmental Health History: Physicians are rarely trained on environmental exposures and how to take an *environmental health history*. If you are concerned about past environmental exposures, talk with your doctor about documenting your exposures and researching potential health implications.

Can cancer be prevented? Americans are especially concerned about cancer, and rightly so. Over 40 percent of Americans will be diagnosed with cancer during their lifetimes, and about 20 percent will die from cancer. The incidences of some cancers are decreasing as new treatments are discovered and people make lifestyle changes. On the other hand, some cancers, including cases among children, are increasing for unexplained reasons. Environmental factors do not cause all cancers, but they are definitely implicated in some.

According to the President's Cancer Panel (prescancerpanel.cancer.gov), a growing body of research finds that environmental factors linked to genetic, immune, and endocrine dysfunction can lead to cancer and other diseases, and the true burden of cancer caused by environmental factors has been grossly underestimated. Furthermore, the WHO reports that cancer is the leading cause of death worldwide, with about 20 percent of all cancers attributed to the environment, particularly air pollution (indoor and outdoor), ultraviolet radiation, radon, secondhand smoke, and occupational exposures, including asbestos. By taking precautions at home and work to avoid these and other cancer-causing environmental agents, you can go a long way in reducing your cancer risk.

The hazards of tobacco smoking are incontrovertible, and there are also health concerns about e-cigarettes. But what about smoking marijuana? Marijuana is growing in popularity for medical and recreation use, and the CDC reports over 22 million users in the United States. Additionally, an increasing number of states have legalized marijuana for medical use. On the other hand, recreational (non-medical) use is perhaps more controversial, in part, due to potential side effects. For example, the CDC indicates (cdc.gov/marijuana) there is “strong evidence” that marijuana use may lead to health effect such as addiction, breathing problems, short-term declines in memory, and increased risk for psychosis or schizophrenia, and there is “some evidence” for an increased risk of some types of cancer and for heart attack and stroke. School performance may suffer too, according to the CDC.

If you are concerned about environmental risks in your community, you can work with community members to build a safe community plan to reduce environmental exposures, particularly for children playing out-of-doors. Begin by identifying community concerns and vulnerabilities. For example, you may be concerned about standing water or ponds that breed mosquitoes, exposure to ticks from deer that wander into town, volatile organic compound fumes from shredded tires used as a base for playgrounds, or air pollution from a nearby manufacturing plant. Do your own research and get the facts. Organize teams of concerned citizens, and enlist the support of local city offices. If necessary, attend city council meetings and make your voice heard, loud and clear. Pollution in your specific community can be investigated with the My Environment tool (epa.gov/myenvironment) developed by the U.S. Environmental Protection Agency.

The widespread presence of toxic substances in the environment is a symptom of our modern lifestyle. As we drive and fly more, use more chemical pesticides and fertilizers, and manufacture more consumer goods, we also produce more toxic pollution. Fortunately, a number of technological innovations in recent years have helped pave the way toward a healthy, environment-friendly future. Getting there from here seems a daunting task, but by reducing our own environmental exposure, we are taking a stand for environmental health and helping drive the national conversation about this important topic.

Glossary

Acid rain Precipitation that is acidic due to sulfuric and nitric acids that form from pollution in the atmosphere, increasing the acidity of bodies of waters where the precipitation falls.

Action level A guideline used by environmental agencies to identify the concentration level of a substance that may present a health hazard when exceeded.

Acute illness An illness with rapid onset, as distinguished from a chronic disease that is long lasting.

Aerodynamic diameter When studying the behavior of an air pollution particle in a gas stream, the diameter of a spherical particle having a density of 1 gram per cubic centimeter and the same settling velocity as the particle under investigation.

Aerosol A solid or liquid particle that is suspended in the air.

Air toxics Air pollutants known to cause cancer or other serious health conditions. Also known as hazardous air pollutants.

Ambient air The outdoor air that people breathe and that can contain air pollutants.

Anthropogenic Referring to something originating with human activity, such as the creation of ground-level ozone pollution. (Stratospheric ozone would not be considered anthropogenic because it occurs naturally.)

Antigen A substance foreign to the human body that can evoke an immune response and bind with the product of the response. The substance can act alone or as a complex with a protein or other larger molecule.

Aquifer Underground water contained in a layer of rock, sand, gravel, or sediment that can be used for drinking water or irrigation.

Area sources A number of small air pollution sources, such as automobile body shops or dry cleaners, that taken together can represent a large amount of pollution.

Asbestosis A chronic lung disease caused by the inhalation of asbestos fibers, resulting in lung tissue scarring and shortness of breath.

Atopy A genetic disposition to develop an allergic reaction, including allergic rhinitis, asthma, and atopic dermatitis, when exposed to an environmental antigen.

Batesian mimicry The ability of an organism to gain extra protection by resembling or mimicking a more dangerous organism, for example, adopting the dangerous organism's coloration, thereby keeping predators away.

Bioaccumulation The concentration of a substance in an organism when the substance builds up faster than it is removed.

Bioavailability The degree to which a substance is absorbed into a living system or made available to a target tissue or organ.

Bioconcentration Bioaccumulation that occurs specifically by absorption directly from water.

Biodegradation The decomposition of a substance by microorganisms or natural processes like sunlight.

Biogenic emissions Acetaldehyde, formaldehyde, methanol, and other volatile organic compounds emitted from natural sources, such as plants and trees.

Biomagnification An increase in the concentration of a substance in organisms while moving up the food chain.

Biosphere The earth, including the crust, oceans, atmosphere, and living organisms that inhabit it.

BPA (bisphenol A) A chemical used in manufacturing polycarbonate plastics and epoxy resins that researchers believe may cause adverse health effects in humans.

Built environment The human-created buildings, parks, and spaces within a city where people live and work.

Carbon dioxide A colorless, odorless, and nontoxic gas formed by the combustion of carbon-containing fuels, such as coal, oil, and natural gas, and the principal gas contributing to climate change.

Carbon offset A credit for greenhouse gas emission reductions achieved by one party that can be sold to another party to compensate for (offset) that party's greenhouse gas emissions.

Carcinogenic Substances known or suspected to cause cancer.

Case-control study A study comparing exposures of people having a disease or condition with people not having the disease or condition for the purpose of identifying risk factors for the disease or condition.

Chronic disease A long-lasting disease, as distinguished from an acute illness having rapid onset.

Cohort study A study where a group of people previously exposed to some environmental factor are followed over time, and their health experience is compared with a control group not previously exposed to the environmental factor.

Colitis An inflammation of the large intestine that is often accompanied by abdominal pain, bloody stools, dehydration, diarrhea, and fever.

Communicable disease A disease spread from one person to another through, for example, contacting blood and bodily fluids, inhaling an airborne virus, or being bitten by an infected insect.

DDT (dichlorodiphenyltrichloroethane) An insecticide first developed in the 1940s that was highly effective against malaria, typhus, and other insect-borne diseases but was later associated with adverse environmental and toxicological effects, as described in Rachel Carson's seminal publication, *Silent Spring*.

Deforestation Logging or burning practices that result in a forested area being cleared of trees, often for harvesting timber for sale or for agricultural purposes.

Detection limit The lowest concentration of a chemical that can be measured with confidence such that the measurement can be reliably distinguished from zero.

Diesel particulate matter A mixture of particles in diesel engine exhaust that are associated with cancer and noncancer health effects.

Dioxin A group of chemical compounds with similar chemical and biological characteristics that bioaccumulate in the food chain, persist in the environment, and can be highly toxic. The most toxic form is 2,3,7,8-tetrachlorodibenzo-p-dioxin, also known as 2,3,7,8-TCDD.

DNA Deoxyribonucleic acid, the self-replicating material present in living organisms that carries genetic information.

Dose The amount of a substance taken or administered at one time, for example, a medicine, radiation for diagnosis or treatment, or an environmental agent tested in animals for toxicity.

Dose-response assessment A determination of the relationship between the magnitude of a dose and a specific biological response.

Dry deposition The sulfuric and nitric acids that form from pollution in the atmosphere and fall back to the earth in a dry form, potentially damaging automobile and building surfaces, injuring wildlife and vegetation, and increasing the acidity of bodies of water.

Endocrine disruptor Chemicals such as dioxin, PCB, DDT, and BPA that are believed to interfere with the body's endocrine system, resulting in adverse developmental, reproductive, neurological, and immune effects.

Enteritis An inflammation of the small intestine that is often accompanied by abdominal pain, diarrhea, fever, and vomiting.

Environmentalism A philosophy and social movement focused on protecting the natural environment from pollution and overuse.

Epidemiology Study of the frequencies, patterns, and causes of health and diseases in populations.

Epitope A location on the surface of an antigen that can both elicit an immune response and combine with the antibody produced by the response.

Erythema Reddening of the skin (i.e., sunburn) caused by overexposure to ultraviolet radiation.

Estuary The area at the end of a river where the current of the river meets the tide of the sea.

Exotoxin A toxic substance produced by a microorganism and released to the surroundings.

Exposure Inhalation, ingestion, or skin contact with a substance, which may be short term or long term.

Exposure pathway A route by which a substance in the environment can come into contact with humans, animals, and plants, for example, the inhalation of an airborne toxic chemical.

Fission The splitting of an atom, resulting in the release of heat that can be used to produce electricity.

Fly ash Particulate matter that does not completely burn up in the combustion process, for example, when coal is burned to generate electricity in an electric power plant.

Fugitive emissions Air pollution escaping from various points in a manufacturing process rather than through a stack, chimney, or vent, thereby making capture and removal difficult.

Fusion The bonding together of two light atoms, forming a heavier one and releasing a large amount of energy.

Genetic engineering The process of manually adding new DNA to an organism so as to add new traits not already present in the organism, for example, creating plants resistant to certain insects.

Genome An organism's complete set of DNA, containing all the information required to build and maintain the organism.

Greenhouse effect Warming of the earth's surface due to the accumulation of gases in the atmosphere that absorb heat and prevent it from escaping into outer space.

Greenhouse gas Atmospheric gases, for example, carbon dioxide, methane, nitrous oxide, and ozone, that contribute to climate change and often originate with electric power generation and other human activities.

Greenwashing Unsubstantiated or misleading labeling or marketing claims, making a product or practice appear better for the environment than it actually is.

Hazard index The sum of hazard quotients when multiple substances affect the same target organ or organ system.

Hazard quotient The ratio of the level of exposure of a substance to the level where no adverse health effects occur.

Hazardous air pollutants Air pollutants known to cause cancer or other serious health conditions. Also known as air toxics.

Heat island effect How urban areas, because of their dense materials (asphalt, brick, concrete, steel, and stone), heat up faster and hold their heat longer than rural area.

Heat wave A period of unusually hot weather lasting for a number of days and often resulting in an increase in heat-related illnesses.

Heavy metals A group of elements, such as chromium, copper, lead, and zinc, that are toxic at low concentrations and can accumulate in the food chain.

Hypoxia The condition where insufficient oxygen reaches the tissues of the human body.

Incidence The number of cases of a disease over a specified period.

Industrial hygiene A professional field concerned with protecting the safety and health of workers while on the job.

Industrial Revolution The growth of industrial manufacturing from roughly 1760 to 1840, when industry supplanted agriculture in many countries as the major driver of the economy.

Infectious disease A human disorder caused by bacteria, viruses, fungi, parasites, and other organisms that grow and multiply in the body. Some infectious diseases may be passed from person to person, while others are transmitted by insect or animal bites or by consuming contaminated food or water.

Latency period The period between exposure to an agent causing a disease and the onset of the disease.

Leaching The process by which water dissolves chemicals as it flows through contaminated soils or landfills and transfers the chemicals to groundwater or surface water.

Longitudinal study A study type that follows individuals over a prolonged period of time and is useful in evaluating the relationship between risk factors and the development of disease and in evaluating the outcome of treatments.

Low latitudes The part of the earth's surface that is located near the equator.

Melatonin A hormone that helps regulate other hormones and maintains the body's circadian rhythm.

Mesothelioma A form of cancer almost always attributed to asbestos exposure that most commonly affects the outer lining of the lungs or chest cavity, the lining of the abdominal cavity, or the sac surrounding the heart.

Methane A colorless, nontoxic, and flammable hydrocarbon gas created by the anaerobic decomposition of organic compounds, and a potent greenhouse gas.

Methyl isocyanate A highly toxic chemical used to produce pesticides that was accidentally released in 1984 from the Union Carbide plant in Bhopal, India, resulting in thousands of deaths and injuries.

Miasma Gases given off by putrid matter or marshy regions, once believed to cause diseases such as cholera and malaria.

Microbes Living organisms, such as bacteria, archaea, viruses, fungi, prions, protozoa, and algae, that are too small to be seen with the naked eye.

Microbiology The study of microbes, which are living organisms too small to be seen without a microscope.

Microbiome A community of bacteria, fungi, viruses, and other microorganisms that inhabits a particular environment; often referring to the microorganisms inhabiting the human body.

Micron A unit of length equal to one-millionth of a meter. Also called a micrometer.

Mutagen A substance that causes mutations, which are changes to DNA, genes, or chromosomes.

Mutagenic Substances having the potential to cause changes in genetic material, such as DNA.

Mutation A change to the DNA, genes, or chromosomes of a living organism.

Nanometer A unit of length equal to one-billionth of a meter.

Napalm A highly flammable and sticky substance containing gasoline and other chemicals that was used in bombs during the Vietnam War and unsuccessfully applied to the *Torrey Canyon* oil spill in an attempt to set fire to and disperse the oil.

Neonatal Referring to or affecting the newborn, particularly human infants in the first month following birth.

Nicotine The addictive substance found naturally in tobacco.

Nonpoint source pollution Pollution originating from multiple diffuse sources, such as drainage, land runoff, and atmospheric deposition.

Odor threshold The lowest concentration of a substance in the air that can be detected with the human nose. Substances have different odor thresholds, and people often have different sensitivities for detecting odors.

Organic compound A large class of chemical compounds containing carbon, where the carbon atoms are covalently bonded to other atoms, typically hydrogen, oxygen, and nitrogen.

Ozone A molecule comprising three oxygen atoms that is formed by a chemical reaction between nitrogen oxides and volatile organic compounds in the presence of sunlight. Ground-level ozone is a harmful air pollutant, whereas ozone in the stratosphere helps block the sun's harmful ultraviolet radiation.

Pandemic A disease outbreak that spreads quickly and affects a large segment of a population over a wide geographical area.

Parts per million (ppm) The number of molecules of a substance contained in a million parts of another substance.

PCB (polychlorinated biphenyl) A group of chemicals widely used in hundreds of industrial and commercial applications, such as electrical and hydraulic equipment, plasticizers, pigments, and dyes, until manufacturing was banned in 1979 due to concerns about adverse health effects.

Perinatal Pertaining to the period around the time of birth.

Permafrost A thick subsurface layer of soil in the polar regions that remains in a frozen state throughout the entire year.

Phthalates A group of chemicals used to make plastics, including polyvinyl chloride, and other materials found in a wide range of products. Phthalate exposure is widespread in the U.S. population, although the human health effects are unknown.

Point source pollution A single source of pollution, such as at an industrial or sewage treatment plant.

Premature mortality Death, due to an environmental exposure, that occurs sooner than would otherwise be expected.

Quality assurance/quality control (QA/QC) A system of checks and audits to control the quality of measurements or products. Quality assurance is often conducted by an independent consultant or organization.

Radiation, electromagnetic A form of energy produced by electric and magnetic fields oscillating at right angles to each other. It takes many forms and is all around us, such as TV signals, radio waves, sunlight, ultraviolet radiation, and X-rays.

Radiation, ionizing A form of radiation, such as alpha and beta particles, gamma rays, X-rays, and neutrons, that is powerful enough to produce ions by breaking molecular bonds and displacing electrons from atoms and molecules. Ionizing radiation has many medical applications, but it can be a threat to human health at high doses.

Radiation, nonionizing A form of radiation, such as radio waves, microwaves, infrared and ultraviolet radiation, and visible light, that is not powerful enough to produce ions. Nonionizing radiation is not considered as great a threat to human health as ionizing radiation at high doses.

Radioactivity The emission of alpha or beta particles or gamma rays from radioactive elements like uranium, polonium, and radium. Also known as radioactive decay.

Radon A radioactive, alpha particle–emitting gas that exists naturally in many regions of the world and can be a health hazard if it accumulates in the basements and crawl spaces of homes.

Record of decision A public document that records a federal agency's decision about a proposed action for which an environmental impact statement has been prepared.

Rickettsial infection An infection caused by a type of bacteria that can only live inside the cells of another organism and that spreads primarily by ticks, mites, fleas, and lice.

Risk assessment A determination of the likelihood of events, such as the probability of a disease following exposure to an infectious agent or toxic pollutant.

Secondhand smoke Tobacco smoke exhaled by a smoker or given off by a tobacco product and inhaled by someone nearby. Also called passive smoke.

Smog A mixture of ground-level pollutants consisting primarily of ozone.

Social capital The relationships among people that allow society to function effectively.

Solar insolation A measure of the solar radiation striking the earth's surface, which varies according to the angle of the sun, location, elevation, and atmospheric conditions, including cloud cover.

Soot A black substance composed of mainly small particles of carbon that is emitted during the combustion of fossil fuels.

Stationary source An air pollution emission source other than a motor vehicle, such as a power plant, refinery, dry cleaner, commercial cooking establishment, and woodstove.

Stratosphere The part of the atmosphere, ranging from about 6 miles (9.7 kilometers) to 30 miles (48 kilometers) above the earth's surface, where temperature is relatively steady and clouds rarely form.

Subarctic Region located just south of the Arctic Circle.

Surgeon general Often referred to as the nation's doctor, the surgeon general of the United States oversees the U.S. Public Health Service and is responsible for providing Americans information and guidance on how to improve health and reduce the risk of illness and injury.

Synergistic effect Exposure to multiple substances where one substance worsens the effect of another substance.

Temperance movement An effort organized mainly by women in the nineteenth and twentieth centuries to encourage moderation or complete abstinence in the consumption of alcohol, believing alcohol to be the source of health problems, destitution, and crime.

Thermal pollution Heated water from an industrial process that is discharged to a body of water and can adversely affect aquatic organisms.

Thirdhand smoke Tobacco smoke residue that settles on indoor surfaces and interacts with other indoor pollutants to create a toxic mix of chemicals that may or may not become airborne.

Toxicant A toxic substance created by human activity, for example, an air pollutant or pesticide.

Toxicology The study of how chemical, physical, and biological agents can adversely affect people, animals, and the environment.

Toxin A toxic substance that is found in nature, for example, a snake venom or poisonous mushroom.

Transuranic waste A material produced from the recycling of spent nuclear fuel or the fabrication of nuclear weapons that is contaminated with artificially made radioactive elements having atomic numbers higher than uranium.

Tropism The involuntary orientation of an organism or one of its parts in response to stimulation.

Troposphere The lowest part of the atmosphere, ranging from the earth's surface to the bottom of the stratosphere, where weather systems and most air pollution occur.

Tsunami A large ocean wave or series of waves that sometimes occur following strong offshore earthquakes.

Turbidity A basic water quality test that measures the degree of cloudiness or haziness.

Urban runoff Stormwater from city streets and properties that can pick up and carry pollutants present on the ground as the stormwater flows into sewers or bodies of water.

Valley fever A fungal infection, characterized by fever, chest pain, coughing, and other symptoms, that thrives in arid desert soils.

Vector An organism, such as an insect or rodent, that carries a disease.

Volatile organic compound An organic compound that participates in the formation of photochemical smog.

Wet deposition The sulfuric and nitric acids that form from pollution in the atmosphere and fall back to the earth with rain, snow, fog, or hail, potentially damaging automobile and building surfaces, injuring wildlife and vegetation, and increasing the acidity of bodies of water.

Wetland An area saturated with surface or groundwater, such as a swamp, marsh, or bog, that supports wetland vegetation and helps sustain many species of fish and wildlife.

WTC dust A highly alkaline mixture of crushed concrete, gypsum, fibers, and many other substances that descended upon New York City as a dense cloud following the September 11, 2001, terrorist attack and subsequent collapse of the World Trade Center twin towers.

Zoonoses Diseases and infections transmitted between vertebrate animals and humans, where the zoonotic agent may be a bacterium, virus, fungus, or other communicable agent.

Zoonotic Diseases and infections transmitted between vertebrate animals and humans.

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Directory of Resources

Air and Waste Management Association

Pittsburgh, Pennsylvania
https://www.awma.org

The Air and Waste Management Association (AWMA) is a professional organization dedicated to enhancing knowledge and expertise in the areas of air quality and waste management by providing a neutral forum for exchanging information. The AWMA provides professional development opportunities to its members, promotes global environmental responsibility, and helps organizations make critical decisions that benefit society.

American Public Health Association

Washington, D.C.
https://apha.org

The American Public Health Association (APHA) is a professional association with over 25,000 members representing virtually every field of public health and medicine. The APHA's Environment Section (apha.org/apha-communities/member-sections/environment) sponsors initiatives to protect environmental health, promotes the work of environmental health professionals, and develops outreach programs to educate the public on environmental health issues.

Carter Center

Atlanta, Georgia
https://www.cartercenter.org

The Carter Center was founded by President Jimmy Carter and Rosalynn Carter as a nongovernmental organization to help advance peace and worldwide health by resolving global conflicts, advancing democracy and human rights, promoting economic opportunity, preventing diseases, improving mental health, and teaching farmers how to increase crop production. The center has been particularly effective in the environmental health field by reducing the incidence of infectious diseases.

Centers for Disease Control and Prevention

Atlanta, Georgia
https://www.cdc.gov

The mission of the Centers for Disease Control and Prevention (also known as the CDC) is to protect Americans from health, safety, and security threats originating both in the United States and overseas. The CDC conducts research, provides health information to health agencies and the public, issues health alerts, and coordinates response activities with state and local agencies. The National Center for Environmental Health (cdc.gov/nceh) and National Institute for Occupational Safety and Health (cdc.gov/niosh) are organizational components of the CDC.

Council on Environmental Quality

Washington, D.C.
https://www.whitehouse.gov/ceq

The Council on Environmental Quality (CEQ) is located in the White House and falls under the Executive Office of the President. The CEQ coordinates the federal government's environmental efforts by developing environmental policies and initiatives, overseeing implementation of the environmental impact assessment process, and working with agencies to select environmental actions consistent with the president's goals.

David Suzuki Foundation

Vancouver, British Columbia
http://www.davidsuzuki.org

The goal of the David Suzuki Foundation is to promote environmental conservation and sustainability through science-based research, education, and policy development. The foundation's priorities include protecting the climate, creating livable communities, establishing environmental rights and justice, transforming the economy through efficient resource use, helping youth connect with nature, and building community with earth-friendly infrastructure, smart energy choices, and efficient transportation.

Environmental Protection Agency

Washington, D.C.
https://www.epa.gov

The U.S. Environmental Protection Agency (EPA) is the nation's leading environmental agency for protecting human health and the environment. The EPA's priorities include developing and enforcing regulations, issuing research grants, studying environmental issues, sponsoring partnerships, teaching people about the environment, and protecting the rights of low-income and minority populations to a clean environment.

Federal Emergency Management Agency

Washington, D.C.
https://www.fema.gov

The Federal Emergency Management Agency (FEMA) provides support to citizens, first responders, and state and local governments to prepare for, protect against, respond to, and recover from all hazards. For example, FEMA routinely provides emergency supplies and assistance during natural disasters caused by severe storm outbreaks, hurricanes, forest fires, and earthquakes.

Food and Drug Administration

Silver Spring, Maryland
https://www.fda.gov

The Food and Drug Administration (FDA) has a variety of responsibilities for protecting the safety of food and drugs in the Unites States. Additionally, the FDA ensures that vaccines and medical devices are safe and effective, protects the public from electronic product radiation, assures cosmetics and dietary supplements are safe and properly labeled, regulates tobacco products, and helps speed up the pace of product innovation.

Intergovernmental Panel on Climate Change

Geneva, Switzerland
http://www.ipcc.ch

The Intergovernmental Panel on Climate Change (IPCC) is the world's leading international body for assessing the science related to climate change and providing the latest information to governments and policymakers. The IPCC conducts regular assessments of climate change science, impacts and future risks, and options for adaption and mitigation.

Land Institute

Salina, Kansas
https://landinstitute.org

The Land Institute is working to replace traditional agricultural practices, including the widespread use of pesticides, herbicides, and chemical fertilizers, with sustainable practices based on natural systems that preserve culture and ecology. The institute's goal is to develop an agricultural system featuring perennial plants that will have ecological stability and crop yield comparable to today's annual crops.

National Center for Environmental Health

Atlanta, Georgia
https://www.cdc.gov/nceh

The mission of the National Center for Environmental Health (NCEH) is to promote a healthy environment, prevent premature death, and help people avoid illness and disability caused by environmental factors other than infectious disease agents and occupational exposures. The NCEH focuses particularly on vulnerable populations, such as children, older adults, and people with disabilities.

National Institute for Environmental Health Sciences

Research Triangle Park, North Carolina
https://www.niehs.nih.gov

The goal of the National Institute for Environmental Health Sciences (NIEHS) is to promote healthier lives for Americans by conducting research on how the environment affects people and by disseminating information to the research community and the public. The NIEHS is world renowned as a leader in the field of environmental health sciences.

National Institute for Occupational Safety and Health

Atlanta, Georgia
https://www.cdc.gov/niosh

The National Institute for Occupational Safety and Health (NIOSH) conducts research on occupational safety and health issues and puts its research findings into practice in the workplace. NIOSH's goals are to reduce worker illness and injury and advance well-being, promote safe and healthy workers through interventions and capacity building, and sponsor and participate in global collaborations aimed at enhancing worker safety and health.

National Institutes of Health

Bethesda, Maryland
https://www.nih.gov

The National Institutes of Health (NIH) is the nation's leading medical research agency, with many research programs at the forefront of global health protection. The NIH is made up of 27 separate institutes and centers, each having specific research agenda concerning diseases, health challenge, and body systems. The National Institute of Environmental Health Sciences (niehs.nih.gov) is an organizational component of the NIH.

National Oceanic and Atmospheric Administration

Washington, D.C.
http://www.noaa.gov

The mission of the National Oceanic and Atmospheric Administration (NOAA) is to conduct research, collect data, and disseminate information on the nation's climate, weather, oceans, and coasts. NOAA studies the structure and behavior of the oceans and atmosphere, conserves and manages coastal and marine ecosystems and resources, and responds to environmental emergencies.

Occupational Safety and Health Administration

Washington, D.C.
https://www.osha.gov

The mission of the Occupational Safety and Health Administration (OSHA) is to ensure that working Americans experience safe and healthful working conditions by implementing the requirements of the Occupational Safety and Health Act. OSHA sets and enforces standards, delivers training to employers and workers, and provides technical assistance.

Ocean Alliance

Gloucester, Massachusetts
http://www.whale.org

The Ocean Alliance collects information on whales and other ocean life, with the goal of educating policymakers and the public on the wise stewardship of the oceans to prevent the collapse of marine mammal populations and promote ocean and human health. A project known as the Voyage of the Odyssey provided the world's first set of data on the widespread distribution of synthetic contaminants in the oceans and how they affect ocean life.

Water Environment Federation

Alexandria, Virginia
http://www.wef.org

The Water Environment Federation (WEF) is a professional organization representing over 33,000 individual members and 75 affiliated organizations around the world. The

WEF's goals are to protect public health and the environment by enriching the experience of water pollution professionals, increasing public awareness about the importance of water, and providing a platform for innovation.

Woods Hole Oceanographic Institution

Woods Hole, Massachusetts
http://www.whoi.edu
The Woods Hole Oceanographic Institution is one of the world's leading nonprofit organizations for ocean research, exploration, and education, including environmental threats to the oceans and coastal areas. The institution's research covers a range of topics related to ocean and earth science, marine policy, and climate change.

World Health Organization

Geneva, Switzerland
http://www.who.int
The World Health Organization (WHO) provides global leadership on matters critical to human health by shaping the global research agenda, setting norms and standards, articulating ethical and evidence-based policies, providing technical support, and monitoring health trends. The WHO employees over 7,000 people in its headquarters office and over 150 country offices.

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About the Editor and Contributors

Editor

Richard Crume is an environmental engineer, educator, and journalist with over 40 years of experience in the environmental health field. He previously managed the program planning and budget staff for the U.S. Environmental Protection Agency's national air quality planning and standards office, where he received the agency's highest honor award, the Gold Medal for Exceptional Service, and the Suzanne E. Olive Award for outstanding service in promoting equal opportunity and diversity. Crume was also principal engineer at the Parson's Corporation, head of the Environmental Engineering Section at MRI Global, and adjunct associate professor at North Carolina A&T State University, where he taught classes for many years on air pollution, climate change, and renewable energy. Crume has written and lectured extensively on environmental health and renewable energy topics, with nearly 100 publications and seminars covering air pollution and climate change, waste management, environmental justice and leadership, and green building design. Additionally, he has published 19 feature stories in *Solar Today* magazine, and he has chaired sessions at eight national environmental conferences. As a member of the American Public Health Association, Crume recently authored their national policy on air pollution and the Clean Air Act, and he also belongs to the National Association of Science Writers and Society of Environmental Journalists. He is certified as a qualified environmental professional and hazard control manager.

Contributors

Talia E. Abbott Chalew is an adjunct faculty member at Johns Hopkins University, teaching and developing courses in environmental applications and implications of nanotechnology. Her previous research experience has focused on the fate and transport of nanomaterials in the environment and human health effects. Dr. Abbott Chalew is a member of the Society for Environmental Toxicology and Chemistry.

Ifeanyi Abuachi is a physician, medical researcher, and private consultant, and he previously served as medical director of the Jerry Hospital in Lagos Nigeria. Dr. Abuachi's research has included creating a medical diagnostic and communications system (patent pending) aimed at improving patient-doctor communications and outcomes. He is a member of the Inter-American College of Physicians and Surgeons, American Board of Surgical Assistants, and American Public Health Association.

Henry Babatunde Akinleye is a chemist and program leader in the Food Safety Department of *Consumer Reports*. Additionally, he is conducting research on dietary exposure to phthalates at the City University of New York's School of Public Health and Health Policy.

Andrew P. Barefield is a medical support assistant at the Veterans Administration clinic in Carrollton, Georgia, and he has been a registered radiographer for over 30 years. With two autistic adult children living at home, Barefield's passion for the environment is based on the epigenetic link to autism, how that relates to his children's futures, and his desire to leave the world a more ecologically friendly place.

Matthew W. Blair is a plant breeder and research associate professor at Tennessee State University, where he conducts breeding and genetics research on legumes and dicotyledonous C4 crop plants, such as cultivated amaranth. His plant genetics laboratory applies molecular biology research to cultivar and crop development using various agronomic and physiological testing techniques, with the goal of having a major impact on the productivity of small-holder agriculture in the United States and internationally.

Michael S. Bloom is an associate professor and associate chair in the Department of Environmental Health Sciences at the School of Public Health, University of Albany, State University of New York. Dr. Bloom's research is focused on elucidating the impacts of environmental pollutants on reproduction and endocrine function in human populations. He also teaches graduate-level introductory environmental health, reproductive environmental health, and reproductive and perinatal epidemiology.

John K. Borén is the founder of RÄV EHS Consulting. He has over 25 years of environmental health and safety experience covering areas such as compliance auditing, management systems design, hazardous waste and toxics substances control, storm water and wastewater management, climate change, and air permitting. Borén is a registered professional engineer, certified hazardous materials manager, certified industrial hygienist, and certified safety professional.

Georgiana Bostean is an assistant professor of environment, health, and policy at Chapman University. Her research is broadly in the area of social determinants of health, and she has examined the individual and ecological correlates of adolescent e-cigarette use. Dr. Bostean has published in various academic journals, including the *American Journal of Public Health, Health and Place*, and the *Journal of Immigrant and Minority Health*.

Jeanine Botta is a writer, editor, and consultant with particular interest in nonauditory effects of noise exposure and health benefits of access to quiet. As a member of the Right to Quiet Society for Soundscape Awareness and Protection, she provides educational programs at environmental trade shows. She is a cofounder of the Silence the Horns project and a founding member of the Quiet Coalition.

Ronda Bowen is an independent researcher covering subjects ranging from metaphysics and epistemology to the philosophy of technology. Her current research interests include environmental solutions, biomedical ethics, and corporate agriculture's responsibility to citizens. Additionally, Bowen has published or presented on why we need a green revolution, steps to sustainability, and focal practices in response to a hot, flat, and crowded world. She also contributed chapters to *Native America: A State by State History*.

Thomas D. Byl is a research biologist with the U.S. Geological Survey. He is stationed at Tennessee State University, where he oversees research on hydrology and water quality in natural systems having nonideal flow, such as wetlands and karst aquifers. Additionally, Dr. Byl teaches environmental chemistry, biogeochemistry, and water quality management courses. He is a member of the Society of Environmental Toxicology and Chemistry, American Water Resources Association, National Speleological Society, and Tennessee Academy of Science.

Philip A. Clifford is dean of math and science at Volunteer State Community College and has taught biology, ecology, research and statistics, and related courses for over 30 years. He has also worked in the environmental consulting business for a number of years as an ecotoxicologist. In that role, he studied many bioaccumulative substances, wrote numerous mathematical models for predicting their behavior in the environment, and authored a variety of articles describing relevant case studies.

Chatten Cowherd Jr. recently retired as principal advisor for environmental studies at MRIGlobal. He has more than 30 years of experience in field studies directed toward the characterization and control of fugitive dust, and he is a fellow member of the Air and Waste Management Association, having served on its board of directors. Dr. Cowherd is one of the world's foremost experts on fugitive dust.

Yoko S. Crume has over 30 years of work experience in the environmental and social work fields, most recently as a tenured professor at North Carolina A&T State University, where she started a community-based mental health service for the non-English-speaking population in Greensboro, North Carolina. Her latest activities include developing a senior transportation system in Nashville, Tennessee, and researching assistive technology innovations for older adults in Japan.

Mallory L. Daily is a freelance reporter with strong roots in the Midwest. She has worked for St. Louis public radio, reported on state politics in Missouri, and farmed organic vegetables in Iowa. Daily's latest project is to write environmental stories while helping small farmers in El Salvador incorporate sustainable, economically feasible growing practices.

Charles Daniel is an environmental health officer for the city of Melrose, Massachusetts, and a former infectious disease epidemiologist for the Massachusetts Department of Public Health. He teaches epidemiology and biostatistics at Kaplan University and is a health sciences lecturer at Northeastern University's College of Professional Studies. Daniel is a member of the American Public Health Association and National Environmental Health Association.

Richard S. Davis has been an environmental lawyer at Beveridge and Diamond PC in Washington, D.C., for over 30 years, specializing in the Clean Water Act and Safe Drinking Water Act. He works with industry and municipalities to help them ensure compliance with these important laws. Davis is chair of his firm's clean water practice group and helps direct one of the most innovative and dynamic clean water practices in the United States.

Qi Deng is a research associate at Tennessee State University. His research covers the broad area of plant ecology and global change ecology, including both laboratory and field experimentation. Dr. Deng is also interested in metadata analysis and applications of modeling approaches for processing experimental data.

Aaron Dorman is a freelance science writer and editorial assistant for *The American Gardener* magazine. Among his more recent projects, Dorman published articles on upstate New York environmental issues, such as electric vehicle charging stations and vermicompost, and he contributed fact sheet and curriculum materials for the Earth Day Network. Dorman's writing often concerns the human impact on ecosystems and the environment, particularly garbage and electronic waste. He is a member of the Society of Environmental Journalists.

Abhishek Dubey is an assistant professor in the Department of Computer Science at Vanderbilt University. Additionally, he is a senior research scientist in the university's Institute for Software Integrated Systems. Dr. Dubey oversees research into the problems of interoperability, scalability, and dependability of Internet of Things networks in the domain of smart transportation and smart grid. He is a senior member of the Institute of Electrical and Electronics Engineers.

Lawrence K. Duffy is a professor and director of the Resilience and Adaptation Program at the University of Alaska-Fairbanks, where he teaches biochemistry and environmental toxicology and conducts research on issues related to environmental biochemistry and health. Dr. Duffy previously held research positions at Boston University, the Roche Institute of Molecular Biology, the University of Texas Medical Branch, and Harvard Medical School. He is a fellow of the American Institute of Chemistry and the Arctic Institute of North America.

Leah A. Dundon is an environmental attorney with the Beveridge and Diamond PC law firm in Washington, D.C. She has over 15 years of experience in advising clients regarding major federal environmental statutes, such as the Clean Air Act and Clean Water Act, and their state counterparts. Dundon is a member of the Tennessee and DC Bars and the American Bar Association's Environment, Energy, and Resources section. She regularly speaks and publishes on environmental issues, including climate change, risk, environmental disclosures, and resiliency.

E. Kudjo Dzantor, an associate professor of soil microbiology/biochemistry at Tennessee State University, has over 30 years of experience involving bio/phytoremediation investigations and studies of soil contamination with pesticides, polychlorinated biphenyl, polyaromatic hydrocarbons, explosives, and coal fly ash. Dr. Dzantor's current research is focused on coupling bio/phytoremediation to bioenergy feedstock production on marginal and degraded lands.

Joe Elkins has worked for the federal government for over 30 years, managing monitoring and quality assurance programs over much of this time. Elkins has taught monitoring and quality assurance courses around the world for the World Health Organization, and he has also worked as a college professor. His professional memberships have included the American Chemical Society, the Air and Waste Management Association, and the American Society of Quality.

Hana Elliott is a senior business manager in the technology industry with a background in environmental studies. She currently resides in Nashville, Tennessee, in a platinum LEED-certified, passive solar home, built using reclaimed materials, including recycled drywall and exterior siding made from a combination of old tin roofing material and charred oak (a traditional Japanese technique to preserve wood). Her work has previously been published in *Solar Today* magazine.

Beth J. Feingold is an assistant professor in the Department of Environmental Health Sciences at the University at Albany School of Public Health, State University of New York. She teaches global environmental health policy, geographic information systems and public health, and introduction to environmental health sciences. Dr. Feingold conducts interdisciplinary research to understand the drivers of environmental health disparities.

Linda Forst is board-certified in the field of occupational and internal medicine, and she is a professor at the School of Public Health, University of Illinois at Chicago. Dr. Forst conducts research related to occupational safety and health, underserved working populations, worker compensation, and surveillance for occupational illnesses and injuries in Illinois. Additionally, she is the director of a World Health Organization Collaborating Center on Occupational and Environmental Health.

Elizabeth Ann Glass Geltman is an associate professor at the City University of New York's Graduate School of Public Health and Health Policy. Additionally, she serves as secretary and communications officer for the Environment Section of the American Public Health Association. Dr. Geltman is an attorney and author of 17 books on environmental health law and policy.

Matthew O. Gribble is an assistant professor of environmental health at Emory University. He is a genetic epidemiologist by training and has conducted research on arsenic toxicokinetic genetics using both linkage and association approaches, focusing on families recruited from Arizona, Oklahoma, North Dakota, and South Dakota. Dr. Gribble also has broader interests in exposure science, environmental epidemiology, marine ecosystems, and ecotoxicology, and he is a diplomate of the American Board of Toxicology.

Gwen Griffith is program director of the Cumberland River Compact in Nashville, Tennessee. Dr. Griffith is a veterinarian turned educator who applies her science and health background to promoting ecosystem health at the landscape scale, including watershed stewardship, low impact development, and water conservation. Her background includes veterinary practice and science fellowship positions, and she was previously executive director of the Tennessee Environmental Council.

Justin M. Gundlach is an associate research scholar at Columbia Law School and a fellow at the Sabin Center for Climate Change Law. His work at the Sabin Center focuses on using existing legal and regulatory tools to promote efforts on the part of government and the private sector to mitigate and adapt to climate change. He is a member of the New York bar.

Meredith Hale holds the position of Kress Fellow in art librarianship at Yale University. She formerly was a librarian at the U.S. Environmental Protection Agency, specializing in resources for environmental research and rule development and handling requests from the public for information on environmental issues. She is a member of the Art Libraries Society of North America.

Maryam Hatcher is an associate with Beveridge and Diamond PC in Washington, D.C., where she maintains an environmental regulatory and litigation practice. Hatcher advises clients on various environmental compliance, contamination, and liability matters and provides guidance on federal environmental and occupational safety laws. During law school, Hatcher served as editor-in-chief of the *Howard Law Journal* at Howard University.

Adam Hess is an environmental health and safety assistant in the Environmental Health and Safety Department of New York University's Langone Medical Center. He previously conducted research at the City University of New York's School of Public Health, where he coauthored a data set and articles for the LawAtlas, concerning mold remediation and certification laws in the United States.

Anthony C. Holderied is a librarian and current assistant director at the U.S. Environmental Protection Agency (EPA) library in Research Triangle Park, North Carolina. Under contract with the School of Information and Library Science at the University of North Carolina at Chapel Hill, the EPA Research Triangle Park Library is one of 24 libraries in the EPA National Library Network. Holderied oversees the areas of reference, literature searching, and user education, helping to support over 2,000 local EPA research scientists.

Melisa L. Holman is associate director of Donor Communications for the Nature Conservancy in Asheville, North Carolina. She focuses on the Asia Pacific region, raising funding and awareness for the Conservancy's work. Holman has a background in forest ecology and environmental science and has published on topics ranging from invasive species to forest conservation.

Marilyn Holt is a research assistant in the chemical and physical biology program at Vanderbilt University, where she is studying the effects of enzyme dynamics on DNA replication. Additionally, as an accomplished science writer, Dr. Holt assists students in the university's writing center. She is a member of the Biophysical Society and the American Medical Writers Association.

Dafeng Hui is an associate professor at Tennessee State University, where he teaches ecology and conducts research in the areas of plant, global change, and ecosystem ecology and modeling. He has authored or coauthored more than 80 papers and serves as editor and reviewer for scientific journals. Dr. Hui's research has been sponsored by the U.S. Department of Energy, U.S. Department of Agriculture, and the National Science Foundation.

Elise C. Hunter is a site design engineer specializing in urban water resources. Additionally, she is experienced with wastewater treatment, stormwater development plans, and regulatory compliance. Hunter previously conducted research at Vanderbilt University on multidisciplinary approaches to assessing urban water security, incorporating physical and social sciences, engineering, and policy.

Ans Irfan is an adjunct professor at George Washington University's Milken Institute School of Public Health, where he teaches environmental health science and public health biology. Dr. Irfan is a certified public health professional, and he is chair of the Environmental Health and Safety Committee of the Metropolitan Washington Public Health Association.

Jyotsna S. Jagai is a research assistant professor at the University of Illinois at Chicago's School of Public Health. She is an environmental epidemiologist whose broad research interest is characterizing the impact of changing water quality and land use on human health. Dr. Jagai is also interested in developing comprehensive indicators to characterize the cumulative environmental impact on human health. Her work includes time series analyses, meta-analysis methods, and development of environmental exposure measures.

Adrienne L. Katner is an assistant professor at Louisiana State University's Health Sciences Center in the School of Public Health. Dr. Katner's research involves evaluating human exposure to heavy metals. Formerly with the Louisiana Office of Public Health, she oversaw Louisiana's Environmental Public Health Tracking and Occupational Health programs. Dr. Katner teaches principles of occupational health and environmental policy, and she is a member of the Society of Toxicology and the American Public Health Association.

Alison K. Krajewski is research associate at the University of Illinois at Chicago's School of Public Health, where she specializes in environmental epidemiology and occupational surveillance research. Dr. Krajewski's primary research project involves assessing the relationship between cumulative environmental exposures and diabetes outcomes.

Emmanuel Kyeremateng-Amoah is a public health/occupational health physician with the Ghana Health Service, where he conducts research on the health impacts of extractive industries and associated air pollution. Dr. Kyeremateng-Amoah is currently conducting research on pesticide poisoning reporting and the Adult Blood Lead Registry at the Illinois Occupational Surveillance Program within the Department of Environmental and Occupational Health Sciences, University of Illinois at Chicago.

Rachel L. Lamb is a University of Maryland Flagship fellow and steering committee member for Young Evangelicals for Climate Action. Additionally, she teaches environmental law and policy at Au Sable Institute of Environmental Studies. Lamb previously worked as a fellow for the U.S. Environmental Protection Agency, where she produced a collection of tribal best practices for climate change adaptation. Her professional expertise is in cultivating interdisciplinary strategies to combat climate change that simultaneously address ecological, economic, and sociopolitical concerns.

Megan W. Latshaw is a member of the faculty at the Johns Hopkins Bloomberg School of Public Health and is past chair of the American Public Health Association's Environment Section, serving from 2015 through 2017. She created and formalized a national biomonitoring network at the Association of Public Health Laboratories, and she has published and presented on this topic both domestically and internationally. Dr. Latshaw's earlier research involved measuring biomarkers as part of a larger study focusing on memory in older Baltimore residents.

David A. Lawrence is a senior research scientist with the Wadsworth Center of the New York State Department of Health in Albany, New York. At the Wadsworth Center, Dr. Lawrence is laboratory chief of immunology. His research addresses the influences of environmental stressors on the multifunctionality of nervous, endocrine, and immune system interactions. Dr. Lawrence received the Vos Lifetime Career Achievement Award in Immunotoxicology from the Society of Toxicology.

Thomas B. Lawrence is a consulting engineer specializing in water quality protection and restoration, including projects as varied as underground storage tank remediation, construction site pollution prevention design and implementation, and municipal stormwater pollution prevention. He is an experienced speaker and instructor, having spoken at professional conferences throughout the country. Lawrence is a registered professional engineer, and he has worked in the civil engineering field for over 25 years.

Nichole LeClair is a research fellow at the City University of New York's Graduate School of Public Health and Health Policy. She is coauthor of data sets published by LawAtlas, involving technologically enhanced mapping of naturally occurring radioactive materials and radon laws in the United States.

Shao Lin is a professor of environmental health sciences and associate director for Global Health Research, University of Albany, State University of New York. As a principal investigator, she has directed multiple studies of the September 11 terrorist attacks as well as other research involving the health effects of extreme weather, natural disasters, air pollution and traffic, and the home/school environment. Additionally, Dr. Lin was a member of the advisory board of the World Trade Center Health Registry for many years.

Yi-Pin Lin is a research scientist at the Wadsworth Center, New York State Department of Health at Albany, New York. His research focuses on how Lyme disease–causing bacteria survive in two distinct host environments (ticks and vertebrate animals), causing transmission between these hosts and resulting in diseases. Dr. Lin also teaches immunology and medical entomology at the State University of New York at Albany.

Howard W. MacLennan Jr. is the lead physician in medical readiness standards for the North Carolina Army National Guard, where his specialties include genetics, molecular biology, and osteopathic medicine. Dr. MacLennan is a member of the American Academy of Family Physicians, American Board of Family Medicine, and American Osteopathic Association, and he has widely published in a variety of medical journals. (The views expressed by Dr. MacLennan are those of the author and do not reflect the official policy or position of the Department of the Army, Department of Defense, or U.S. government.)

Jessica M. Madrigal is a research specialist at the University of Illinois at Chicago, where she contributes to public health research related to diabetes and other chronic diseases. Her academic and research interests focus on environmental and occupational exposures and chronic disease outcomes. Madrigal is a member of

American Public Health Association, American College of Sports Medicine, and the Society for Epidemiologic Research.

Susan J. Montgomery has more than 40 years of experience as a professional journalist and teacher. For much of her career, her writing has focused on healthcare topics for major healthcare organizations, and she has an expertise in communicating technical, health-related topics to a lay audience. Montgomery has also published two artists' biographies and is currently managing an online magazine, Life-Uncorked.com, that includes articles on travel and cuisine throughout Southern California.

Jill Warnasch Mozier is an environmental engineer with SC&A, Inc., an environmental and energy consulting firm. Mozier is the project manager for technical support to the U.S. Environmental Protection Agency in developing its residential wood heater air emission standards. Additionally, she is the project manager for the inhalation risk modeling (cancer and noncancer) of emission source categories evaluated under the agency's Risk and Technology Review and National Air Toxics Assessment programs.

Alisha K. Newton is the environmental literacy coordinator for the Tennessee Department of Environment and Conservation, where she is responsible for implementing the Tennessee state environmental literacy plan. As a student at Vanderbilt University, Newton founded a publication about environmental issues. She previously worked for the National Park Service at Wrangell-St. Elias National Park and Preserve in Alaska.

Joanne O'Loughlin is an environmental scientist and registered nurse at SC&A, Inc., an environmental and energy consulting firm, where she analyzes air pollution emission sources, health effects from exposure to air pollutants, and emission mitigation options. O'Loughlin is currently supporting the development of a healthcare provider training course to educate providers on communicating with patients who are at high risk from air pollution exposure.

Mary V. O'Reilly, an industrial hygienist and ergonomist, is on the faculty of the State University of New York's School of Public Health and a member of the faculty advisory committee for the university's Institute for Health and the Environment. Dr. O'Reilly is board president for Workplace Health Without Borders (U.S. Branch), and she received the American Industrial Hygiene Association's 2016 Alice Hamilton Award. She also belongs to the American Conference of Governmental Industrial Hygienists and the Society for Risk Analysis.

Richard F. Pandullo has over 30 years of professional experience covering a broad range of environmental management issues, including air quality planning and permitting, climate change strategy, greenhouse gas emissions management, health and safety management systems, and various types of environmental auditing. Pandullo is currently director of Trinity Consultants' business line for environmental health and safety performance and risk management, overseeing client technical support work involving sustainability, management systems, and auditing.

Anthony G. Papetti is an environmental attorney at Beveridge and Diamond PC, a national environmental law firm of 100 lawyers, where he maintains a general environmental litigation and regulatory practice. He also has work experience with the United Nations and the U.S. Environmental Protection Agency. Prior to becoming an environmental attorney, Papetti worked as a chemical analyst in the elemental analysis section of a global company that provides testing and inspection services for the petroleum, refining, and petrochemical industries.

Chelsea N. Peters is a hydrologist specializing in drinking water resources. She is experienced with stream restoration planning and water quality modeling, and her recent research at Vanderbilt University focuses on groundwater-surface water interactions in southwest Bangladesh. Peters has taught a variety of K–12 hydrology and environmental stewardship courses across Tennessee.

R. Christopher Rustin is director of Environmental Health for the Georgia Department of Public Health, and he has 18 years of experience working in local and state environmental public health programs. He was previously an assistant professor at Georgia Southern University's Jiann-Ping Hsu College of Public Health, where he taught courses in environmental health science and conducted research on the application of environmental health programs, surveillance of mosquito vectors, and lead poisoning risk factors.

A.J. Smuskiewicz is a freelance writer and editor who specializes in science, medicine, and world events. Prior to entering the writing profession, Smuskiewicz worked as a laboratory and field biologist, including analyzing zooplankton species and water chemistry for the U.S. Environmental Protection Agency's Great Lakes Monitoring Project and conducting dose-response tests on National Institutes of Health projects at the Illinois Institute of Technology Research Institute.

Victor B. Stolberg is an assistant professor/counselor at Essex County College in Newark, New Jersey, where he previously directed the Office of Disability Support Services and Office of the Substance Abuse Coordinator. He has authored 49 scholarly articles, 87 encyclopedia articles, six chapters and contributed papers, and 63 other miscellaneous publications. Stolberg also has several publications in press, including the book *Painkillers: History, Science, and Issues*.

Kathy Stolley is a professor of sociology at Virginia Wesleyan College. Her emphasis is applied sociology, which involves using sociological tools and perspectives to bring about positive social change. A recipient of Virginia Wesleyan College's Samuel Nelson Gray Distinguished Teaching Award, Dr. Stolley formerly served as associate dean for Innovative Teaching and Engaged Learning. Her written work appears in a variety of professional journals, and she has published five books.

Timothy J. Sutton is a physician specializing in occupational and environmental medicine. Dr. Sutton's field of expertise lies in the evaluation and management of workplace injuries and toxic exposures, and he also focuses on evaluating environmental pollutants and their effects on the human population. Dr. Sutton is a member of the American College of Occupational and Environmental Medicine.

Ranjita Thapa is a plant breeding specialist experienced in the genotyping and phenotyping of *Amaranthus*, a highly nutritious and ancient pseudocereal. She is presently involved with a rice breeding project in the Department of Soil and Crop Sciences at Texas A&M University. The goal of this research is to improve rice through the deployment of genetics and genomics tools.

Leon D. Tillman Jr. is a resource conservationist with the Natural Resources Conservation Service, where he provides technical leadership, guidance, and assistance in developing and implementing Farm Bill conservation programs. His work contributes to increasing conservation implementation on private agriculture land and improving water quality through U.S. Department of Agriculture programs and initiatives.

Kelley Trahan is the environmental librarian at the San Francisco Public Library. She has worked previously as a librarian at the Oakland Public Library and as an archivist at the National Archives' San Francisco regional office. She is passionate about fostering the information literacy skills that patrons need to become critical information consumers and developing innovative programs to highlight collections.

Robert Ukeiley is a public interest environmental lawyer and consultant with his own practice based in Boulder, Colorado. He represents and supports nonprofit environmental and community organizations in their efforts to reduce air pollution and foster the transition to clean, renewable energy. Ukeiley has presented at numerous workshops and panels on air pollution and energy issues.

Simon Waldbaum has spent over a decade conducting biomedical science research, most recently at the University of Colorado Anschutz Medical Campus in a laboratory studying the contributing effects of environmental toxins on neurological disorders, such as Parkinson's disease and acquired epilepsy. Dr. Waldbaum's primary research focus and areas of publication have been in elucidating inhibitory synaptic signaling, studying neuronal control of respiration, and investigating the link between mitochondrial dysfunction and neurological disorders.

Jessica Wentz is a staff attorney at the Sabin Center for Climate Change Law at Columbia Law School. Her work at the center spans a variety of topics related to climate change mitigation, adaptation, sustainable development, and environmental justice. She is a member of the California Bar.

Xingbo Wu specializes in plant breeding in the Agricultural and Environmental Sciences program at Tennessee State University. He has a special interest in researching the plant genomics and genetics of cowpea, an important sub-Saharan African crop, with the goal of improving nutritional quality through molecular breeding. Dr. Wu is a member of the Crop Science Society of America.

Damba Yahaya is a plant biotechnologist and assistant lecturer at the University for Development Studies in Tamale, Ghana, where he conducts tissue culture and plant propagation on roots and tubers crops, such as cassava and yam. Additionally, he is conducting breeding and genetics research at Tennessee State University involving legumes and dicotyledonous C4 crop plants, such as cultivated amaranth.

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Index

Note: page numbers in **bold** indicate main encyclopedia entries.