NEBOSH INTERNATIONAL DIPLOMA UNIT IB

Hazardous Substances/Agents Part 1

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NEBOSH INTERNATIONAL DIPLOMA

UNIT IB: HAZARDOUS SUBSTANCES/AGENTS - PART 1

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Introduction

Element IB1: Managing Occupational Health

Element IB2: Identification, Assessment and Evaluation of Hazardous Substances

Element IB3: Control of Hazardous Substances

Contents

Element IB4: Monitoring and Measuring of Hazardous Substances

Element IB5: Biological Agents

Suggested Answers

Course Structure

This textbook has been designed to provide the reader with the core knowledge needed to successfully complete the NEBOSH International Diploma in Occupational Health and Safety, as well as providing a useful overview of health and safety management. It follows the structure and content of the NEBOSH syllabus.

The NEBOSH International Diploma consists of four units of study. When you successfully complete any of the units you will receive a Unit Certificate, but to achieve a complete NEBOSH Diploma qualification you need to pass the three units within a five-year period. For more detailed information about how the syllabus is structured, visit the NEBOSH website (www.nebosh.org.uk).

Assessment

Unit IB is assessed by a three-hour exam that is set out in two sections. Section A consists of six 10-mark compulsory questions, and Section B consists of five 20-mark questions, of which you must choose three.

NEBOSH set and mark this exam paper.

More Information

As you work your way through this book, always remember to relate your own experiences in the workplace to the topics you study. An appreciation of the practical application and significance of health and safety will help you understand the topics.

Keeping Yourself Up to Date

The field of health and safety is constantly evolving and, as such, it will be necessary for you to keep up to date with changing legislation and best practice.

RRC International publishes updates to all its course materials via a quarterly e-newsletter (issued in February, May, August and November), which alerts students to key changes in legislation, best practice and other information pertinent to current courses.

Please visit www.rrc.co.uk/news/newsletters.aspx to access these updates.

Unit IB: Hazardous Substances/Agents	
Element IB1	Managing Occupational Health
Element IB2	Identification, Assessment and Evaluation of Hazardous Substances
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Element IB1

Managing Occupational Health

Learning Outcomes

Once you've read this element, you'll understand how to:

1. Outline the nature of occupational health.
2. Outline the principles and benefits of vocational rehabilitation including the role of outside support agencies.
3. Outline the management of occupational health (including the practical and legal aspects).

Contents

Nature of Occupational Health

IN THIS SECTION...

- Occupational health can be defined as "*the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations by preventing departures from health, controlling risks, and adapting work to people and people to their jobs*".
- Occupational health deals with health hazards that can be categorised under five headings: chemical, physical, biological, psycho-social and ergonomic.
- Work-related ill health is far more prevalent than work-related injury, with many thousands of deaths occurring each year as a result of exposure to various health hazards such as asbestos.
- There are strong links between occupational health and public health, particularly in cases of serious health issues which will impact on individuals and employers.

The Meaning of Health, Occupational Health and Well-Being

Before we begin to consider the practicalities of this topic, it is useful to spend some time examining its nature by posing a few questions such as "What does the word health mean?" and "What is occupational health?".

There are several definitions of "health", but you have to remember that these are subjective and can mean different things to many people. The term may be used to indicate the state of individuals', families', communities' or even the wider populations' health.

Health

There are several definitions of "health", but you have to remember that these are subjective and can mean different things to many people. The term may be used to indicate the state of individuals', families', communities' or even the wider populations' health.

One definition of health (according to the western scientific medical model) is merely: "...the absence of disease or illness".

However, in 1948, the World Health Organisation (WHO) defined health as: "*...a state of complete physical, mental and social well-being, not merely the absence of disease or infirmity*".

(Preamble to the Constitution of the World Health Organisation, 1946)

Health is a state of physical, mental and social well-being

It is important to recognise that this definition goes beyond physical well-being and the absence of disease to identify mental and social well-being as components of health.

Occupational Health

The International Labour Organisation (ILO) and the World Health Organisation (WHO) define occupational health as:

"*the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations by preventing departures from health, controlling risks, and adapting work to people and people to their jobs.*"

The discipline of occupational health is concerned with the two-way relationship of work and health. We are concerned about the effects of the working environment on the health of the worker, but we must also consider the influence of the worker's state of health on their ability to perform workplace tasks.

Well-Being

As with "health" there are many varied definitions of the term "well-being" and the term is often linked to feelings of happiness, fulfilment and satisfaction.

The UK's Economic and Social Research Council (ESRC) have defined well-being as:

"... a state of being with others, where human needs are met, where one can act meaningfully to pursue one's goals, and where one enjoys a satisfactory quality of life".

Well-being consequently goes far beyond basic physical health and absence of disease to consider psychological aspects of health. In this respect there is a clear commonality of approach between the WHO definition of "health" and the broad definition of well-being stated above.

You should note, however, that as well as being subjective, the definitions of these terms is open to debate and argument. For example, there might be a perceived conflict between "health" and "well-being" if well-being is often associated with feelings of happiness, fulfilment and satisfaction; an individual can do things that make them feel happy and satisfied, but which are essentially unhealthy, e.g. smoking and drinking alcohol.

Categories of Occupational Health Hazard

Occupational health hazards can be classified into five categories:

- **Chemical**

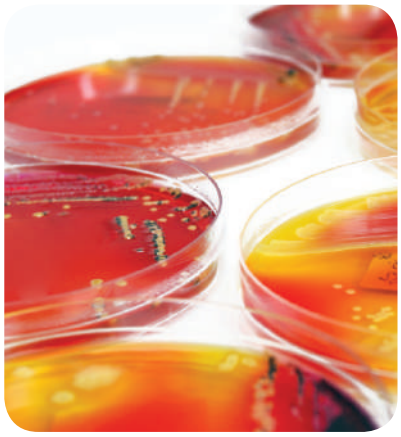
  Dusts, fibres, gases, vapours, etc. and the associated hazards. These will be dealt with in Elements IB2 to IB4.

- **Physical**

  Noise, vibration, radiation, heat, etc. These will be dealt with in Elements IB6, IB7 and IB10.

- **Biological**

  Bacteria, fungus, virus, human endoparasites, etc. These will be dealt with in Element IB5.



Chemical hazards can account for a range of occupational diseases

- **Psycho-social**

  Stress, substance misuse, violence at work, etc. These will be dealt with in Element IB8.

- **Ergonomic**

  Posture, workplace layout, etc. These will be dealt with in Element IB9.

These five categories of health hazard between them account for a wide variety of occupational diseases and ill-health conditions, many of which will be studied during this unit. Some of these occupational diseases are relatively common and are found in a wide variety of different workplaces.

For example, dermatitis is a common occupational disease found in many different types of workplace, from restaurants and kitchens, to science laboratories, industrial workshops and construction sites.

It is also worth remembering that these hazards sometimes are not the sole or principal cause of occupational disease or ill health; they are simply a contributing factor. For example, noise-induced hearing loss may be due solely to workplace exposure to excessive noise, or it may be due to leisure activities with a contribution from the workplace.

In many instances, separating out the workplace contribution from the non-work contribution is difficult, if not impossible.

Prevalence of Work-Related Sickness and Ill Health

It is estimated that, globally, there are 2.3 million work-related deaths annually. By far, the largest proportion of these deaths is linked to work-related diseases, 2.0 million, with 0.3 million linked to accidental injuries. The ratio of these two factors varies, depending on the level of development. In industrialised countries, the share of deaths caused by non-communicable diseases are the overwhelming cause. Economic costs of work-related injury and illness vary between 1.8 and 6.0% of Gross Domestic Product (GDP), the average being 4% according to the ILO.

MORE...

An 'At a glance guide to HSE's statistics' can be found at:

www.hse.gov.uk/statistics/at-a-glance.pdf

Because reporting practices vary internationally, it can be difficult to directly compare health statistics on a global basis. However, the statistics collected by the Health and Safety Executive (HSE) for Great Britain give a fair indication of the occupational health statistics within a developed nation.

HSE annual statistics report that:

- Work-related ill health kills an estimated 13,000 people each year of which work-related cancer and lung disease account for over 90% of cases.
- Around 1.2 million people suffer from an illness (long standing as well as new cases) they believe is caused or made worse by their current or past work.
- Around half of these cases are new cases of illness.
- Over 28 million days are lost due to health and safety incidents:
  - Around 40% of these relate to ill health.
  - Ill health accounts for about 85% of the related sickness absence and over 99% of the work-related deaths each year.

Prevalence by Types of Ill Health

Statistics released by the HSE relate to particular diseases or types of ill health:

- **Musculoskeletal disorders** have decreased over the last decade but still account for 40% of the 1.2 million cases of work-related illnesses with around 180,000 new cases per year.
- Reports from GPs suggest there could be over 35,000 new cases of work-related **skin disease** per year.
- **Stress** accounts for around 40% of work-related illness and the incidence of cases has remained broadly flat over the past decade.
- Around 18,000 workers suffer **hearing problems** believed to be work-related, with around 120 individuals per year qualifying as new cases of noise-induced deafness under the Industrial Injuries Disablement Benefit scheme.
- Deaths from **asbestos exposure** continue to increase in Great Britain, a legacy of heavy exposure in the past, resulting in:
  - Over 200 deaths per year due to asbestosis and another 450 where asbestosis contributed as a cause.

Monitoring a worker's health

- Approximately 2,500 deaths due to mesothelioma (an increase from 500 in the early 1980s). The expected number of mesothelioma deaths is predicted to increase to a peak around the year 2017/18.
- Around 2,000 lung cancer deaths where asbestos was the cause (this can only be estimated as asbestos cannot be proven as the cause).

The above statistics show the significant scale of work-related ill health in Great Britain at the present time.

Statistics on work-related ill health can come from a variety of sources. The HSE collates ill-health statistics from a number of sources such as:

- The **Reporting of Injuries, Diseases and Dangerous Occurrences Regulations** (**RIDDOR**) - which require the reporting of specific occupational diseases by the employer.
- Labour Force Survey (LFS) - is a national survey of private households in the UK each quarter. The survey is managed by the Office for National Statistics.
- The Health and Occupation Reporting (THOR) network - a voluntary surveillance scheme for work-related ill health under which specialist doctors systematically report all new cases that they see in their clinics.
- The Industrial Injuries Scheme - administered by the Department for Work and Pensions (DWP) to compensate workers who have been disabled by a prescribed occupational disease.
- Death certificates - as a source of information on deaths from asbestos-related and other occupational lung diseases.

Occupational Health and Public Health

It is in the nature of biological agents that new strains or types of pathogen (disease-causing agent) emerge from time to time. These pathogens sometimes cause serious outbreaks of disease that are locally contained. On occasion, outbreaks can be more widespread and have more significant impacts for employers, e.g. norovirus outbreaks (also referred to as the "Norwalk" or" winter vomiting virus") affecting cruise ships, workplaces and schools.

Sometimes, outbreaks reach epidemic or even pandemic proportions, such as the Ebola pandemic in Western Africa in 2014 and 2016, the H1N1 'flu virus pandemic of 2009 and the Sudden Acute Respiratory Syndrome (SARS) near-pandemic of 2002-03.

These emerging health issues are of interest and consequence to various employers because of the application of health and safety law. The employers affected and the actions that they have to take vary depending on the nature of the health issue. For example, pandemic 'flu is of interest to health care employers whose staff will have to provide front line services to patients; laboratory managers where diagnostic and research work is carried out on the virus and other employers whose staff might come into contact with symptomatic members of the public (such as local authority employees).

MORE...

There are lots of useful sources of information for occupational health; have a look at the following:

www.hse.gov.uk/statistics/index.htm

www.dwp.gov.uk/docs/hwwb-is-work-good-for-you.pdf

www.gov.uk/government/uploads/system/uploads/attachment_data/file/209782/hwwb-working-for-a-healthier-tomorrow.pdf

Aside from any specific legal duties that may apply, there is a clear incentive for employers to manage the risks presented by these public health issues and there is a clear public health dimension to the management of workplaces.

Public health impacts on the workplace, and the workplace can also have an impact on public health.

There is, therefore, a strong link between occupational health and public health. In the case of epidemics, such as Ebola, SARS and H1N1, public health and occupational health authorities issued guidance and information to prevent and limit the spread of the disease. This guidance was used by employers and, in particular, occupational health professionals, to formulate company policy and arrangements for the management of the risks presented.

It should be noted that though biological agents are responsible for recent epidemics that have come to public attention, there are other types of health hazard that are capable of creating a public health issue that fall within the sphere of influence of work. Smoking and asbestos are two prime examples of such health issues. Asbestos has become tightly regulated over several decades, with heavy emphasis of the management of the public health risk falling on the employer or premises controller. Smoking as a public health issue has undergone a similar regulatory approach, with the emphasis on the prohibition of smoking in enclosed spaces falling under the control of employers or other workplace and premises controllers.

STUDY QUESTIONS

1. State the five categories of health hazard. Give an example of each.
2. Outline some of the main sources of data used to compile occupational ill-health statistics.

(Suggested Answers are at the end.)

Management of Return to Work

IN THIS SECTION...

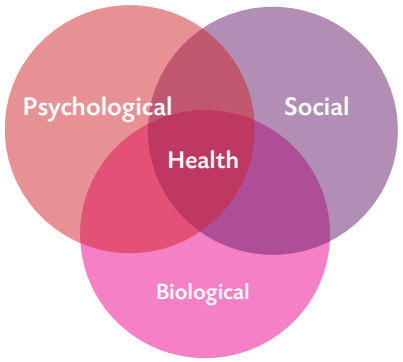
- The bio-psychosocial model is a way of considering human ill health as being more than simply a case of medical disease, but a combination of biological disease and psychological response by the individual within a social context.
- Fitness-to-work standards are defined levels of health and fitness that are used to determine whether a worker is capable of carrying out a defined type of work safely. These standards are sometimes defined in statue law but are often a matter of good practice.
- A pre-placement health assessment is undertaken as part of the risk assessment process (usually only after a job offer has been made) to determine the health and fitness of the worker in respect of the job that they will be carrying out.
- Employers must establish policies and procedures to actively manage employees' return to work from long-term and short-term frequent sickness absence. This is best done through appropriate liaison between managers, occupational health and other health care providers as outlined in NICE guidance note PH19.
- Vocational rehabilitation is concerned with helping someone with a health problem to stay at, return to, and remain in work. There are benefits to rehabilitating workers back into the workplace, both for the employer and the employee, and the bio-psychosocial model can be used to identify barriers to the rehabilitation of ill workers and has been used in the rehabilitation of workers with musculoskeletal disorders (MSD) and other common work-related conditions.
- Risk assessment plays an important role in the return to work of an employee following ill health or incapacity.
- Various external agencies such as Occupational Therapists (OTs) exist to provide support to the employer and employee during the return-to-work and rehabilitation process.

Basic Principles of the Bio-Psychosocial Model

According to the Health and Safety Executive (HSE Management Standards Approach: An Update, 2010), the bio-psychosocial model of health considers the individual, their health and their social context:

Bio-psychosocial is a clumsy, technical term but it is difficult to find any adequate, alternative word. Put simply, this is an individual-centred model that considers the person, their health problem and their social context:

- **Biological** refers to the physical or mental health condition.
- **Psychological** recognises that personal/psychological factors also influence functioning and the individual must take some measure of personal responsibility for his or her behaviour.
- **Social** recognises the importance of the social context, pressures and constraints on behaviour and functioning.



The bio-psychosocial model

The bio-psychosocial model is a holistic model of health, acknowledging that the health condition of the individual is not the only factor that needs to be managed.

Individuals are affected by external factors, such as home responsibilities, financial pressures, relationships and social interaction with colleagues and friends. These factors can be positive and supportive, but can also be destructive.

Additionally, personality type and psychological resilience also play a role in how the individual copes with external pressure; the optimist may be able to cope with pressures that would cause the pessimist to struggle. Another factor in long-term health conditions is whether the individual understands their condition and can normally manage it, e.g. asthmatics are usually good at knowing when and how much medication to use but may struggle if the condition is exacerbated by chest infections or 'flu.

The World Health Organisation's (WHO) International Classification of Functioning, Disability and Health (ICF) is based on the bio-psychosocial model, and is now widely accepted as the framework for disability and rehabilitation.

In the context of occupational health and vocational rehabilitation, the bio-psychosocial model has been successfully used as a model for rehabilitation of those with ill health and disability back into work. In particular, it is being used as a treatment model for musculoskeletal disorders, such as upper-limb disorders and back pain.

DEFINITIONS

BIOLOGICAL ASPECTS

The physical and/or mental condition of the individual.

PSYCHOLOGICAL ASPECTS

The personal or psychological factors that influence function, behaviour, beliefs, coping strategies, emotions and distress. (This term does not relate to mental illness.)

SOCIAL ASPECTS

The culture of the individual, the workplace and society, and social interactions and relationships.

Fitness-to-Work Standards

There are many types of work where a certain level of fitness is required in order for the work to be done safely.

In some cases, this minimum level of fitness is necessary to prevent unacceptable risk to the worker carrying out the work. An example of this is working at height, where workers suffering from heart conditions or recurrent dizziness would be at far greater risk of a fall.

In other cases, this minimum level of fitness is necessary to prevent unacceptable risk to other people (such as fellow workers or members of the public) who might be affected by the worker. An example of this is lorry driving or train driving where workers suffering from uncorrected eyesight could put others at risk.

As a consequence, many organisations have established **fitness-to-work standards** that workers are then assessed against in order to ensure that their level of fitness is acceptable for the specific type of work that they are to do.

In some cases, there is a clear legal duty on the employer to undertake this fitness assessment and the standards are established by or under the relevant statute law. An example of this would be the UK's statutory medical for Large Goods Vehicle (LGV) drivers that they would have to undertake in order to first obtain their licence to drive on the public roads, followed by five-yearly re-assessment from age 45 onwards. Similar statutory fitness assessments are required from train drivers, commercial pilots, etc.

In other cases, there may be no specific statutory duty on the employer. Instead, there may be the general duties implicit in national legislation, along with the employer's desire to comply with industry guidelines, industry good practice or some other non-statutory code. Examples of this would include the fitness-to-work standards for oil and gas company workers produced by the International Association of Oil and Gas Producers (IOGP), and those aimed specifically at wind turbine workers produced by RenewableUK (a renewable energy trade association).

The primary purpose of a medical fitness assessment for work is to ensure that a worker is fit to perform the work/task they are required to carry out without putting their own or others' (e.g. colleagues) health and safety at risk. This might include:

- an individual's condition limiting, reducing or preventing them from performing a job effectively (e.g. musculoskeletal or heart conditions, restricting the ability to climb a fixed vertical access ladder, work in a confined space or in hot conditions);

- their condition being made worse by a job (e.g. heart conditions exacerbated by physical exertion);
- their condition making certain jobs/tasks unsafe (e.g. potential loss of consciousness and the risks associated with falls from height); or
- ensuring there are no underlying medical conditions that could compromise the safe emergency rescue of the individuals or colleagues (e.g. emergency rescue in remote locations and offshore).

Where fitness-to-work standards are to be used, then the standards will have to be identified and described so that the relevant health care professional can apply the standards during the assessment process. For example, the UK's Driver and Vehicle Licencing Agency (DVLA) has published guidance for use by medical doctors during the assessment of a person's fitness to drive on the public highway. This document describes, in detail, the disorders that might warrant restriction or removal of a person's driving licence, along with guidance on the extent of the disorder and the restriction that might be imposed. Disorders are covered under seven general headings, including neurological, cardiovascular, psychiatric, visual and respiratory. Under each disorder heading, a wide range of specific health issues is then described along with the outcome associated with that health issue. The document runs to 75 pages long.

Cardiovascular Disorders	Group 1 Entitlement ODL - Car, Motorcycle	Group 2 Entitlement VOC - LGV/PCV (LORRY/BUS)
Angina	Driving must cease when symptoms occur at rest, with emotion or at the wheel. Driving may recommence when satisfactory symptom control is achieved. DVLA need not be notified.	Refusal or revocation with continuing symptoms (treated and/or untreated). Re-licensing may be permitted thereafter provided: • Free from angina for at least 6/52. • The exercise or other functional test requirements can be met. • There is no other disqualifying condition.

Example of the DVLA fitness standard for drivers

From "At a glance guide to the current medical standards of fitness to drive"; DVLA (www.gov.uk/government/uploads/system/uploads/attachment_data/file/457961/aagv1.pdf)

Examples of Occupations Requiring Specific Fitness Standards

Great Britain's **Working Time Regulations 1998 (as amended)** and **EU Working Time Directive 2003 (Directive 2003/88/EC, Article 9)** require employers to offer health assessments for night workers before they start work and on a regular basis while they are working nights.

Professional drivers of Group 2 vehicles (lorries/buses, etc.) must be fit in accordance with Great Britain's **Road Traffic Act 1988**, the **Motor Vehicles (Driving Licence) Regulations 1999** and the second **EC Directive on Driving Licences (91/439/EEC)**, which set out the medical standards for Group 1 and Group 2 licence holders. The medical standards for Group 2 drivers are much higher than those for Group 1, reflecting the size and weight of the vehicle driven, the higher risk, the length of time spent driving and the occupation.

In Great Britain, professional divers must be fit under the requirements of the **Diving at Work Regulations 1997** and guidance under the **Confined Spaces Regulations 1997** states workers in confined spaces must be of a suitable build, not suffer from claustrophobia, and have the physical capability to wear self-contained breathing apparatus if necessary.

TOPIC FOCUS

Occupations requiring specific fitness standards include:

- Vehicle driving (forklift trucks (FLT), Heavy Goods Vehicles (HGV), cranes, buses, trains, etc.).
- Working with dangerous machinery.
- Working at heights.
- Working in confined spaces.
- Emergency service workers.
- Night shift workers.
- Divers.

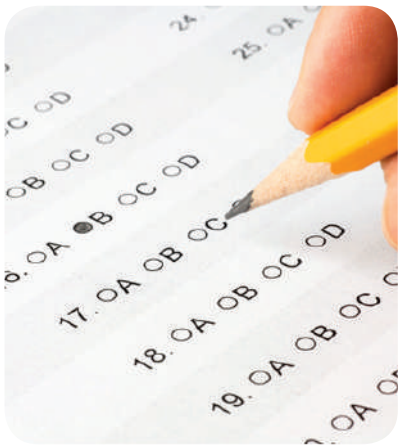
Pre-Placement Health Assessments

A pre-placement health assessment is undertaken by a health professional as part of the risk assessment process and (usually) only after a job offer has been made. The pre-placement assessment can consist of any or all of the following:

Questionnaires are usually used as a method of pre-screening to establish whether a more detailed medical examination is required.

Medical examination is used where:

- The questionnaire has indicated a problem which requires further investigation.
- It is a statutory requirement or if specific medical standards have to be met.
- A baseline examination is required since those involved will be exposed to high-noise levels; respirator sensitisers; radiation, etc.



Questionnaires can indicate problems that need further investigation

The reasons for undertaking pre-placement health assessments are to:

- Ensure that all new employees are medically fit to fulfil the duties and responsibilities that are intrinsic to their role.
- Consider reasonable adjustments that could be made to assist the person in their role.
- Assess whether the job may adversely affect the new employee's health, and whether any extra precautions are therefore needed.
- Provide a record of health information as a base line for comparison before work begins (such as a hearing test on a worker before they begin work in a high-noise environment).

Results of Pre-Placement Assessment

Prospective employees are usually classified as "fit" or "unfit" to do the job. Rarely is a person classified as "provisionally fit" and then reassessed.

If a person is:

- **Fit** – there are no health or fitness reasons as to why they cannot do the job.
- **Unfit** – the person has a health or fitness problem which will prevent them from doing the job to the standards required.

- **Provisionally fit** – a health or fitness issue has been identified that could prevent this person from doing their duties safely; however, some time observing them in the work situation is needed before a final decision is made. A probationary period of work may be offered so that further assessments can take place.

Employment and anti-discrimination law will often set out employers' responsibilities towards disabled employees, or those who may require adjustments to the workplace in order to be able to work safely and without harm to health. The pre-placement health assessment provides a means of early identification of those in need of assistance or extra protection. However, it must also be recognised that the use of health or disability questionnaires or assessments before a job is offered might be discriminatory and hence unlawful.

For this reason, many organisations will not undertake any form of health questionnaire or assessment until after a job offer has been made.

As was noted in the section on fitness-to-work standards, there may be specific legislation that requires pre-placement health assessments for those involved in particular areas of work, such as train drivers. Or there may be a semi-legal guidance, code or good practice that the employer wishes to comply with.

In these circumstances, a job offer might be made that is conditional on the employee being able to pass the fitness assessments. In limited instances, the fitness assessments might be carried out before a job offer is made without it being unlawful. Detailed guidance on the use of health and fitness questions during the recruitment and selection process have been published by the Equality and Human Rights Commission.

MORE...

www.

Guidance on the use of health questions during recruitment is available form:

www.equalityhumanrights.com/sites/default/files/documents/EqualityAct/pre-employment_health_questions_guidance_for_employers_final.pdf

Managing Long-Term and Short-Term Frequent Sickness and Incapacity for Work

Managing Short-Term Frequent Absence

Short-term absence is where an employee is repeatedly absent for short periods of time, such as one or two days. Absence such as this can have an effect on the person's performance and be disruptive to others and the organisation as a whole (particularly small and medium-sized enterprises). Employers should take a systematic approach to managing such absences.

- ### Proactive Application of the Policy

  The organisation's policy will outline the procedure to follow for the management of short-term absences. Line managers should know the steps to take and should follow the procedures, supporting the employee and ensuring that all relevant information on sick pay and return to work is given. Managers should stay in contact with the employee without appearing to be harassing them. A good manager will appear supportive and it has been shown that regular contact reduces short-term absences and the length of long-term sickness absence.

- ### Return-to-Work Interviews to Establish Real Reasons for Absence

  Research has shown that the single most effective action to reduce absence is to consistently conduct return-to-work interviews for all staff who have been absent, however long or short the absence period. The purpose of the return-to-work interview is to:

  – Determine the reason for absence.
  – Assess whether the reason is consistent with other reliable evidence.
  – Discuss any doubts/issues with the employee and give them the opportunity to explain the reason for absence.

The employee may have been genuinely sick and it is always best to start with that assumption unless patterns start to emerge. However, there may be underlying issues at work such as workload, relationships with colleagues, training issues or environmental factors, or external factors such as caring or parenting issues, financial pressures, relationship breakdown or bereavement. Good managers will know their staff well enough to identify that there may be a problem and will have the skills to deal with it. If the absence is of a genuine nature (medical) then procedures should be put in place to support the employee; if it is due to a temporary domestic issue then the employer may need to decide on the appropriate action to take, but in all cases the employee will be expected to improve their attendance rate

- ## Procedures to Deal with Unacceptable Absence Levels and/or Breach of the Policy

Persistent absence must be dealt with promptly, firmly and consistently in order to show both the employee concerned and other employees that absence is regarded as a serious matter and may lead to disciplinary procedures being followed.

MORE...

www.hse.gov.uk/sicknessabsence

Staff need to be aware of the consequences of repeated short-term absence, whether disciplinary action or loss of earnings. It is often the case that, under a country's employment laws, workers are entitled not to be unfairly dismissed. When determining unfair dismissal claims, court and tribunals will often consider two points:

- Has the employer established a potentially fair reason for dismissal?
- Did the employer act reasonably in all the circumstances and use proper procedures?

Employers should ensure they can demonstrate that they have:

- Carried out a fair review of the employee's attendance record and reasons for the absences.
- Provided an opportunity for the employee to make representations.
- Given appropriate warnings of dismissal if the employee's attendance does not improve.

In the case of sickness absence, the potentially fair reason will usually be on the grounds of the employee's capability to perform the kind of work they were employed to do. 'Capability' in this instance refers to the skill, aptitude, health or any other physical or mental quality, and 'the kind of work' as work the employee could be required to do under the contract of employment, not just the kind of work actually being performed before the sickness absence.

- ## Use of Trigger Mechanisms to Review Attendance

Trigger points are a common method used to identify repeated short-term absences in individuals and should be part of the overall monitoring system which analyses short-term absences in teams or departments to try to identify hot spots that can then be investigated. The Bradford Factor is often used for this.

Common trigger points are:

- **Length of period of sick leave** (duration) – over 10 days may trigger a review.
- **Number of absences** (frequency) – the number of times a person is off in a given period (e.g. three periods of absence in a rolling six-month period or six days lost in three months).
- **Patterns of absence** – based around days of the week (commonly Fridays or Mondays), Bank Holidays or school holidays.

- ## Early Involvement of Occupational Health Professionals

Occupational health staff can react very quickly to intervene if a problem is spotted. They can advise whether a given pattern of absence is likely to be consistent with a stated medical condition, or whether the available evidence suggests some additional underlying factor that has not yet been identified. They should be able to provide advice as to appropriate interventions and other sources of specialist advice. Possible interventions include: counselling, continuing health monitoring, risk assessments, and in the case of repeated musculoskeletal problems a workstation assessment.

Managing Long-Term Absence

In many ways, long-term absence is easier for an organisation to manage than short-term absence. If an employer is aware of long-term health problems then they can arrange cover more easily and plan return-to-work strategies.

Sometimes, repeated short-term sickness is indicative of a long-term condition and the two can be managed in the same way through proactive application of the policy - return-to-work interviews and involvement of the occupational health professionals.

- ### Identification of Someone to Undertake Initial Enquiries

  Sometimes, it is not appropriate for line managers to carry out initial enquiries into causes of long-term absence or the possibility of a return to work. A suitably trained, impartial person may be able to gain a better understanding of the problem. This is typically someone from HR, but they may also be from occupational health, a trade union representative or a mediator or 'buddy'. Some local authorities train staff as 'Listening Officers'.

  Such enquiries are best initiated between two to six weeks after the beginning of the absence.

DEFINITION

BUDDY

Usually a colleague working at the same level who gives support and helps with any practical day-to-day issues or problems that arise.

- ### Keeping in Contact with the Individual

  Regular contact is vital to prevent the employee from feeling isolated, to keep them up to date with developments in the workplace, and to prepare them for return to work. Sometimes (usually with permission from the occupational health department or the employee's doctor) the employee will be allowed to come in and carry out some training or they might meet up socially with their colleagues. It is part of a process of 'normalising' them back into the workplace. Such contact is usually undertaken by the manager.

Contact with employees helps to prepare them for return to work

  However, there may be occasions where managers may find it hard to keep their own feelings hidden and remain impartial. This may be due to a previous conflict or dislike for the member of staff, or to lack of knowledge about the medical condition. In particular, mental health problems can elicit feelings of 'why can't they just pull themselves together?' or 'they can't be as stressed as I am right now'.

  Some conditions, such as bipolar disorder, HIV or cancer can create feelings of unease or even fear in colleagues.

  This is where occupational health professionals or the HR department can be useful in finding out more about the condition and showing that people suffering from the condition can live a normal life and return to work with any necessary support.

  If an absent employee is having difficulties communicating with their manager, they may request to liaise with another manager or colleague. As long as this is not a problem (e.g. in a very small team), the request should be accommodated, but it will highlight a problem that needs to be dealt with preferably before the employee returns to work.

- ### Flexibility and Restricting Sick Pay

  In some organisations, there are flexible working arrangements and employees on long-term sick leave may be able to use holiday entitlement and flexi-time to prevent them slipping into restrictive pay (e.g. someone who has been off following major surgery and is due back after they have dropped to half pay may be allowed to use holiday entitlement (at full pay) for the last few weeks of their absence).

- **Detailed Assessment by Relevant Specialists**

  The organisation may feel that the employee needs more detailed medical assessment than is available in the workplace and may pay, for example, for a spinal assessment, hearing screening or respiratory function tests.

  Arrangements for any such special assessments could be co-ordinated by a suitably trained case worker, usually from the occupational health department.

- **Health, Occupational or Rehabilitation Interventions**

  It is vital that the manager, health specialists, HR and the employee work together to bring about the most positive outcome – usually a return to work and an on-going reduction in sickness absence. Early investment (financial, training or time) is more likely to lead to a complete recovery and positive return to work.

- **Changes to Work Patterns or the Environment**

  Temporary or permanent changes to work patterns or to the working environment are often an effective way of managing a return to the workplace after long-term sickness absence.

  - **Temporary Changes**

    Can include:

    - Phased return to previous job and hours.
    - No night shifts.
    - No lone working.
    - No driving (e.g. cars or forklift trucks).
    - Not operating specific pieces of equipment.
    - Not working in specific areas (e.g. outdoors, hot rooms, confined spaces, heights).
    - Buddying with a colleague.
    - Shadowing for training purposes if the job has changed, or to refresh skills.

  - **Permanent Changes**

    Can include:

    - Change of job or job level/responsibility.
    - Change of hours.
    - Change of team.
    - Change of base.
    - Permanent workstation or environmental adaptations (reasonable adjustments).

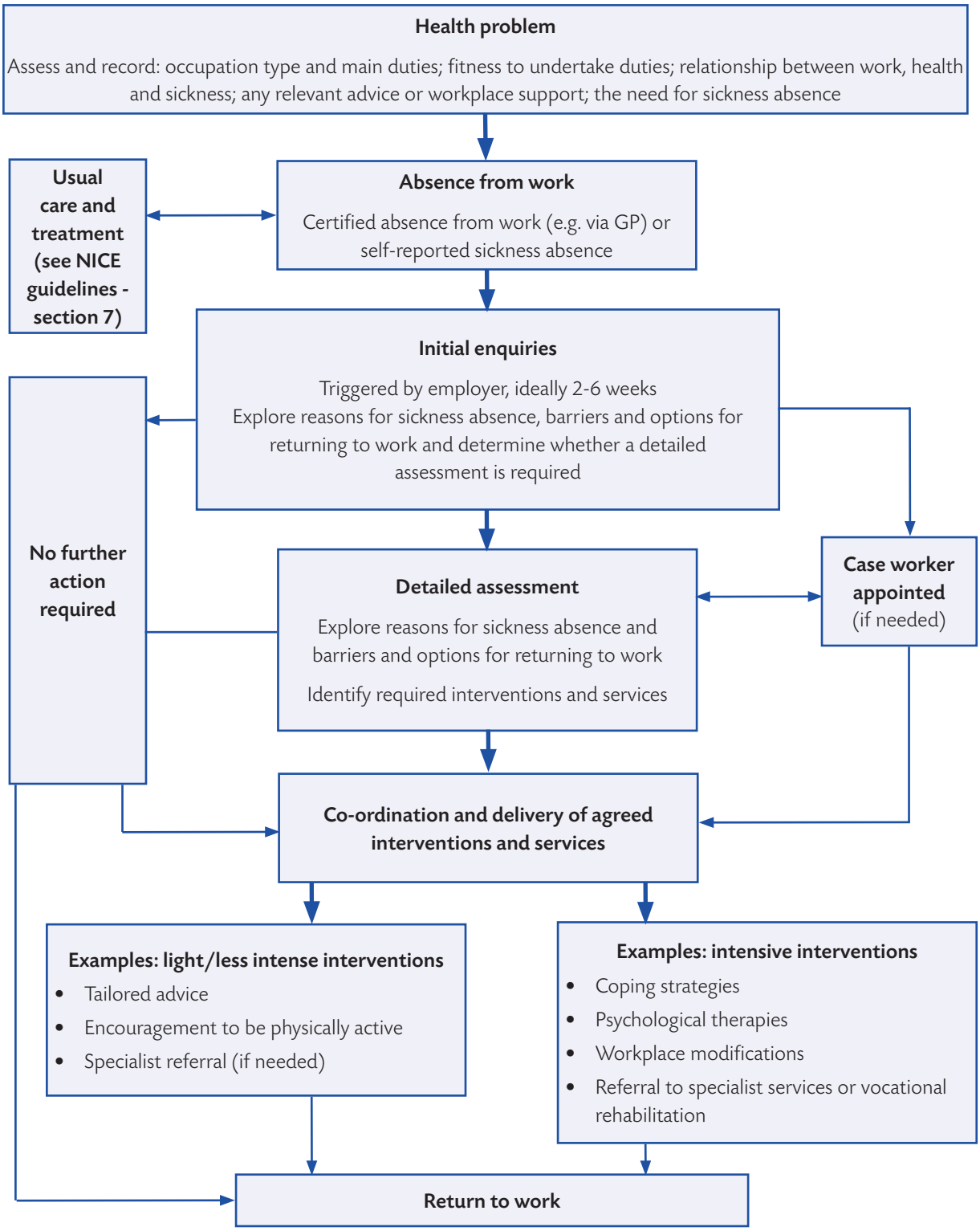
TOPIC FOCUS

Key elements of managing sickness absence are:

- Recording sickness absence.
- Maintaining contact.
- Return-to-work interviews.
- Making use of professional advice.
- Planning and undertaking workplace adjustments.
- Agreeing and reviewing a return-to-work plan (rehabilitation programme).
- Co-ordinating the return-to-work process.

National Institute for Health and Care Excellence (NICE) Guidance PH19

The UK's National Institute for Health and Care Excellence (NICE) has published guidance (PH19) on the management of long-term and short-term frequent sickness absence. The guidance is wide-raging, but the recommendations aimed specifically at employers is summarised in the flow diagram below and in the following section.



Based on: Managing long-term or recurring short-term absence
Source: NICE, PH19 (www.nice.org.uk/guidance/ph19)

Stage 1 – Initial Enquiries

The employer should identify someone who is suitably trained and impartial to undertake initial enquiries with the absent employee (e.g. an occupational health physician or nurse or a human resource specialist).

Ideally, this should happen within 2 and 6 weeks of a person starting sickness absence (or following recurring episodes of short- or long-term sickness absence).

MORE...

www.nice.org.uk/guidance/ph19

The aim is to determine:

- The reason for the sickness and how likely it is that they will return to work.
- If they have any perceived (or actual) barriers to returning to work (including the need for workplace adjustments).
- The options for returning to work and jointly agree what, if any, action is required to prepare for this.

It may be necessary to move on to Stage 2.

Stage 2 – Detailed Assessment

The assessment should be co-ordinated by a suitably trained case worker/s with the skills and training to act as an impartial intermediary.

The case worker should arrange for the relevant specialist/s (such as occupational health practitioner or physiotherapist) to undertake the detailed assessment in conjunction with the employee.

This assessment should take into account the person's functional capacity to carry out tasks at work and any reasonable adjustments that may be required as a result of disability. Barriers to return to work should be identified, including psychological and social barriers. A range of interventions and support services might be identified that will facilitate the employee's recovery and return to work. A return-to-work plan might be developed that determines how the employee might return to work and whether it is appropriate for them to return to their previous job or to partial duties or an alternative job.

Stage 3 – Interventions and Services

The case worker must co-ordinate and oversee the delivery of the various interventions and services identified by the detailed assessment. Some of these interventions may be 'light' in nature, but others may be intensive and may involve both physical and psychological therapies (such as Cognitive Behaviour Therapy (CBT)).

NICE has developed a series of tools and resources to help employers in the management of long-term absence, such as a checklist developed in collaboration with the UK's Chartered Institute of Personnel and Development (CIPD) to facilitate use of the guidance.

Vocational Rehabilitation

Meaning of Vocational Rehabilitation

The concept of **vocational rehabilitation** has grown out of efforts to rehabilitate people with disabilities. Today it encompasses the provision of assistance to a much broader group, including people with physical health conditions and mental health problems.

Vocational rehabilitation can be defined in a number of ways. One short and useful definition is:

"Vocational rehabilitation is whatever helps someone with a health problem to stay at, return to and remain in work."

(Waddell, G, Burton AK, Kendall NAS eds. Vocational Rehabilitation. What works, for whom, and when?, 2008)

The focus is to help people retain or regain the ability to participate in work, rather than to treat any illness or injury itself. It is now well recognised that, as well as providing economic benefits, engagement in work has health benefits for the individual, and can aid recovery from physical or mental health problems.

There is growing evidence that health, work and well-being are closely connected.

Work is known to be the best route out of poverty and the UK Government's 2006 Department for Work and Pensions (DWP) report - Is Work Good for Your Health and Well-Being? - found that work is also usually good for health.

For all age groups, work generally:

- Makes people healthier.
- Helps people with a health condition get better.
- Improves the health of people returning to work from unemployment.
- Far more people gain health benefits from work than suffer negative effects:
- The long-term unemployed or those who have never worked are two to three times more likely to have poor health than those in work.
- People are twice as likely to become psychologically distressed after going from work to unemployment.

Absence has further health implications too - the longer someone is out of work due to ill health, the lower their chance of getting back into work:

- Someone off sick for six months, has an 80% chance of being off for five years.
- 90% of people making a claim for incapacity benefits expect to return to work, but if they claim for two years or more, they are more likely to retire or die than return to work.

Because of this growing evidence base that working is good for health, the DWP launched Health, Work and Well-being, a cross-Government initiative to improve the health and well-being of working age people, in 2005. The initiative aims to help more people with health conditions to find and stay in employment.

Benefits of Vocational Rehabilitation

Vocational rehabilitation has significant benefits both for the employer and the employee.

Employer Benefits

Rehabilitation of workers back into work, with the consequent improvements to their health and well-being, can bring a range of business benefits:

Vocational rehabilitation benefits both employer and employees

- Simple measures to prevent and manage ill health can lead to a decrease in employee absence, which in turn can improve productivity and competitive edge.
- Healthy working environments can contribute to reduced employee absence through sickness and stress.
- Employees who feel cared for are often more satisfied and perform better, which can have the effect of reducing staff turnover and increasing productivity.
- Getting employees back into work after illness reduces the loss of experienced staff and the cost of recruiting new staff.
- Being known as an organisation that cares about employees can enhance business reputation and helps attract staff and customers.

Employee Benefits

The benefits to individuals of returning and remaining at work are:

- Better physical health.
- Better mental health.
- Increased financial security.

Improvements in the physical health of employees who have rehabilitated back into the workplace are derived from the physical and mental demands of the job that they are performing. If carefully managed so as to match the capabilities of the employee, these demands have been shown to have a positive effect. This is counter to some historic preconceptions that the best place for an ill worker to recover is at home.

Improvements to the mental health of employees are linked to the fact that many people define themselves by the work that they do and society at large defines individuals in the same way. Work is therefore often a vital component to an individual's self-esteem. There is also a strong social component to most people's work. For many individuals, work provides social contact, with the mental health benefits that such interactions bring.

The financial benefits to an employee of returning and remaining at work are both direct and indirect, such as wage or salary, pension contributions and the opportunity for advancement and pay increases that may result from work.

Overcoming Barriers

Using the bio-psychosocial model, it is possible to identify barriers to the rehabilitation of a worker back into work. These might be:

- **Biological barriers** – the physical disease, ill-health condition, disability or mental health condition that the worker might be suffering from. For example, they may be have a form of musculoskeletal disorder, such as back pain or carpal tunnel syndrome. They may be suffering from anxiety or depression. They may have impaired mobility or a sensory impairment. They may be recovering from major heart surgery. Each of these conditions presents restrictions on the types of work that the individual can safely perform.
- **Psychological barriers** – which the individual may have to overcome in order to feel comfortable returning back to work. These psychological barriers do not arise from mental health conditions (since these are aspects of biology and so fall under that heading). Rather, these barriers are the inevitable psychological ones that will arise following any long-term absence from work. The worker may be fearful that returning to work may worsen their ill-health condition. They may worry that work colleagues will think less of them if they are unable to work to the full extent due to restriction on working hours or types of work. They may be understandably anxious about their future prospects should their rehabilitation back into work not go as smoothly as was hoped.
- **Social barriers** – that may be imposed by the work and the working environment. These barriers may be physical in nature, such as access to and from the workplace, appropriate sanitary conveniences and workstation design and layout. In other instances, these barriers may be more to do with workplace arrangements and the way that work is organised.

Effective rehabilitation will require that the employer recognises these barriers and takes steps to eliminate or reduce their impact. This often requires the involvement of internal occupational health services and external agencies.

MORE...

Useful sources of information include:

www.healthyworkinglives.com

www.hse.gov.uk/sicknessabsence

www.gov.uk/browse/disabilities/work

http://fitforwork.org

http://fitforworkscotland.scot

Risk Assessment

Prior to return to work, it may be necessary to undertake or review the risk assessment that relates to the worker's job. Risk assessment should not focus on the person's ill health or disability, but should look more broadly at the overall demands of the job and how any risks can be appropriately managed.

The standard risk assessment should ideally involve the worker themselves as they are often the best person to identify what is needed and to ensure that it refers to the individual circumstances of the worker. The assessment should to identify the hazards and risks associated with the nature of the task and whether reasonable adjustments need to be made to remove or reduce such risks to the individual. The risk assessment should cover the:

- Specific needs of the individual with respect to their ill health or disability.
- Design of the job and the working environment, such as access to the workstation and layout of the premises, heating, lighting, etc.
- Work equipment and workstations to be adjusted to individual needs and use of assistive technologies.
- Health hazards that may affect the individual – chemicals, respiratory sensitisers, etc.
- Work organisation, specific training needs and methods of communication.
- Psycho-social aspects, such as stress, bullying, etc.

In addition to the standard risk assessment, fire safety legislation may place a requirement on employers to make evacuation plans for disabled people, which will include workers, visitors or service users.

This may involve the development of a Personal Emergency Evacuation Plan (PEEP) which is tailored to meet the individual needs of a disabled employee, visitor or service user. It outlines the safe means of escape and identifies the support which may be needed in the event of an emergency evacuation.

Role of Other Disciplines and External Agencies

Many external agencies offer help and support both for employers and employees during the vocational rehabilitation process.

Below are some examples of external agencies that offer such help and support in the UK:

- ### Primary Care

  The National Health Service provides advice and support to individuals suffering from various health conditions to facilitate the management of those conditions. This includes supporting individuals to return and remain in work.

- ### DWP Jobcentre Plus

  Jobcentre Plus advises employers on ways to adopt good employment policies and practices in the recruitment, retention, training and career development of disabled people. Jobcentre Plus also operates a range of schemes and services designed to assist both employers and disabled people looking to work. Disability Employment Advisers (DEA) are based at local Jobcentre Plus offices and offer advice on employing disabled people.

- ### Access to Work (AtW)

  Access to Work helps disabled people to get or keep jobs by contributing towards their extra employment costs. It provides advice and practical support to disabled people and their employers to help overcome work-related obstacles.

- ### Occupational Therapists (OTs)

  Occupational Therapists (OTs) have a central role in resolving issues following a period of illness and medical treatment, and also in advising employers about the needs of sick or disabled workers when they return to work. OTs can assist employees who are still at work but having difficulties due to illness or disability.

An OT will carry out a detailed assessment of the needs of the workplace and the abilities of the individual, and identify problems and potential solutions. Where appropriate, the OT will provide an action plan and oversee its implementation.

- **Fit for Work**

  The 'fit-to-work' service is a UK-government-funded initiative to assist GPs, employers and employees where there are health issues associated with the employee's work or absence caused by health issues. The service includes support and advice for both GPs, employers and employees provided by occupational health professionals.

STUDY QUESTIONS

3. Give three examples of occupations where there are likely to be defined fitness-to-work standards.
4. Outline the meaning of vocational rehabilitation.
5. What is the bio-psychosocial model?

(Suggested Answers are at the end.)

Managing Occupational Health

IN THIS SECTION...

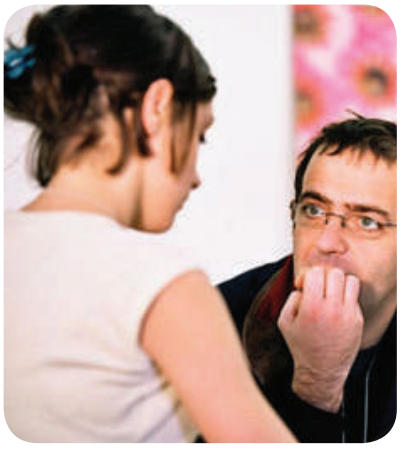
- Occupational health services are concerned with the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations.
- An occupational health service will involve the services of occupational health doctors, nurses and technicians, as well as specialists in particular fields, such as audiometricians. There are minimum standards of qualification and registration for occupational health doctors and nurses, as well as specialists such as audiometricians.
- The typical services provided by occupational health include pre-employment screening, health surveillance, return-to-work rehabilitation programmes, sickness absence management, counselling, risk assessment (both general and personal), health education and promotion campaigns, treatments services, management of first aid and immunisation programmes.
- General health assessment is an assessment of an individual's general health and fitness, whereas health surveillance is the monitoring of an individual's health to ensure that they are suitable for work involving exposure to a specific type of health hazard and to track their health over time as they work with that hazard.
- Health Needs Assessment (HNA) is the systematic review of the health issues facing a population, leading to prioritisation and resource allocation to improve health and reduce inequalities. HNA can be used to identify the occupational health priorities that are of concern to the workplace, so that an appropriate occupational health service response can be planned and implemented.
- Employers must ensure that any occupational health service provider appointed by them will meet minimum standards with regards to their service provision. To that end, the Faculty of Occupational Medicine has established a voluntary accreditation scheme (SEQOHS).

Occupational Health Services

The ILO Occupational Health Services Convention C161 defines occupational health services as:

> *"services entrusted with essentially preventive functions and responsible for advising the employer, the workers and their representatives in the undertaking on:*
>
> *(i) the requirements for establishing and maintaining a safe and healthy working environment which will facilitate optimal physical and mental health in relation to work;*
>
> *(ii) the adaptation of work to the capabilities of workers in the light of their state of physical and mental health;"*

The provision of an occupational health service to the workforce requires the involvement of a range of professionals, including physicians, nurses, occupational hygienists, ergonomists and safety engineers. We will be considering this aspect later when we look at the role of the occupational health specialist.



Occupational health services aim to provide a safe and healthy working environment

A hypothetical example of the combined approach working in practice could be:

- The recognition of a particular health effect by a worker, safety representative, nurse or doctor.
- Diagnosis of the illness and treatment by a nurse or doctor.
- Discovery of the environmental cause by a hygienist.
- Implementation of controls by a safety engineer, hygienist or ergonomist.

Role and Benefits of Occupational Health Services

The discipline of occupational health aims to anticipate and prevent those health problems which can be caused by the types of work which people do. There is a two-way relationship between work and health; in some circumstances, environmental conditions at work can aggravate an existing medical condition. So we are concerned about the general health and susceptibility of the worker, as well as the workplace environmental conditions. When we refer to occupational health and hygiene, we are considering both the health (occupational) of the worker and the hygiene (environmental) conditions of the workplace.

Health hazards often take a significant time to reveal their effects on the body, in comparison to the effects of an industrial accident. One model which relates occupational health and safety is the idea that cases of occupational ill health can be considered as 'slow accidents'. Whether this model is useful or not, it emphasises the point that it is sometimes difficult to persuade others of the need for caution and control with occupational health hazards, due to the fact that the effects are often not immediately apparent. Sometimes, they are cumulative and the final outcome may not be apparent for some time and possibly irreversible when it is detected.

Occupational health services have developed over many years in the UK and in other parts of the world. Before the second world war, they were confined mainly to heavy industries, where physical injury as well as ill health were common. Where public safety was involved in the transport industries, medical services checked the health of those who, in the event of a health failure, could endanger the lives of others, e.g. airline pilots.

Following the war years, economic growth became the dominant aim in all industrialised countries and there was a move towards the concept that all people had a right to health care, both in their everyday life and in their occupation. In 1950, this led a Joint Committee of the World Health Organisation (WHO) and the International Labour Organisation (ILO) to recommend that occupational healthcare organisations should be set up with the aims of promoting well-being. In 1959, this was eventually expanded on by the ILO, in Recommendation 112. It gave the basis on which it was considered that occupational health services in places of employment should be organised.

Benefits of an Occupational Health Service

The benefits that result from the use of an occupational health service will inevitably be linked to the type of service that is used and its specific functions. There are, however, some general benefits that might result from the use of a service, such as:

- Statutory compliance with health and safety and equal opportunities legislation.
- Reduction in the absence rates and number of days lost through ill health and the resulting costs associated with absence.
- Improved management of rehabilitation and return-to-work processes.
- Early recognition of work-related health hazards allowing for improved identification, assessment and control.
- Improved management of work-related ill health allowing for earlier and better treatment and, consequently, better recovery and minimisation of ill health.
- Reduction in ill-health compensation claims.
- Better screening prior to employment to allow matching of personal characteristics and job requirements.
- Improved worker morale.

Make-Up of a Typical Occupational Health Service

Types of Occupational Health Service

Occupational health services can fall into a range of categories, such as:

- A full occupational health service, staffed by a full-time doctor, with a supporting nurse(s) (perhaps working on a shift basis). Specialist treatment might also be available in a work's health centre, such as dental, optical, chiropody and physiotherapy. This type of service might be found in a large organisation, where the risk profile of the organisation requires a full provision, or where the organisation can afford to offer such a provision as a benefit of employment.
- An occupational health service staffed by an occupational health nurse(s) (perhaps on a shift basis) with regular visits by a doctor and clinics (perhaps weekly). The doctor combines their duties with other work (such as GP or other occupational health work). This type of service might be found in a smaller organisation or a large organisation that does not have a risk profile that demands the full provision above.
- An outsourced occupational health service provided by a private occupational health-service provider. This might comprise weekly visits by a occupational health nurse and/or doctor or the provision of on-request advice and services as required. This type of service might be retained by a small- to medium-sized employer with a low-risk profile.

The type of service provided, the make-up personnel providing the service and its functions have to be determined by the employer. This might be done by conducting a Health Needs Analysis (HNA) described later in this section. Some of the specialist roles involved in the provision of an occupational health service are outlined below.

Occupational Health Physician

Occupational medicine is a professional discipline concerned with the diagnosis and assessment of health hazards and stressors at work. Since it is a specialist branch of the medical profession, we need a medical practitioner with suitable training and/or experience in the field. This type of doctor is referred to as an occupational health physician.

An occupational health physician

The exact role of an occupational health physician can be determined (to a degree) by the organisation retaining their services. There are certain types of work that can only be performed by the physician. Other types of work might equally well be carried out by an occupational health nurse. It is important to note that occupational health physicians are bound by the legal and ethical rules of their profession.

An occupational health physician may carry out:

- Statutory medicals.
- Health surveillance under relevant legislation (e.g. in Great Britain, **COSHH**).
- Pre-employment health assessment.
- Post-sickness/rehabilitation/ill-health retirement health assessment.

Occupational Health Nurse

Occupational health nursing is a specialist branch of the nursing profession. Similar to the occupational health physician, the occupational health nurse must be a qualified nurse with appropriate training and/or experience. The exact role of an occupational health nurse can be determined by the organisation, though there are certain functions that they are not able to perform since they can only be conducted by a physician.

It is important to note that the designation "nurse" is often misleading in the context of the role of an occupational health nurse. Use of the word "nurse" brings to mind a traditional image of someone in a hospital or healthcare setting carrying out practical care duties under the supervision of a medical practitioner. An occupational health nurse will rarely be involved in the direct treatment of injury or ill health (such as minor-injury first-aid treatment).

Instead, they will be very involved in the proactive prevention of disease and ill health and the management of treatment and care programmes.

An occupational health nurse may be concerned with:

- Assisting the employer in complying with health and safety legal responsibilities.
- Monitoring the health of employees.
- Promoting good health activities in the workplace.
- Working with line managers to minimise hazards, ensure compliance with health and safety legislation and implement the organisation's occupational health policies.
- Dealing with cases of substance misuse.
- Advising on placement at work through pre-employment health assessments.
- Health assessment after return to work from accident or ill health.
- Managing health-centre facilities, offering basic health checks and co-ordinating first-aid services.
- Advising on ergonomic issues.
- Promoting good health education and activities in the workplace, geared to encouraging employees to take personal responsibility for their health.
- Providing advice and counselling.

Occupational Health Adviser

The job title 'occupational health adviser' is often used to indicate an occupational health nurse concerned with the provision of occupational health services.

Occupational Health Technician

Occupational health technician is a developing role. With supervision from occupational health nurses and doctors and the correct training, they may be able to carry out some aspects of health surveillance. This frees up doctors and nurses for other tasks.

Occupational Hygienist

Hygiene is generally considered to be the maintenance of health and the prevention of disease. Occupational hygiene applies this definition to the place of employment and the principal aim is to prevent occupational ill health.

The work of the occupational hygienist generally follows the steps we have already noted for the study of occupational health and hygiene:

- Identification of the hazard.
- Assessment of the risk.
- Measurement of the risk and interpretation of the result.
- Application of control measures and their maintenance.
- Information, instruction and training.

However, the key speciality of the occupational hygienist is the measurement of risk and interpretation of results. A wide range of monitoring techniques is

Occupational hygienists work to prevent occupational ill health

available, making use of special equipment and instruments. The occupational hygienist is trained in their selection and use, but most importantly, in the interpretation and evaluation of the results which they provide.

As inhalation is the most important method of entry of a toxic substance into the body, the work of the occupational hygienist often involves measurement of airborne contaminants, using personal or static samplers and comparing the results with those published in relevant standards. The correct sampling instruments, methods and analytical procedures must be identified.

As well as airborne dust, gas and vapour, the occupational hygienist is concerned with measurement of heat, noise and other pollutants. Another important area of involvement is the monitoring of control measures to ensure they are working effectively. Consequently, the occupational hygienist may be skilled in carrying out measurements on ventilation systems and other environmental control devices to ensure they operate at optimum performance.

Determining Competence within Occupational Health

An organisation appointing occupational health doctors and/or nurses must ensure that they are competent in the role. When appointing an occupational health doctor or nurse, their registration/Personal Identification Number (PIN), can be used to confirm their registration status with the appropriate governing body.

Below are some of the competency requirements relevant to occupational health in Great Britain:

- ### Occupational Health Doctors

  For occupational health doctors, the General Medical Council (GMC) website provides information relating to an individual's registration and fitness to practice and the Faculty of Occupational Medicine (FOM) should be able to confirm their occupational health qualification.

  
  An occupational health doctor

  Occupational health doctors are expected to have skills and expertise that include:

  – an understanding of the health hazards that can arise at work;
  – an ability to assess risks relating to the health of individuals and groups;
  – knowledge of the law relating to workplace issues; and
  – an awareness and understanding of the way business operates.

  There are currently three levels of qualification in occupational medicine for doctors:

  – Diploma in Occupational Medicine (DOccMed);
  – Associateship of the Faculty of Occupational Medicine (AFOM); and
  – Membership of the Faculty of Occupational Medicine (MFOM).

  Doctors without these qualifications who rely solely on experience gained in the workplace may not meet the requirements for competence demanded by some health and safety legislation. Consequently, the HSE recommends that the Diploma in Occupational Medicine is used as the minimum standard of qualification.

- ### Occupational Health Nurses

  For occupational health nurses, the Nursing and Midwifery Council (NMC) website should be able to confirm their registration and qualifications.

  Nurses who carry out occupational health surveillance should, as a minimum, be registered with the NMC. They may also hold an occupational health qualification at Certificate, Diploma or Degree level. If the nurse does not have an occupational health qualification then they should work under the supervision of an appropriately qualified clinician (doctor or nurse).

For a nurse-led occupational health service, the lead nurse should also be registered with the NMC as a specialist community public health nurse in occupational health (or be sufficiently qualified to register as such and have access to specialist occupational physician advice as needed).

- Occupational Health Technicians

  Occupational health technician is a developing role. With supervision from occupational health nurses and doctors and the correct training, they may be able to carry out some aspects of health surveillance. This frees up doctors and nurses for other tasks.

  Technicians may need specific qualifications (see below) to be able to demonstrate competence in certain fields.

- Specific Qualifications

  Some aspects of health surveillance require additional qualifications, such as:

  – **Hand-arm vibration syndrome:** a Faculty of Occupational Medicine (FOM) approved training course in hand-arm vibration syndrome, or equivalent level of competency.
  – **Noise-induced hearing loss**: a British Society for Audiology approved course for industrial audiometricians, or equivalent level of competency.
  – **Respiratory**: Association for Respiratory Technology and Physiology (ARTP) diploma, or equivalent level of competency.

Typical of Services Offered by an Occupational Health Service

Pre-Employment/Pre-Placement Screening

This is done to ensure as far as possible that the person is fit, both mentally and physically, to do the duties required of them in the job they have been successfully interviewed for.

In some instances, the employer will be under a statutory duty to perform this type of pre-employment screening to ensure that the worker is medically fit for the type of work they are being employed for. For example, in Great Britain, a Classified Person under the Ionising Radiation Regulations must be certified as fit to work with ionising radiation before they can be designated as a Classified Person. This assessment can only be made by an Employment Medical Advisory Service (EMAS) Adviser or an Appointed Doctor (a medical practitioner appointed by the HSE).

In other instances, there is no statutory duty on the employer, they are simply screening employees to ensure that workers are not put into positions for which they may prove unsuitable. For example, workers required to undertake manual labour might be screened to ensure that they do not have any obvious medical condition that might make them unsuitable for manual labour.

Health Surveillance

This is performed according to identified measurable risks in the job, e.g. airborne substances, noise, etc.

Preliminary health checks are carried out to ensure that a worker is fit to work with a specific hazard (often referred to as 'baseline screening') and follow-up checks are then conducted routinely to ensure that the work is not making the worker ill. Health surveillance is conducted as a statutory requirement and there are recognised methods and standards for the evaluation of results.

For example, a worker in a bakery will undergo health surveillance because of the risks presented by flour dust exposure. Lung function tests can indicate whether the worker is asthmatic (in which case they will not be considered fit to work with flour dust in the first instance) or showing signs of becoming asthmatic.

Return-to-Work Rehabilitation Programmes

Occupational health services are usually heavily involved in providing advice and support to get workers back to work after a long-term absence for whatever reason. This is usually done by formulating a return-to-work programme in collaboration with the workers and line managers to enable the worker to return according to their capabilities. There are often physical and psychological barriers to the rehabilitation of workers following long-term absence which the occupational health service is well placed to recognise and address.

External specialists (such as occupational therapists) and agencies (such as the UK's Access to Work) may be pulled in to assist as required.

Sickness Absence Management

Occupational health services may be directly involved in ill-health absence management or they may simply offer advice, support and education for anyone who requires assistance in this area. Depending on the nature of their involvement, this might include:

- The collection of self-certifying notifications from employees absent for less than seven days.
- The collection of medical fitness-to-work declarations from employees absent for over seven days.
- Initial and follow-up contact with employees following the notification of absence.
- Medical assessment of workers who have phoned in sick or submitted a medical fitness-to-work declaration.
- Treatment or referral of absent workers who have phoned in sick or submitted a medical fitness-to-work declaration to aid their recovery (e.g. a worker phoning in sick with a bad back might be referred on to private physiotherapy treatment which may speed their recovery and return to work).
- Collation of statistics on ill-health absence.

Counselling

Occupational health services usually offer a 'Listening Ear' support service for any situation which may be affecting workers, whether it is work-related or personal. The service may include trained counselling staff, or they may refer on to specialist in-house counsellors or external providers. This service is often central to the role of an occupational health service and is significant in the management of stress and traumatic stress

Risk Assessments

A proactive occupational health service may be fully involved in many of the health risk assessment being conducted within the workplace. This might include:

- Display Screen Equipment (DSE) workstation assessments.
- Hazardous substance exposure risk assessments.
- Manual handling assessments.
- Ergonomics assessment, such as those for musculoskeletal disorders and upper-limb disorders.
- Personal protective equipment assessments.

Involvement might be on a routine basis or ad-hoc. This type of involvement can be important to fully integrate occupational health into the health and safety management of the organisation, so that occupational health personnel gain an understanding of the workplace environment and practices and are not simply reactively advising once illness has been caused.

Specific Risk Assessments

The occupational health service will be involved in the risk assessment and management of new and expectant mothers within the workplace. The service may be involved in all such assessment as a matter of policy, or may be involved in certain assessments as required. The service may be involved in other individual assessments where health conditions may complicate risk (such as lone worker risk assessments).

Health Education and Promotion

Though some occupational health personnel view their role as strictly advising workers and the employer on specific work-related health issues, most take the view that health and well-being cannot be conveniently divided up into work and home partitions. Occupational health services will usually take part in national health promotion campaigns, e.g. Stop Smoking Day, Sun Awareness, Drink Awareness, etc. They can often advise and support people on a one-to-one basis for weight loss, stopping smoking, etc. They will also be involved in the formulation, and perhaps implementation, of policy on some of these areas. For example, an occupational health service might be involved in:

- Formulating an organisational policy on where smoking is permitted (the law may prevent people from smoking in enclosed places, but the employer may also decide to restrict smoking in outside parts of their premises or may decide whether or not to provide facilities for smokers, such as shelters).
- Providing factual advice on the health risk associated with smoking to encourage workers to quit.
- Providing an in-house support service to assist workers to quit.
- Signposting external services that a worker can use if they want to quit.

Providing Advice

The service will usually provide advice to both line managers and employees on work-related issues. This might be done via telephone or on a 'drop-in' basis. This might be done informally for minor queries, but will normally be formalised in writing where a specific health issue has been raised with regards to workplace standards. For example, an employee complaining of a wrist ache might be diagnosed with upper-limb disorder and recommendations made to them and their line manager to prevent the condition worsening.

Treatment Services and First Aid

An occupational health service will usually provide treatment in the event of injury or ill health that occurs at work. This is often restricted to first-aid treatment of casualties only (e.g. first-aid treatment of a heart attack victim or casualty with a broken leg). In some cases, the service may be equipped to deal with the injury in the longer term because of the lack of an immediate emergency service response (e.g. remote locations).

In many instances, the service will be involved in the assessment and management of the first-aid provision in the workplace. That is to say, the occupational physician decides what kind of facilities, equipment and personnel are provide by the organisation. They then manage this provision and oversee the training of the first aiders.

First-aid treatment may be provided in the event of an occurrence at work

The service may provide specialist treatments, such as chiropody and physiotherapy. In other instances, these treatment services will not be provided in-house but by referral to external providers.

Management of Infectious Diseases

The service will offer advice on whether workers suffering from contagious diseases can work or if they need time off, and if so, when they can return to work in order to minimise the risk of cross-infection in the workplace. In many workplaces, this is an important but relatively minor part of the services role, but in some instances (such as in a healthcare setting or on an oil platform) it is more significant.

Immunity Assessment and Vaccination

In some workplaces, where contagious disease are a health hazard requiring management, the occupational health service may be involved in assessing workers' immune status and vaccinate as appropriate. Immunisation must always be done with informed consent.

Health Assessment, Health Surveillance and Medical Surveillance

It is important to distinguish between general health assessment and health surveillance.

General health assessment is any form of medical assessment that determines the general state of health or fitness of an individual. This assessment will normally be carried out by an occupational health doctor or nurse. However, it is quite possible that it is carried out by the individual themselves through some form of self-assessment. It may also be carried out by a specialist focusing on one specific aspect of health, e.g. an eye test carried out by an optician.

General health assessments are often carried out by organisations as a form of pre-placement assessment. These may take the form of self-assessment health questionnaires with follow-up by an occupational health doctor or nurse where specific issues are raised by the answers given. These health assessments may then be repeated periodically.

In some instances, there is no specific health and safety aspect to this assessment and it is provided as a benefit of employment.

Alternatively, specific health assessments are carried out by an organisation to ensure that a worker is fit for a specific role or task, e.g. the DSE user's eye and eyesight test, a forklift truck driver's medical and a crane operator's medical are all forms of health assessment that ensure that an individual is medically fit for work. These health assessments may be provided:

- to comply with a clear statutory duty (e.g. the DSE eye test is a specific requirement of the DSE regulations); or
- as a matter of good practice (e.g. a health assessment for a company car driver; though the driver has to be medically fit to drive, there is no statutory duty on their employer to carry out an assessment of fitness to drive).

MORE...

Further information and guidance on health surveillance is available from the UK HSE online at:

www.hse.gov.uk/health-surveillance/index.htm

TOPIC FOCUS

Health Surveillance

Health surveillance is a more specific assessment of a worker's medical fitness that focuses on one specific aspect of health in relation to a particular hazard or hazard group. The intention of health surveillance is to determine a worker's state of health with regards to the hazard and then to track that aspect of their health forward in time through repeat assessments.

Health surveillance is only required where the following criteria are met:

- there is an identifiable disease or adverse health condition related to the work concerned; and
- valid techniques are available to detect indications of the disease or condition; and
- there is a reasonable likelihood that the disease or condition may occur under the particular conditions of work; and
- surveillance is likely to further the protection of the health and safety of the employees to be covered.

Health surveillance is normally provided where there is a clear statutory duty under specific health and safety legislation.

The way that health surveillance is carried out will vary, depending on the form of health surveillance and the relevant standards. Health surveillance might be carried out by:

- Examination and assessment by a specialist or an occupational health doctor or nurse with a specific qualification in that particular form of health surveillance.

- Examination and assessment by an occupational health doctor or nurse using appropriate guidance to determine the method and standards.
- Examination and assessment by a responsible person under the supervision of an occupational health doctor or nurse.
- Self examination and/or self-assessment by the worker under the supervision of a responsible person.
- Most forms of health surveillance should be carried out by the first group.
- A notable exception to this is the skin check that is often carried out whe workers are potentially exposed to primary cutaneous irritants or skin sensitisers. These substances are capable of causing primary contact dermatitis or secondary allergic dermatitis, respectively. Since skin checks usually involve visual examination of exposed skin (on the hands and forearms), self assessment or assessment by a responsible person are normally adequate to ensure freedom from symptoms.

Medical Surveillance

The difference between medical surveillance and health surveillance is determined by the person carrying out the surveillance. Medical surveillance is a specific statutory requirement under certain pieces of legislation and has to be conducted by a doctor appointed by the authorities in a particular country, e.g. in Great Britain, a doctor appointed by the HSE.

Health Needs Assessment

HNAs are carried out to identify the occupational health priorities that are of concern to workers, which may also include safety concerns. HNAs can be used to identify the occupational health priorities that are of concern to the workplace, so that an appropriate occupational health service response can be planned and implemented.

Carrying out a workplace HNA survey can have several **benefits**:

- The data can be used to identify priority areas.
- The results can act as a baseline for measuring change and progress.
- Asking employees what health and well-being support they would like will give them ownership of the issues and they will be more likely to engage in any follow-up initiatives.

DEFINITION

HEALTH NEEDS ASSESSMENT (HNA)

"*A systematic method of reviewing the health issues facing a population, leading to agreed priorities and resource allocation that will improve health and reduce inequalities.*" (Health Development Agency, 2005).

Carrying Out an Occupational Health Needs Assessment

The first step in carrying out an occupational health needs assessment is to secure the commitment and support from senior management and obtain the resources, such as time, meeting space, access to employees, access to data, etc. to carry out the assessment.

It is then necessary to decide on the method to use to collect the data. HNA surveys commonly take the form of self-completion questionnaires, but information can also be obtained from interviews or focus groups.

Once the method of data collection has been established, you need to decide on the survey sample. This will depend on the size of the organisation and resources available.

DEFINITION

SAMPLING

A statistical method of obtaining representative information from a group taken from a parent population, e.g. questioning 20 employees from a workforce of 100.

Some organisations will survey **all** members of staff, whilst the larger ones may decide to sample a proportion of the workforce. If using a sample of the workforce, it is essential to get a representative sample which reflects as closely as possible the total population of the workforce in order to ensure relevant issues are not missed and to alleviate any suspicions about not being included in the sample.

The content of the HNA will depend upon whether it is the first survey and whether there is already sufficient local knowledge to indicate which areas of working life could usefully be targeted. When designing the question sets, there are certain factors that need to be considered, such as:

- **Job roles** – jobs that carry different levels of responsibility and different skills may have different health needs. Manual workers, for example, may have a range of physical health issues, whereas managers and supervisors may be more prone to stress, although stress can also be high in manual jobs, such as those within the security and emergency services and the home care sector.
- **Work processes** – how a job is done can have a major impact upon the health of the individual. Different processes and the tasks involved in those processes are associated with a range of potential hazards and should be included in the health needs assessment.

The workplace health needs assessment, in conjunction with up-to-date sickness absence statistics, should identify areas that may need extra support in the workplace.

All members of the workforce should be provided with a copy of the findings so that effective consultation can take place to determine the level and types of service necessary.

In smaller organisations, it is often easy to consult with staff on a face-to-face basis and get ideas about services and support that would be of benefit to them, but in larger organisations this may not be possible, although team meetings and staff feedback via the organisation's website or suggestion boxes can be used to gather ideas.

Once this information has been collected, an action plan can be developed which will outline appropriate interventions to support the health and well-being of the workforce. Involving the workforce will allow staff to take ownership of the interventions, so encouraging their engagement with the initiative.

Standards in Occupational Health Provision

When looking to appoint an occupational health service provider, an employer must be satisfied that the provider will meet minimum standards with regards to their service provision, record keeping, ethical behaviour, etc. As students of Unit IA will know, there are often significant liabilities associated with commissioning the services of a third-party organisation and consequently vetting and approval processes must be applied.

MORE...

www.seqohs.org/Default.aspx

www.seqohs.org/documentstore/2015%20SEQOHS_Standards_web_03-15.pdf

To this end, in the UK, the Faculty of Occupational Medicine (FOM) has established a set of standards for occupational health service providers and a membership scheme. Members of the scheme are audited and accredited to the standards and, consequently, employers retaining the services of members can have some assurance that they meet the minimum standards of the scheme.

The scheme is called "Safe, Effective, Quality Occupational Health Service" (SEQOHS) and is a set of standards and a voluntary accreditation scheme for occupational health services in the UK and beyond. SEQOHS accreditation is the formal recognition that an occupational health service provider has demonstrated that it has the competence to deliver against the measures in the SEQOHS standards.

The scheme is managed by the Royal College of Physicians of London on behalf of the FOM. SEQOHS is also available in Ireland and is endorsed by the Faculty of Occupational Medicine, Royal College of Physicians of Ireland.

The standards comprise of just under 50 specific standards under six general headings: Business Probity; Information Governance; People; Facilities and Equipment; Relationships with Purchasers; Relationships with Workers.

STUDY QUESTIONS

6. Outline the typical functions of an occupational health service.
7. When is health surveillance a requirement of good practice?
8. What is the purpose of carrying out a workplace health needs assessment?
9. What is SEQOHS?

(Suggested Answers are at the end.)

Summary

Nature of Occupational Health

We have:

- Defined occupational health as "*the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations by preventing departures from health, controlling risks, and adapting work to people and people to their jobs*".
- Identified that occupational health deals with health hazards that can be categorised under five headings: chemical, physical, biological, psycho-social and ergonomic.
- Outlined how work-related ill health is far more prevalent than work-related injury, with many thousands of deaths occurring each year as a result of exposure to various health hazards, such as asbestos.
- Outlined that there are strong links between occupational health and public health, particularly in cases of serious health issues which will impact on individuals and employers.

Management of Return to Work

We have:

- Outlined the bio-psychosocial model as a way of considering human ill health as being more than simply a case of medical disease, but a combination of biological disease and psychological response by the individual within a social context.
- Outlined the use of fitness-to-work standards to define levels of health and fitness that are used to determine whether a worker is capable of carrying out a defined type of work safely (sometimes defined in statue law but often adopted by the employer as a matter of good practice).
- Explained that a pre-placement health assessment is undertaken as part of the risk assessment process (usually only after a job offer has been made) to determine the health and fitness of the worker in respect of the job that they will be carrying out.
- Described how employers must establish policies and procedures to actively manage the return to work of employees from long-term and short-term frequent sickness absence through appropriate liaison between managers, occupational health and other healthcare providers, as outlined in NICE guidance note PH19.
- Defined vocational rehabilitation as helping someone with a health problem to stay at, return to and remain in work and outlined the benefits to rehabilitating workers back into the workplace, both for the employer and the employee and how the bio-psychosocial model can be used to identify barriers to the rehabilitation of ill workers as has been used in the rehabilitation of workers with musculoskeletal disorders (MSDs) and other common work-related conditions.
- Identified how risk assessment plays an important role in the return to work of an employee following ill health or incapacity.
- Identified the various external agencies, such as Occupational Therapists (OTs) that exist to provide support to the employer and employee during the return-to-work and rehabilitation process.

Managing Occupational Health

We have:

- Identified that occupational health services are concerned with the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations.
- Explained that an occupational health service will involve the services of occupational health doctors, nurses and technicians, as well as specialists in particular fields, such as audiometricians, and outlined the minimum

standards of qualification and registration for occupational health doctors and nurses, as well as specialists, such as audiometricians.

- Described the typical services provided by occupational health include pre-employment screening, health surveillance, return-to-work rehabilitation programmes, sickness absence management, counselling, risk assessment (both general and personal), health education and promotion campaigns, treatment services, management of first aid and immunisation programmes.
- Highlighted the difference between general health assessment - an assessment of an individual's general health and fitness - and health surveillance - the monitoring of an individual's health to ensure that they are suitable for work involving exposure to a specific type of health hazard, and to track their health over time as they work with that hazard.
- Defined Health Needs Assessment (HNA) as the systematic review of the health issues facing a population, leading to prioritisation and resource allocation to improve health and reduce inequalities and explained how HNA can be used to identify the occupational health priorities that are of concern to workers, so that an appropriate occupational health service response can be planned and implemented.
- Outlined how employers must ensure that any occupational health service provider appointed by them meets minimum standards with regards to their service provision and explained that to that end the Faculty of Occupational Medicine has established a voluntary accreditation scheme (SEQOHS).

Exam Skills

Introduction

It should go without saying that to achieve the NEBOSH Diploma you will need to work carefully through your course. But you also need to perform when it really matters - in the exam.

Working through this course will help you build up your confidence in preparation for the exam day.

Before we go any further, let's outline at some basic information about the exam itself:

- You have three hours, plus 10 minutes' reading time.
- There are two sections:
  - Section A: six compulsory questions (10 marks each).
  - Section B: you can choose to answer **three** questions from five on the paper (20 marks per question).
- So there are 120 marks available in total.

The exam questions require you to demonstrate your knowledge and understanding of the elements you have studied as part of your course – and to show that you can apply your knowledge and understanding to both familiar and unfamiliar situations.

That might sound daunting, but basic exam technique is really quite simple (as long as you know the required information, of course!). Essentially, what you need to do is:

Step 1: Read each question carefully.

Step 2: Review the marks available (consider how long you should spend on the question and how many points of information you need to include).

Step 3: Highlight the key action words.

Step 4: Read the question again.

Step 5: Plan your answer (using mind maps, bullet points, etc.) so that you have a structure to work to.

Step 6: Answer the question in full, keeping a close eye on the time (allow 15 minutes for a Section A, 10-mark question, and 30 minutes for a Section B, 20-mark question).

Command Word	Meaning
Analyse	To divide or break down the subject matter or topic into parts, reasons, aspects, etc. and then examine their nature and relationship.
Assess	To present judgments of the factors raised, their significance, importance and why they are important and/or significant.
Calculate	To ascertain or determine by mathematical processes.
Comment	To give opinions (with justification) on an issue or statement by considering the issues relevant to it.
Compare and contrast	To provide a point-by-point account of the similarities and differences between two sets of information or two areas.
Consider	To offer some detail about an issue or event and to deliberate about the value of that issue/event.
Define	To give the meaning of a word, phrase or concept, determine or fix the boundaries or extent of. A relatively short answer, usually one or two sentences, where there is a generally recognised or accepted expression.
Demonstrate	To prove or make clear by reasoning or evidence how some relationship or event has occurred.
Describe	To give a detailed written account of the distinctive features of a subject. The account should be factual, without any attempt to explain.
Determine	To come to a decision as the result of investigation or reasoning.
Discuss	To give a critical account of the points involved in the topic.
Distinguish	To present the differences between; to separate into kinds, classes, or categories.
Evaluate	To determine the value or character of something by careful appraisal.
Explain	To provide an understanding. To make an idea or relationship clear.
Give	To provide short, factual answers. NB: Normally a single word, phrase or sentence will be sufficient.
Identify	To give a reference to an item, which could be its name or title.
Justify	To prove or show to be valid, sound, or conforming to fact or reason.
Outline	To indicate the principal features or different parts of.
Recommend	To bring forward as being fit or worthy; to indicate as being one's choice for something.
Review	To make a survey of; examine, look over carefully and give a critical account.

We have provided some sample answers that a student may give, together with some possible answers points that the examiners would expect to see covered. They are based on examiners' reports but neither the student response nor the possible answer points are model answers. The possible answers are also NOT provided as a full answer – you would need to expand upon the bullet points taking into account the command word in order to answer the question correctly. Providing the examiner with such a brief answer would **not attract good marks.**

You will find more guidance as you work through the course along with plenty of sample/practice questions. It's really important that you complete these and get in touch with a tutor if you have any queries or there is anything you are struggling with. Taking into account what we have just covered on exam technique, consider the following question:

QUESTION

Outline the possible functions of an occupational health service within a large manufacturing company.

(10)

Suggested Answer Outline

The examiner would be looking for 10 of the following points in your answer: pre-employment health screening, return-to-work assessments, biological monitoring, health surveillance, contributing to health and safety policies, providing specialist input to risk assessment and health education and training, sickness absence monitoring, keeping health records, managing first-aid provision, rehabilitation programmes, liaising with local and national authorities, immunisation, drug/alcohol screening, counselling, audiometry, etc.

Example of How the Question Could be Answered

In a large manufacturing company, the functions of an occupational health service are many and varied.

Pre-employment medicals are important in determining the fitness of employees joining the company and identifying pre-existing medical conditions which could be worsened by work, (e.g. occupational asthma).

Routine health surveillance, such as checks for dermatitis when working with solvents, noise/audiometric assessments and biological monitoring, all serve to monitor the effectiveness of existing controls.

Stress counselling and health campaigns, such as quitting smoking and healthy eating, serve to improve the health and well-being of the workforce.

Risk assessments, involving potential health issues, such as shift working, can identify areas where further interventions are necessary.

Occupational health professionals can also assist with the design of tasks and equipment to minimise health effects which might arise from manual handling activities and poor ergonomics. They may also be involved in special assessments for young persons and nursing mothers.

Running training courses and education programmes are another key function, as is the provision of return to work medicals to confirm that employees can return to work after illnesses/accidents.

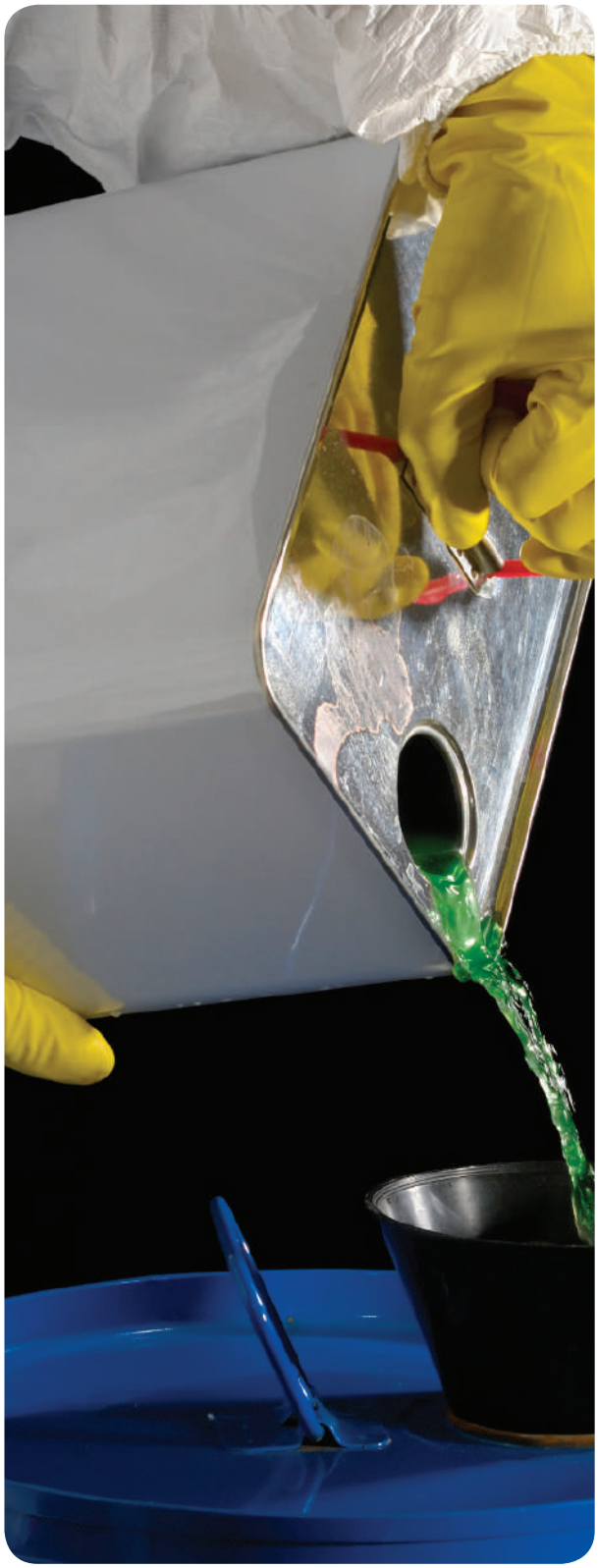
Finally, the occupational health service plays a valuable role in monitoring and evaluating sickness absence to identify possible trends and to recommend any action that can be taken to improve employee health.

Reasons For Poor Marks Achieved By Candidates in Exam

Candidates would achieve poor marks for an answer which details the separate roles of the department.

Element IB2

Identification, Assessment and Evaluation of Hazardous Substances



Learning Outcomes

Once you've read this element, you'll understand how to:

1. Explain the main routes of entry and the human body's defensive responses to hazardous substances.
2. Explain the identification, classification and health effects of hazardous substances used in the workplace.
3. Outline the factors to consider when undertaking assessment and evaluation of risks from hazardous substances.
4. Outline the role of epidemiology and toxicological testing.

Contents

The Human Anatomical System - the Routes of Entry and Defensive Responses

IN THIS SECTION...

- The respiratory system consists of the upper respiratory tract and lungs and its prime function is the delivery of oxygen into the bloodstream.
- The digestive system consists of a continuous tract through the body where ingestion, digestion, absorption and excretion of food stuffs take place.
- The circulatory system consists of the heart, blood vessels and blood and is responsible for the continuous transportation of all of the chemicals essential for life.
- The nervous system is made up of the central nervous system (brain and spinal cord) and the peripheral nervous system (which detects and transmits sensory information and controls motor function).
- The skin is an organ made up of the epidermis and dermis and is the primary barrier between the body and the environment.
- The eye is a delicate sense organ used to detect light; similarly, the nose provides a sense of smell.
- Chemicals gain entry to the body by four principal routes of entry; inhalation, absorption through the skin (pervasion), injection through the skin and ingestion. Aspiration and entry at the eye or ear are other possible routes.
- The health effects of chemicals can be described as local or systemic and often involve specific target organs and target systems.
- The body has innate and adaptive defence mechanism to protect it from attack and damage.
- The respiratory system has a series of defences to combat dust inhalation: the sneeze reflex, nasal filtration, the mucociliary escalator, macrophages and the inflammatory response.

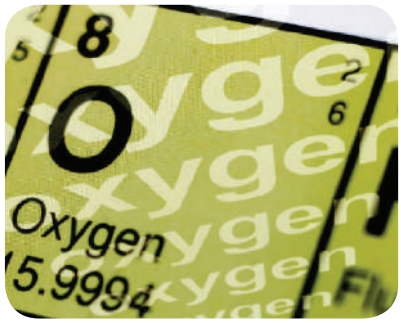
Introduction

This section looks at several anatomical systems and sense organs that are important in the context of exposure to hazardous substances. (We'll start on the following page so you can see the relevant diagram alongside the information about each system.)

Respiratory System

Air enters the nose and passes through the nasal cavity. There, it is warmed and moistened by water vapour from the mucous membranes. It passes out of the nasal cavity, through the pharynx (back of the throat) and then down the trachea (the windpipe).

The trachea carries air down into the thoracic cavity (chest) and then divides into two bronchi, one into the left lung and the other into the right lung. In each lung, the bronchus branches into bronchioles, which repeatedly branch into progressively smaller and smaller tubes. Air is carried to the terminal bronchioles, which lead to an infundibulum of alveoli (similar in appearance to a bunch of grapes). All of these conducting airways are lined with mucous membrane to keep the inhaled air moist.



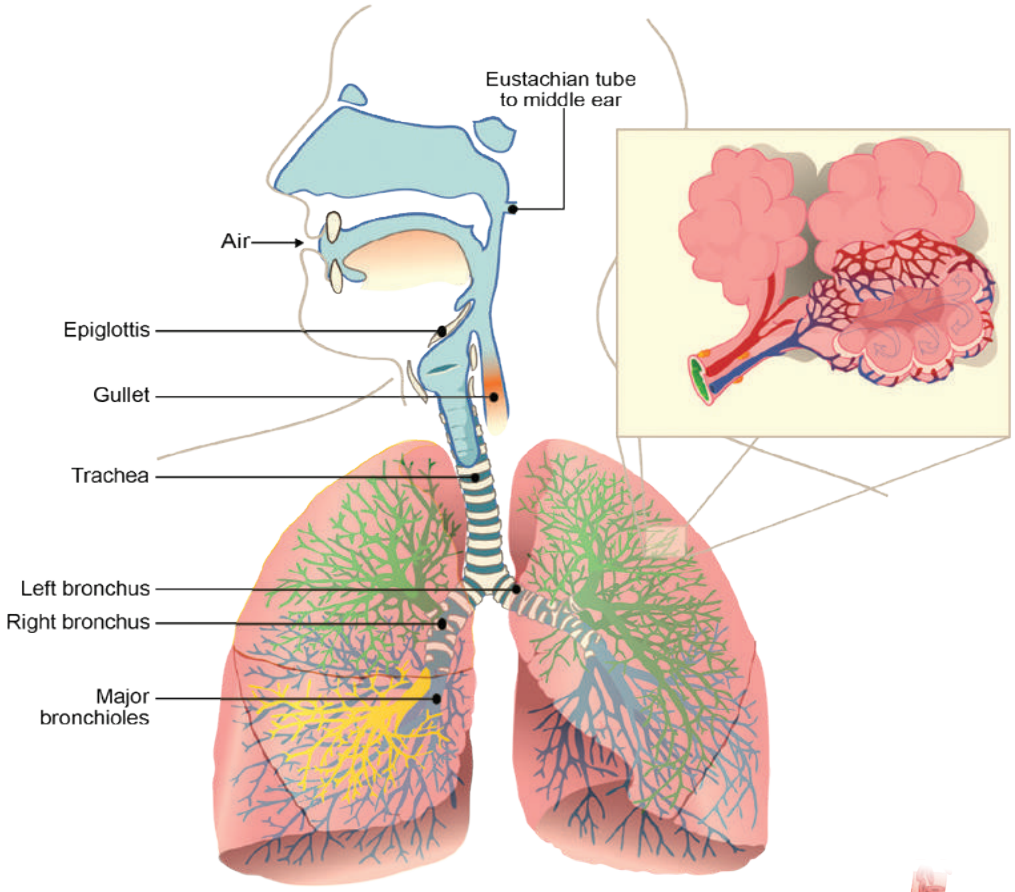
Oxygen passes into the bloodstream when inhaled

The alveoli (or air sacs) is where gas exchange takes place:

- oxygen (O_2) leaves the inhaled air and passes into the bloodstream, and
- carbon dioxide (CO_2) leaves the bloodstream and is then exhaled.

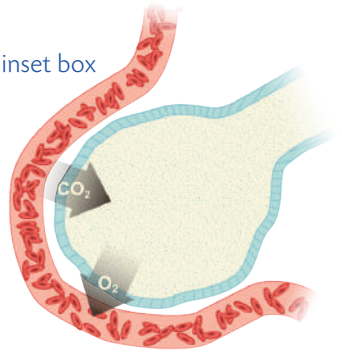
The walls of the alveoli are very thin (one cell thick), moist and delicate.

The basic structure of the airway is shown in the following figure. The upper respiratory system is formed by the nasal cavities, pharynx, larynx and trachea. The lungs contain the bronchi, bronchioles, terminal bronchioles and the alveoli.



The respiratory system showing detail of the alveoli in the inset box

During respiration, oxygen diffuses across the thin membranes of the alveoli into the bloodstream. This bloodstream is carried in capillaries, very thin blood vessels that form a network over the outer surface of the alveoli. As the blood collects oxygen so it becomes oxygen rich (saturated) and fresh, deoxygenated blood is moved through the capillaries to take its place. This gas exchange is illustrated in the diagram.



This shows the diffusion of oxygen from air in the alveoli across the thin membranes of the lung and blood vessel and into the bloodstream. At the same time, CO_2 diffuses out of the bloodstream and into the air in the alveoli. This air is then exhaled. Note the red blood cells (or erythrocytes) in the blood

Digestive System

The function of the digestive system is the digestion and absorption of foodstuffs, which is dealt with in four stages:

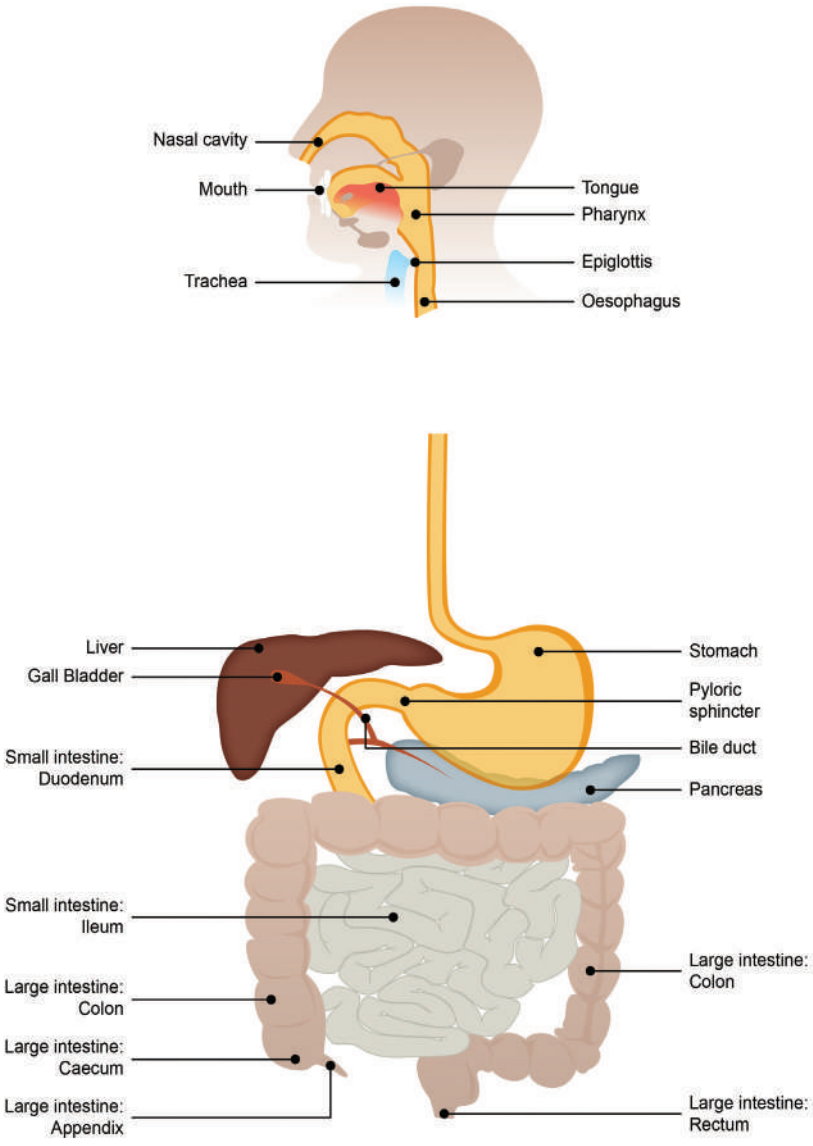
- **Ingestion** – through the mouth with mastication (chewing) and swallowing.
- **Digestion** – the breakdown of food by enzymes secreted into it by the mouth, stomach and duodenum.

- **Absorption** – of the breakdown products of digestion in the small and large intestines.
- **Excretion** – of undigested food and waste through the rectum and anus.

The tube that food passes along as this process takes place is the gastrointestinal tract. This is made up of the following parts:

- Mouth – food is chewed, saliva containing enzymes is secreted. Some digestion starts.
- Oesophagus – swallowed food is squeezed by muscular contractions down this tube.
- Stomach – acidic gastric juices are secreted from the stomach wall into the food. Digestion is in full swing. Food remains in the stomach for some time.
- Small intestine – food from the stomach passes through the first part of the small intestines, the duodenum, where further enzymes and bile are added. Further digestion takes place. The food then passes to another part of the small intestine, the ileum, where the breakdown products of digestion (sugars, amino acids and fatty acids) are absorbed into the bloodstream.
- Large intestine – water is absorbed from the remaining material which is then collected in the rectum prior to excretion.

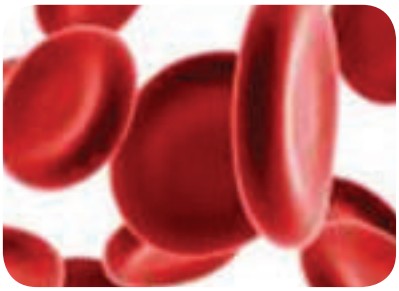
The following diagram shows the various parts of the gastrointestinal tract:



The digestive system

Circulatory System

Every cell in the body relies on a supply of oxygen and the removal of waste. The circulatory system provides this service. The system comprises the blood (fluid), heart (pump) and blood vessels (pipework).



Red blood cells

The Blood

Blood is a viscous fluid made up of blood cells (45%) suspended in a straw coloured liquid (plasma; 55%). The plasma is high in various salts.

The blood cells include:

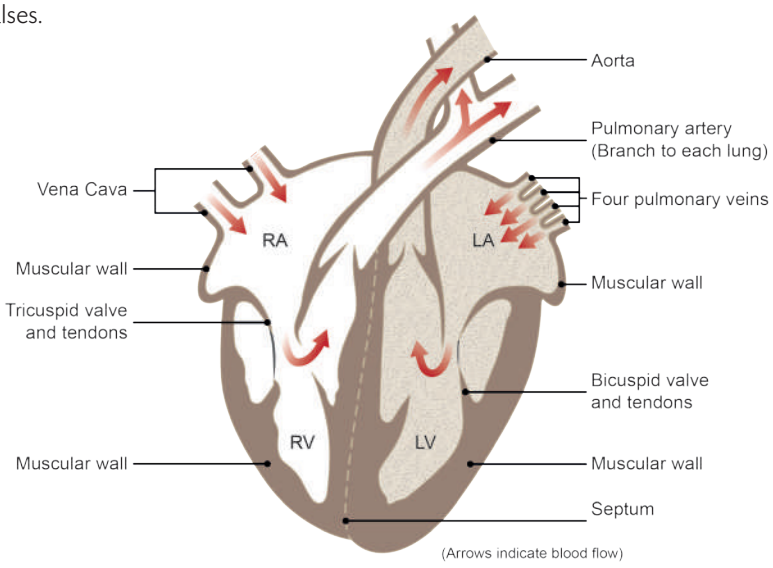
- Erythrocytes (red blood cells) – contain haemoglobin which provides a chemical system that enables oxygen to be transported throughout the body. When oxygen obtained from the lungs is attached to the haemoglobin, it is called oxyhaemoglobin.
- Leucocytes (white blood cells) – there are three main types of leucocyte which together form the main defensive system in combating disease and the effects of toxic actions.
  - Granulocytes – move in and out of blood vessels and through tissues ingesting harmful micro-organisms, such as bacteria, or debris by a process called phagocytosis.
  - Lymphocytes – are associated with the production of antibodies which neutralise the effect of recognised foreign matter (referred to as antigens).
  - Monocytes – change into macrophages when leaving the blood and have a similar ingesting role to granulocytes, but also mediate in some of the jobs of the lymphocytes.
  - Thrombocytes (platelets) – their main function is in the clotting of blood.

The ratio of the cells in blood is 500 red cells: 1 white cell: 30 platelets.

The Heart

The heart is a muscular sack situated in the chest cavity. It is divided by a septum into right and left sides, which in effect makes it two pumps in one.

Each side is divided into an upper and lower chamber: the atrium which receives blood, and the ventricle which distributes blood. Thus, when the heart contracts or beats, it squeezes blood from both atria down into the respective ventricles and then from those ventricles out into the attached blood vessels. The beating of the heart is controlled by nerve impulses.



Key to the diagram:

RA: right atrium

LA: left atrium

RV: right ventricle

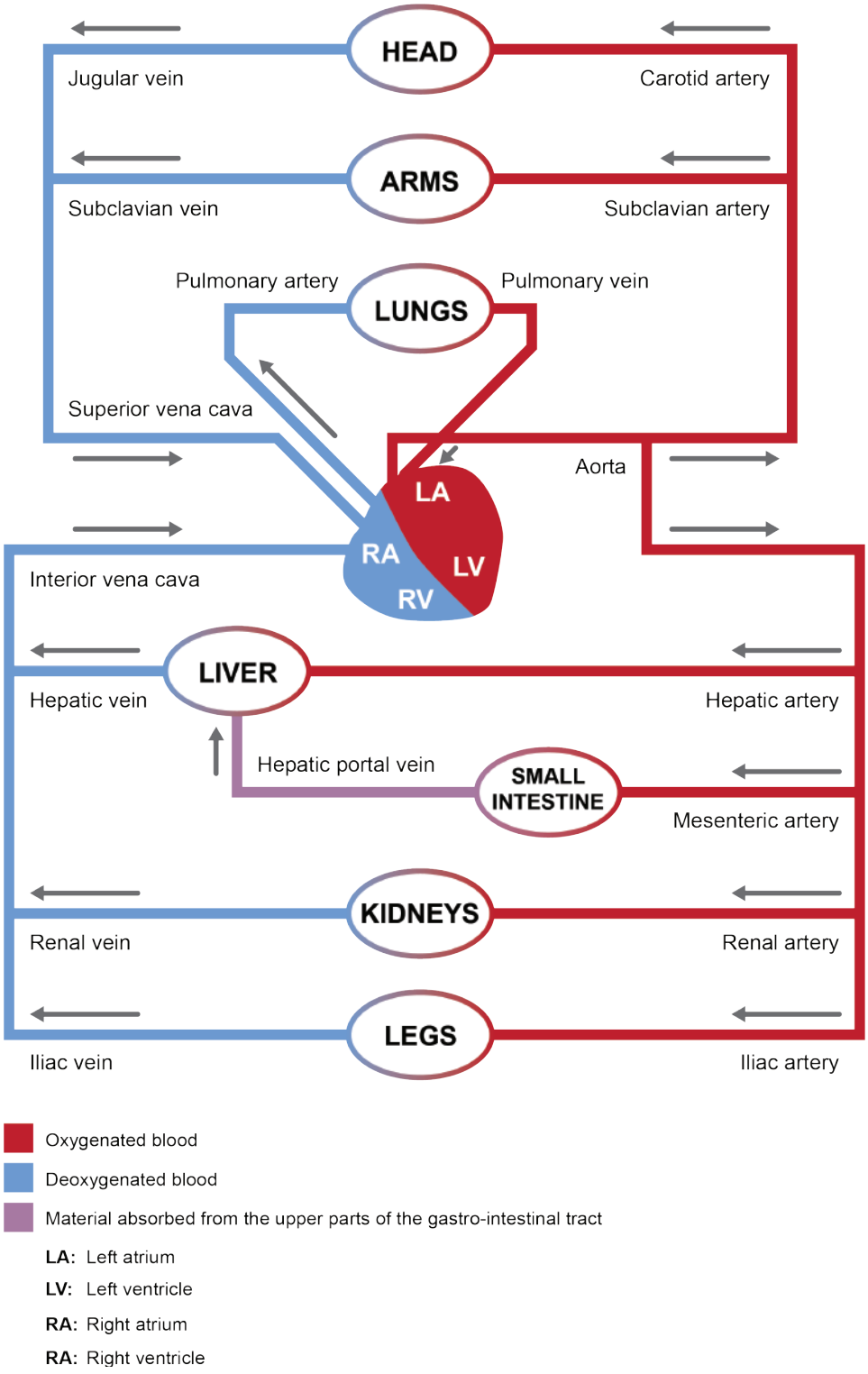
LV: left ventricle

Longitudinal section of the heart (anterior view)

The Blood Vessels

The blood vessels form the pipework down which blood flows as the heart pumps.

The system is represented in the following diagram.



The circulatory system

Note that deoxygenated blood from the body is returned to the heart and is then pumped to the lungs. At the lungs, the blood becomes oxygenated. It is then piped back to the heart where it is then re-pumped out of the aorta and around the body.

The blood vessels that the blood flows through are tubes of varying wall thickness and structure:

- Arteries and arterioles carry blood away from the heart (usually oxygenated blood, with the exception of the pulmonary artery).
- Capillaries form the very fine tubes that carry blood into very close proximity to the cells and tissues that require oxygen.
- Veins and venules carry blood from the capillaries back to the heart (usually deoxygenated blood with the exception of the pulmonary vein).

It typically takes 20 seconds for blood to flow around the entire system (e.g. heart to lungs; back to heart; out to big toe; back to heart again).

Lymphatic System

The **lymphatic system** links with the circulatory system, and is almost as extensive.

A key function of the lymphatic system is to manufacture new **lymphocytes** in the **lymph nodes**. (Lymphocytes are a type of white blood cell (leucocyte) that play a large role in defending the body against disease and are responsible for immune responses. They can produce antibodies that attack bacteria and toxins or can attack body cells themselves and are often present at sites of chronic inflammation.)

Nervous System

The nervous system is divided into two main parts - the central and the peripheral:

- The central nervous system comprises the brain and the spinal cord.
- The peripheral part consists of the motor (controlling movement) and sensory (controlling sensation) nerves.

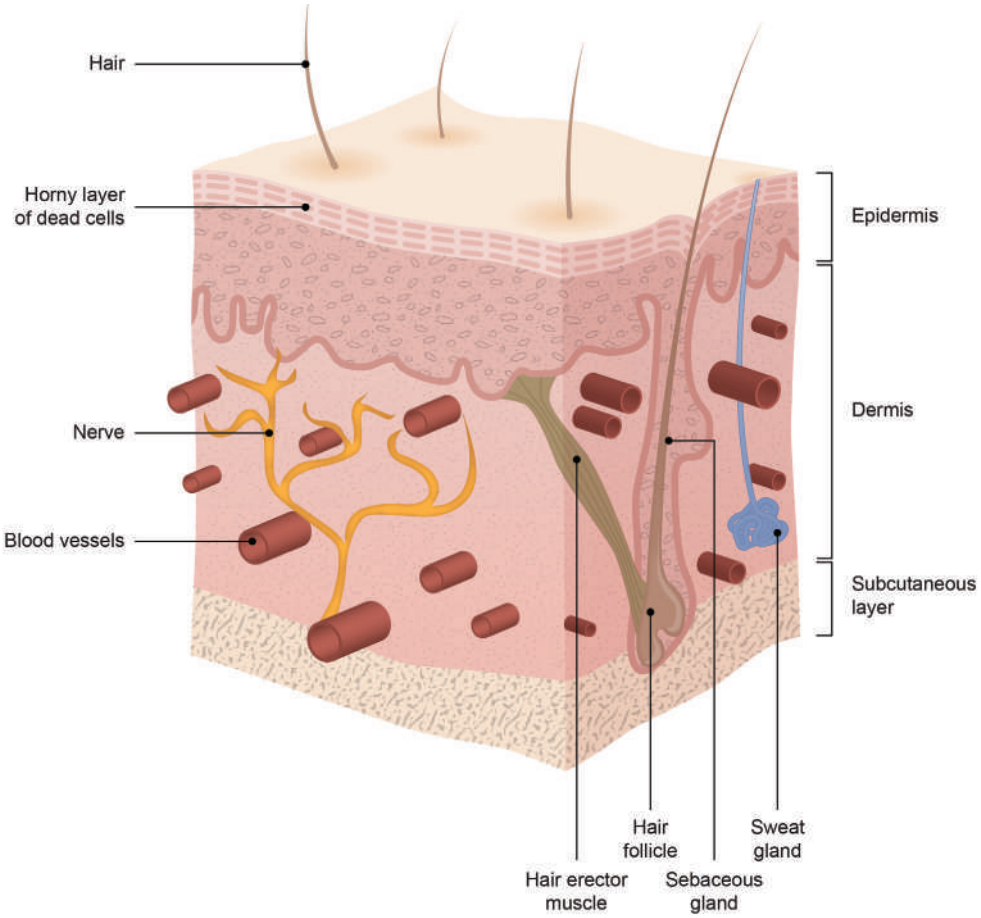
The basic unit of the nervous system is the nerve cell or neurone. Nerve impulses generated at one end of the neurone travel along the nerve fibre to release neurotransmitter chemicals at the other end. Nerve cells, unlike most other cells in the body, do not repair well and so damage to nerve tissue tends to be irreversible.

Skin

The skin is a complex assembly of connective tissues that forms the outer covering of the body and is continuous with the membrane lining which covers the cavities within the body.

The skin has a distinctly layered structure:

- The **epidermis** forms the outermost layer of skin and is composed of:
  - The horny zone – layers of dead cells that protect the outer surface. These are continually being shed and replaced.
  - The germinal (or living) zone – the living cells that reproduce to form the horny zone.
- The **dermis**, a much thicker layer of living tissues that contains most of the interesting structures of the skin:
  - Blood vessels – that supply oxygen and lose heat to the skin.
  - Sweat glands – that excrete sweat (water and salts) from the blood up onto the surface of the epidermis.
  - Nerve endings – for pain receptors, heat receptors, pressure receptors, etc.
  - Hair follicles – where skin hair grows up through the epidermis, with an erectile muscle to the side of the hair follicle capable of contracting to make the hair stand erect (for thermal insulation).
  - Sebaceous glands – that secrete sebum (oily liquid) onto the skin surface where it suppresses bacterial growth.



Cross-section of the skin

The skin is impermeable to water but can be permeated by other liquids, such as organic solvents (e.g. phenol).

The Eye

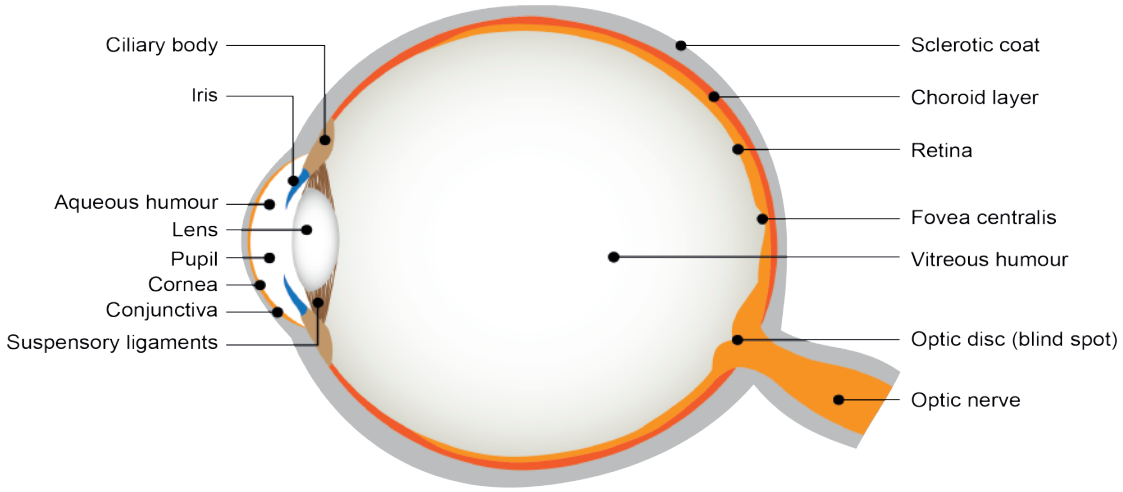
The eyeball contains a transparent liquid through which light is focused by a lens on to a sensitive layer (the retina).

The outer coating of the eyeball (sclerotic coat) is very tough and is also transparent at the front (the cornea).

Light rays entering the eye pass through the cornea and the aqueous humour to be focused by the lens. The light then continues through the vitreous humour and strikes the retina, where electrical impulses are generated and transmitted via the optic nerve to the brain.

The cornea and lens are delicate and therefore vulnerable to damage from chemicals or radiation.

The eyeball sits in a socket lined with delicate mucous membranes which have a rich blood supply.



Cross-section of the eyeball

The Nose

The nose performs a range of functions, one of which we have already outlined; the humidification and warming of air as it is inhaled into the respiratory system. Another important function associated with the nose is the sense of smell. This is provided by nerve cells that are embedded in the mucous membranes at the top of the nasal cavity. When air is inhaled through the nostrils, odour molecules attach to these nerve cells. The nerve cells are then stimulated to send nerve impulses to the olfactory bulbs – these are the parts of the brain responsible for the sense of smell – that are positioned just above the nasal cavity. The sense of smell is useful to give early warning of the presence of certain hazardous substances. However, many hazardous substances do not have an odour (e.g. carbon monoxide gas, CO). And some hazardous substances can destroy the nerve cells responsible for generating the odour signals (e.g. hydrogen sulphide, H_2S).

The Routes and Methods of Entry

Some hazardous chemicals do not need to enter the body in order to have a health effect. For example, a corrosive such as concentrated hydrochloric acid will cause damage to the skin on contact.

Many hazardous substances, however, have to gain entry into the body before they can have a health effect. The routes and methods by which chemicals gain entry to the body are, therefore, important.

The main routes of entry are:

- Inhalation

  Inhalation into the lungs is the most frequent and significant route of entry for the majority of hazardous substances. There are several reasons why the lungs are so vulnerable:

  – The epithelium of the lungs has a massive surface area – the lungs have a highly convoluted structure to create a very large surface area so that sufficient oxygen can be absorbed from inhaled air to supply the body.
  – The epithelium in the alveoli is very thin and in very close proximity to the blood supply – it has to be to allow efficient diffusion of oxygen into the bloodstream. Unfortunately, this means that every other molecule that is soluble in the mucous lining the epithelium can also diffuse across into the bloodstream.
  – You have to breathe – it is not optional (unlike eating or drinking); respiration demands that you inhale air almost constantly. Therefore, if a chemical is in the air, it is going to be inhaled.

Any inhaled substance capable of dissolving in water or capable of passing through membranes will pass into the bloodstream. And, of course, the lungs have a very rich blood supply. Once in the blood, the toxic substance will be efficiently transported to all parts of the body. Typically within 30 to 60 seconds of inhaling a toxic substance, it will be present in the blood in most parts of the body.

Consequently, for the majority of toxic chemicals, inhalation is the primary route of entry that has to be tackled to eliminate or control exposure.

- ## Skin Contact

The skin is the second most vulnerable area after the lungs, as it can come into contact with solid, liquid or gaseous toxic substances, possibly in high concentrations. Fortunately, the epidermis has many layers of protection and does not allow solid or gaseous substances to be absorbed in general.

The skin is also waterproof, so water-soluble chemicals are unlikely to gain entry unless they remain in contact with the skin for long periods of time.

The greatest risk comes from chemicals that can pass through the epidermis. This is sometimes called pervasion. Organic solvents, such as benzene and toluene, are notorious for this property. They achieve this absorption by dissolving the lipid membranes that the cells of the epidermis are made of. If a chemical can pass through the skin in this manner then contact with the liquid, gas or vapour will result in absorption.

The alternative process through the skin is, of course, **injection**. This occurs either where the substance is:

- physically forced through the skin; e.g. needlestick injury, compressed air injection, cut with contaminated sharp object; or
- introduced through the epidermis where it is damaged; e.g. cuts, grazes, dermatitis chaps.

- ## Ingestion

In terms of occupational hazards from toxins, the gastrointestinal tract is the least vulnerable part of the body. The possibility of solid or liquid toxicants being ingested is limited. People are not in the habit of putting toxic substances knowingly into their mouths in most workplaces. It can and does happen by accident of course; either through cross-contamination of food with toxic chemicals (due to poor hygiene practices) or because the individual concerned is not aware of their actions (young children or dementia patient).

When ingestion does occur, the substance must be water soluble or able to pass through membranes to be absorbed and it must reach a part of the gastrointestinal tract where this absorption can occur. The stomach has a thick mucous lining (to prevent attack of the stomach wall by the very acidic gastric juices) so little absorption is likely to take place there. Absorption is most likely to occur in the small intestine, where food is absorbed. Thus if you swallow a small lead pellet, you are unlikely to absorb very much lead into your bloodstream.

- ## Other Routes

There are other routes of entry, but these tend to be less significant in most circumstances. For example:

Aspiration – the direct entry of liquid (or solid) into the lungs. This typically happens in two ways:

- When substances that have been ingested are expelled in vomit and run down into the respiratory tract.
- When substances are sucked directly into the lungs during pipetting or siphoning.

This can be very serious – swallowing a hydrocarbon solvent is unpleasant but survivable; inhaling it can be lethal.

Mucous membrane of the eye – substances may dissolve in the moist covering of the eye and undergo absorption into the bloodstream of the eyelids and eye socket.

Ear – though the ear canal is coated with ear wax and is a relatively poor route of entry, it is possible that substances can pass through the skin of the canal or the ear drum, especially organic solvents.

Local and Systemic Effects and Target Organs

When hazardous substances gain entry to the body, they may have a local or a systemic effect. They may also affect target organs or target systems. To explain:

- **Local effects** – are confined to the specific area of the body where contact with the toxic material occurs, such as the skin, eyes, respiratory tract, etc. For example:
  - A sensitising agent may cause a specific allergic reaction on contact with the skin or respiratory tract.
  - An irritant may cause local irritation to the eyes or skin after contact at those sites.
- **Systemic effects** – occur in organs or parts of the body distant from the site where initial contact with the toxic substance was made. It may be that the entire body system is affected by the substance or several different parts of the body and systems are affected only. For example:
  - Lead inhaled into the lungs as a fume will affect the central nervous system and blood-forming organs, and be incorporated into the bone.
  - Carbon monoxide inhaled into the lungs will combine with the haemoglobin of the blood to inhibit oxygen transfer throughout the circulatory system.
- **Target organs and target systems** – an organ is a group of structurally distinct tissues which perform some specific function, or set of functions, e.g. heart, liver, lungs, etc. Organs are linked to one or more body systems, such as the respiratory or circulatory systems.

  Toxic substances do not often present the same degree of toxicity to all organs; their toxicity may be concentrated in a few organs or systems, referred to as the target organs or systems for that toxin. For example:
  - Carbon tetrachloride affects the liver (organ), causing jaundice and scarring.
  - Mercury affects the central nervous system, causing narcosis and brain damage.

Defence Responses

The body's defences against 'foreign' agents are collectively called the immune system. The immune system is comprised of two complementary and interacting systems:

- Innate (or 'Non-Specific') Immune Response

  This is the response with which we are born. It provides a rapid response, but is non-specific. There are various mechanisms that are innate, such as:
  - Specialised white blood cells, e.g. macrophages.
  - Inflammation.
- Adaptive ('Acquired') Immune Response

  This response is targeted at a specific invader and takes time to develop.

  Once developed, a memory of the invader is formed and subsequent defence response will be triggered very quickly and is likely to be very effective. The mechanism involves various types of specialised white blood cell.

  One of the most important sets of defence mechanisms of interest is the respiratory system. This is largely innate, though an acquired response can also be shown.

The Respiratory System Defences

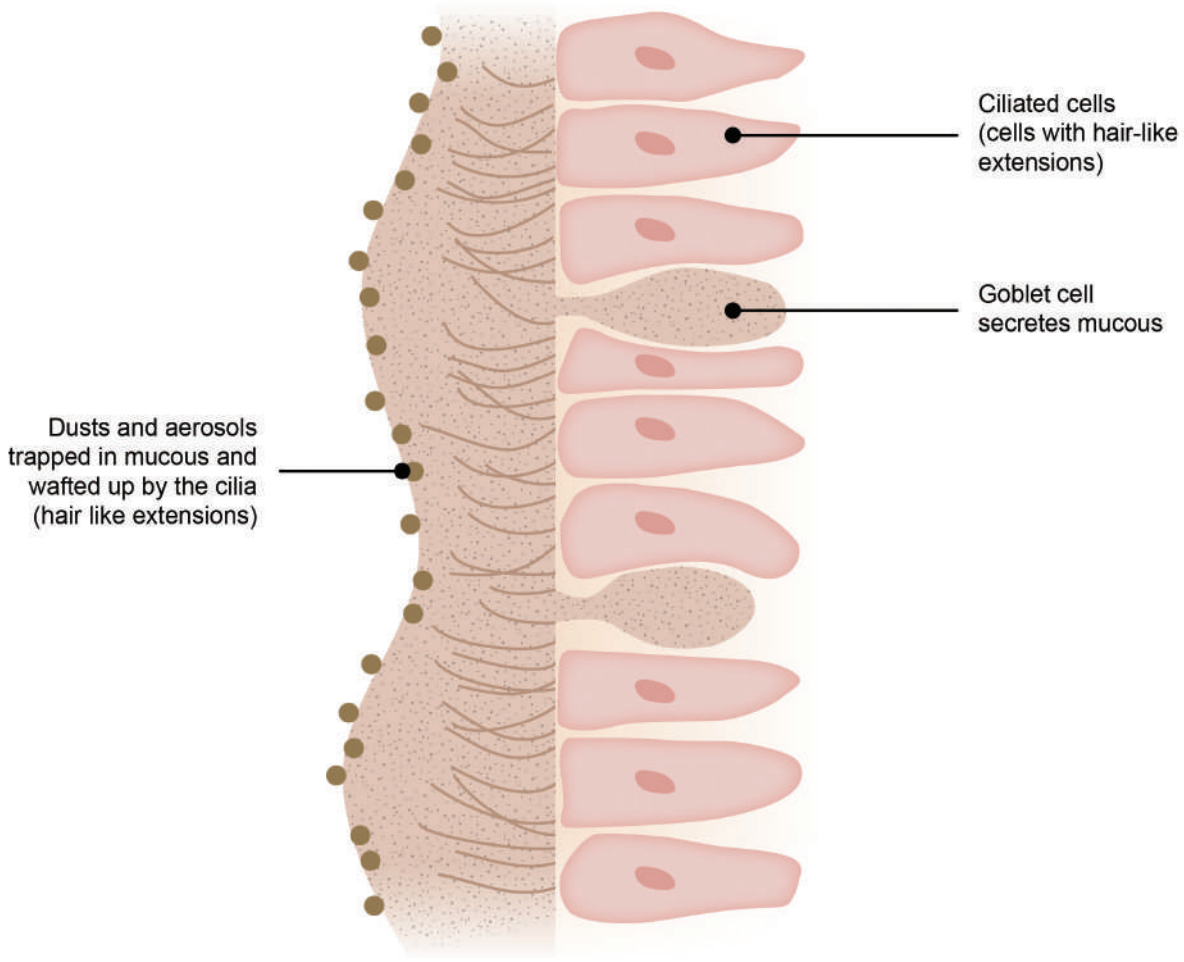
We can summarise the deposition of dust particles in the respiratory system as follows:

Particle Size	Deposition Site
Above 10 µm	Nasal cavity.
7-10 µm	Conducting airways trachea, bronchi and bronchioles.
0.5-7 µm	Respiratory bronchioles and alveoli.
Below 0.5 µm	Most remain airborne and are exhaled. Some diffuse and come into contact with the airway or alveolar membrane.

Note on units: 1 µm is 1/1,000th of a millimetre or 1/1,000,000th of a metre. For comparison purposes, a typical human hair has a diameter of 50-100 µm.

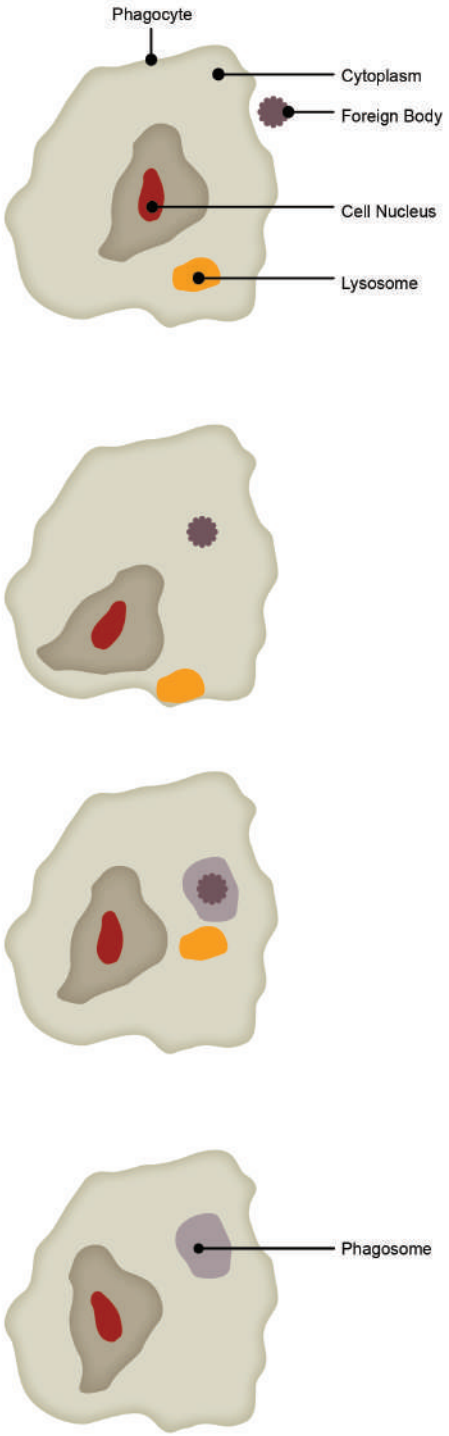
The defence mechanisms at work in the respiratory system (starting from the top) are:

- **Nasal hairs**, which filter out the larger particles (>10µm).
- **Coughing and sneezing**, which result in the forceful ejection of inhaled substances.
- **The mucociliary escalator** – particles are trapped by mucous secreted by goblet cells lining the conducting airways (particles between 7-10µm); the mucous traps the particles and these are propelled towards the nose and throat by the **mucociliary escalator**, forming sputum which is either swallowed or expectorated (spat out).



Mucociliary escalator

- **Macrophages** - specialised attacking white blood cells in the alveoli. Smaller particles and aerosols between 0.5 and 7m pass into the respiratory units where they are deposited. They may then be ingested by macrophages. Macrophages are one form of white blood cell (leucocytes) that are present in body tissues. Macrophages destroy foreign particles by **phagocytosis**; the cell ingests the foreign particle, secretes enzymes onto it and then absorbs the digested remain. Phagocytosis is illustrated in the following figure.



Stage 1
Chemotaxis – proximity of foreign body stimulates movement of phagocyte towards intruder.

Stage 2
Adhesion of foreign body to phagocyte. It is thought the immune response (qv) is the basis for adhesion.

Stage 3
Ingestion of foreign body into the phagocytic cell.

and

Stage 4
Inclusion of the foreign body attracts a lysosome which discharges enzymes into the phagosome - i.e. the mixture of enzymes and the foreign body.

Stage 5
Nitric oxide synthesising enzymes chemically digest the foreign body which may remain in the phagocyte's cytoplasm; or the phagosome may be deposited in the surrounding tissue or fluids and thence into the lymphatic system. Alternatively, the foreign body may remain as an indigestible inclusion whilst the phagocyte migrates to other tissue.

Phagocytosis

In some instances, the filtration mechanism outlined earlier is not effective at removing the substance. This may either be because the substance is not in a particle form (it is a vapour or gas) or because the substance is inert and so cannot be digested by macrophages (e.g. silica dust). In this case, the inflammatory response may be triggered.

- **Inflammatory Response**

  Inflammation is the means by which white blood cells (leucocytes) are called to the site of infection or injury.

  Typically, the response is:

  – Blood vessels dilate and the capillary walls become more permeable.
  – Protein-rich fluid (plasma) exudes from the capillaries into the surrounding tissue, causing swelling (oedema).
  – Leucocytes migrate through the capillary walls towards the harmful input, where they ingest it together with any damaged tissue.
  – Tissue-dwelling macrophages join with other phagocytes and scavenge the affected area, which is sometimes additionally bonded by fibrinogen (a protein associated with blood clotting).
  – Fibroblasts appear and secrete collagen. This fibrous protein forms a meshwork of scar tissue which steadily builds up to repair the affected area.

  Although inflammation is a defensive process of great importance, if called upon to act for too long it can result in disease. In some types of chronic inflammation, the repair process becomes disordered. The overgrowth of scar tissue, brought about by over-production of collagen, shrinks and contracts, tearing and distorting the surrounding tissues. In the lungs, this results in the condition known as emphysema and some types of pneumoconiosis result in extensive scarring and fibrosis.

- **Respiratory Inflammation**

  The respiratory pathway is vulnerable to attack by many irritants and corrosives or any other substances which attack the skin. The terminology of the inflammatory processes follows the pathway of air into the lungs, for example:

  – Rhinitis (nose).
  – Laryngitis (larynx).
  – Tracheitis (wind pipe).
  – Bronchitis (upper lung).

- **Acquired Immunity**

  The acquired immune system is a primary defence against viral and bacterial attack. When a biological agent causing disease (pathogen) is detected, parts of the immune system produce antibodies in response to chemical markers (antigens) on the pathogen. These antibodies are used to attack the pathogen and destroy it, often by labelling the pathogen so that other white blood cells recognise it as a target for destruction.

  Whilst this system is critical in keeping the respiratory system free of viral and bacterial infection, it can sometimes become triggered by large molecules that in their own right do not represent a threat to the body.

  Certain substances (e.g. flour dust) are able to sensitise the respiratory system in this way and evoke an immune response.

STUDY QUESTIONS

1. Describe how oxygen enters the bloodstream.
2. Identify the main purpose of the circulatory system.
3. What are the three essential components of the circulatory system?
4. What is the function of the retina?
5. Outline what is meant by the terms "local effects" and "systemic effects".
6. What are the body's natural defences in the respiratory system?

(Suggested Answers are at the end.)

Identification, Classification and Health Effects of Hazardous Substances

IN THIS SECTION...

- The three physical states of matter are solid, liquid and gas. Within these states, chemicals can take different forms, such as dust, fibres, fume, mist and vapour. The physical form of a chemical influences the possible routes and methods of entry into the body.
- Inhalable dust is all dust that can be breathed into the nose and mouth. Respirable dust is dust that can be inhaled deep into the lungs.
- The United Nations have implemented a Globally Harmonised System of Classification and Labelling of Chemicals (GHS), which aims to standardise the laws governing the classification and labelling of chemicals globally, with the principle "one chemical – one label worldwide".
- Suppliers and manufacturers of chemicals have to classify, label and package chemicals according to GHS. In the EU, this is a legal requirement of EC Regulation no 1272/2008 Classification, Labelling and Packaging of Substances and Mixtures Regulation (CLP).
- Under CLP, harmonised classification and labelling information is available for many substances in Table 3.1 of Part 3 of Annex VI of CLP. Where these tables do not apply, the supplier must classify and label according to CLP.
- Standard health hazard classes are used to classify the health effects of chemicals according to GHS. They are: acute toxicity, skin corrosion, skin irritation, serious eye damage, eye irritation, respiratory sensitisation, skin sensitisation, germ cell mutagenicity, carcinogenicity, reproductive toxicity, specific target organ toxicity (single and repeat exposure) and aspiration hazard.
- In Europe, the EU REACH Regulation requires that suppliers/manufacturers register chemicals that they manufacture or supply in quantities of one tonne or more per year with the European Chemicals Agency (ECHA).
- Specific workplace examples of hazardous chemicals include asbestos, lead, carbon monoxide, isocyanates, metal working fluids, used engine oil, silica and wood dusts (both hard and soft wood).

Physical Forms and Routes of Entry

The ability of a substance to gain entry to the body is hugely influenced by its physical form. This will determine the possible routes of entry and may influence the process of entry as well. It is, therefore, worth considering the various physical forms in which hazardous substances are encountered. There are three basic states of matter: **solid**, **liquid** and **gas**, and each of these states can exist in different physical forms.

Fumes can be caused by welding

Solids

A solid has a defined volume and shape, and resists being deformed:

- **Massive form** – a solid block of material, e.g. a lead ingot. It has very low hazard potential as can't be inhaled and unlikely to be absorbed through the skin on contact. It can be ingested if small enough to be swallowed.
- **Dust** – small solid particles, e.g. flour dust. Usually created by mechanical action, such as grinding, milling, cutting, polishing, etc. and may be a required form or may be an unwanted by-product of work activity (e.g. concrete dust from disc cutting). Dust particles are small enough to stay airborne for some time and so can be inhaled. It may also be ingested and may cover large areas of skin.

- **Fibres** – elongated, stringy matter, e.g. asbestos fibres. Fibres may become airborne and can be inhaled. They may also be ingested and may cover large areas of skin.
- **Fumes** – small solid particles that have condensed from a vapour; usually from hot metal, e.g. welding fume. The particles tend to be very small so stay airborne for long periods of time and can be inhaled. They may also be ingested and may cover large areas of skin.

Liquids

A liquid is largely incompressible, but is fluid, i.e. it flows, it doesn't resist being deformed. It adopts the shape of the container in which it is held:

- **Massive form** – fluid, e.g. sulphuric acid in a beaker.

  It can come into contact with the skin, potentially quite large areas of skin.

  It can also be ingested. It can't be inhaled, unless by aspiration under specific circumstances.
- **Mist** – fine liquid droplets suspended in air, e.g. spray paint from an aerosol. It can be inhaled. It will also contact the skin. It may be ingested.

Gases

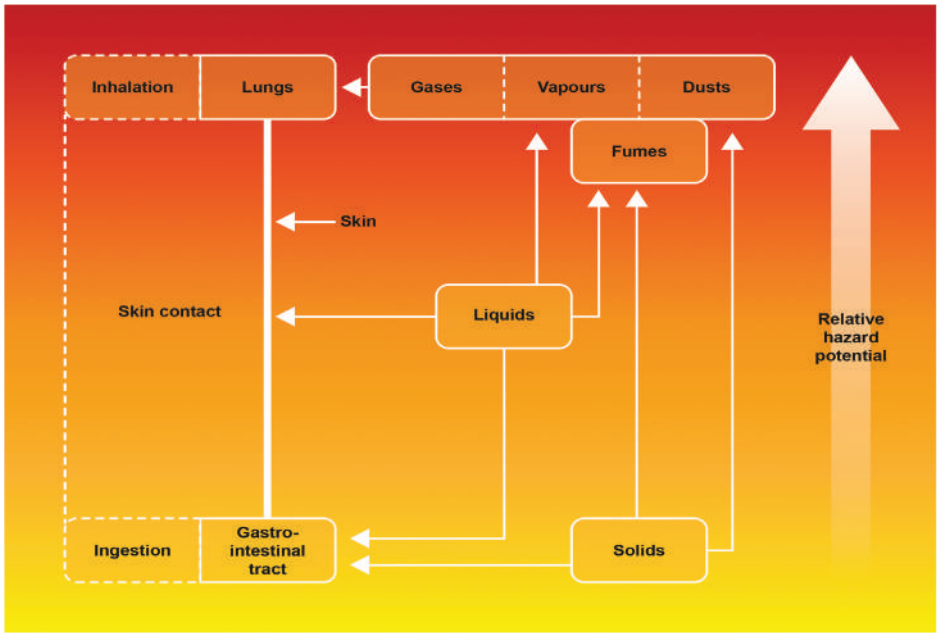
Gases flow, but are highly compressible – they adopt the shape of their container and expand or compress to fill it:

- **Vapour** – this is commonly used to mean the same thing as a gas but it implies that the gas is in equilibrium over the liquid form of the same substance, e.g. water vapour above liquid water (the technical definition of a vapour is the gaseous form of a substance that can be condensed to form a liquid by the addition of pressure without any cooling required).

  Both gases and vapour can of course be inhaled and may contact the skin.

  Note that the term 'aerosol' can be applied to any liquid or solid suspended in air.

  It is important to recognise the influence of physical state and form on hazard potential. A bar of stainless steel is not a health hazard. But when that steel is cut, welded, polished or otherwise worked on, it creates a dust or fume that can be inhaled. Stainless steel contains various toxic metals, such as nickel and chromium. The relative hazard potential of the various physical states and forms can be represented diagrammatically as follows:



Relative hazards of solids, liquids, gases/vapours in terms of ability to enter the body

Solubility of Chemicals

Other properties also affect the route and method by which chemicals enter the body. One very significant property is the solubility of the chemical in water. Since water is the solvent that all metabolic reactions take place in and the body has a very high water content, any substance that is soluble in water can be absorbed and transported around the body fairly easily. Substances that are not water-soluble will not tend to be absorbed or transported so easily (unless they have other characteristics that allow them to pervade the skin or pass readily across membranes).

Inhalable and Respirable Dust

Inhalable dust (or total inhalable dust) is the fraction of airborne dust that **enters the nose and mouth during breathing**, and is therefore available for deposition in the respiratory tract. This definition of inhalable dust is from the World Health Organisation (WHO).

Any dust that will stay suspended in the air can be inhaled into the nose and mouth. One of the defining characteristics of dust is the diameter of the particles, usually given in microns, µm (1 micron = 1/1000th of a millimetre or 10^{-3} mm). Inhalable dust particles can be as large as 100µm or more.

Respirable dust is the fraction of airborne dust that **penetrates to the gas exchange region of the lung**. Again, this definition is from **WHO**.

Dust can be inhalable or respirable

Because the upper respiratory tract (nose, throat and windpipe) have a filtering effect on inhaled dust, larger dust particles are not inhaled deep into the lungs. Typically, all dust particles larger than 7µm in diameter will have been removed by the body's filtration mechanism, so only dust particles of less than 7µm diameter will enter the region of gas exchange.

The distinction between inhalable and respirable dust is important because different Occupational Exposure Limits (OELs) may be given for inhalable dust and respirable dust and the dust monitoring methods used to determine dust exposure are different depending on whether the inhalable or respirable fraction is being measured.

We will consider monitoring and measuring of airborne contaminants, as well as OELs, in Element IB4.

Classification of Hazardous Substances, the Globally Harmonised System (GHS) and the Classification, Labelling and Packaging Regulation (CLP)

This section looks at the classification of chemicals according to their health effects. Historically, this has been carried out in different ways in different regions of the globe – with Europe adopting a different system from the US, for example – with the result that a substance imported into Europe from elsewhere in the world would potentially have to be reclassified and relabelled in order to meet the EU requirements. In an effort to standardise in this area, the United Nations have implemented a **Globally Harmonised System of Classification and Labelling of Chemicals (GHS)**. This has been implemented in different regions around the world through local legislation. We will examine the European regulatory regime as an example. In Europe, the standards of note are:

- **United Nations Globally Harmonised System of Classification and Labelling of Chemicals (GHS)**.
- **European Regulation (EC) No. 1272/2008 on Classification, Labelling and Packaging of Substances and Mixtures (CLP)**.

United Nations Globally Harmonised System of Classification and Labelling of Chemicals (GHS)

GHS is a non-legally-binding international agreement that establishes:

- New harmonised criteria for the classification of chemicals according to their hazardous properties.
- New harmonised labelling and provision of information requirements, including new hazard-warning symbols (pictograms) for labels.

The aim of GHS is to standardise the laws governing the classification and labelling of chemicals globally, the principle being 'one chemical – one label worldwide'.

Chapter 1.3.2 of GHS outlines the assessment of the intrinsic hazards of a chemical in only three steps:

- Identification of relevant data regarding the hazards of a substance or mixture.
- Review of the data to determine the hazards.
- Decision as to whether the substance will be classified as hazardous.

For a large number of chemicals, there will already be data from previous tests – GHS acknowledges this and states that it should be accepted in order to reduce the number of tests conducted (and therefore the number of test animals affected). It also acknowledges that there may be reliable epidemiological data from human exposure which could be used (we will cover the principles of epidemiology later in this element).

European Regulation (EC) No. 1272/2008 on Classification, Labelling and Packaging of Substances and Mixtures (CLP)

This EU Regulation puts a duty on manufacturers and suppliers to:

- Classify dangerous chemicals (both substances and mixtures) using the new scientific criteria agreed under GHS. This requires the manufacturer/supplier to classify according to three different criteria: physico-chemical properties (e.g. explosive); health effects (e.g. acute toxicity); and environmental effects (e.g. toxic to the aquatic environment).
- Provide information to the end user in the form of a label that will make use of new hazard warning symbols (pictograms) agreed under GHS.
- Package the chemical safely.

CLP enacts GHS within the EU. It is a direct-acting Regulation (as opposed to a Directive) and therefore has direct effect in each EU member state. It does not have to be transposed into national legislation.

The **CLP Regulation** became law throughout the EU on 20 January 2009, although it included a transition period. This transition period expired on 1 June 2015 and from that point forward, all substances and mixtures (formerly called preparations) have to be classified according to **CLP.**

Harmonised Classifications

For many substances, the classification and labelling information required by the manufacturer/supplier already exists in the form of European harmonised classifications. These are available in **Part 3 of Annex VI of CLP**. Specifically, **Table 3.1 of Part 3 of Annex VI of CLP** contains the harmonised classification and labelling information under the **CLP** system (incorporating **GHS**).

So, for many chemicals, the classification has already been done and the manufacturer/supplier simply looks up the chemical in Table 3.1 and reads the data entry.

An example of an extract from Table 3.1 of Part 3 of Annex VI of CLP is given with an interpretation of the information below:

For the entry **hydrogen**:

- Index number – a code number relating to the atomic number of the chemical and its physical form.
- International Chemical Identification – the internationally recognised name of the chemical, plus common names where appropriate.
- EC No – the official identification number of the chemical within the EU.
- CAS No – the Chemical Abstracts Service number – an internationally recognised code number for the chemical that is not EU-specific.
- Hazard Class and Category Codes – the classification and category of hazard. In this case, hydrogen is a *Gas under pressure* (Press. Gas) and a Category 1 *Flammable gas* (Flam. Gas 1).
- Hazard statement Code – the code number relating to the specific hazard statement that describes the hazard associated with the chemical for the purposes of classification. In this case, H220 stands for "*Extremely Flammable gas*".
- Pictogram, Signal word Code – the hazard-warning symbol(s) that should be presented on the label, along with the signal word that should appear on the label. In the case of hydrogen, two symbols are required;

  GHS02 represents the *flame* symbol  and GHS04 represented the

  gas cylinder symbol  . The signal word code Dgr stands for Danger.
- Hazard statement Code – the code number relating to the specific hazard statement that should appear on the label. In this case, H220 stands for "*Extremely Flammable gas*". Note that this code appears in both the classification column and the labelling column.

Index No	International Chemical Identification	EC No	CAS No	Classification		Labelling			Specific Conc. Limits, M-factors	Notes
				Hazard Class and Category Code(s)	Hazard statement Code(s)	Pictogram, Signal Word Code(s)	Hazard statement Code(s)	Suppl. Hazard statement Code(s)		
001-001-00-9	hydrogen	215-605-7	1333-74-0	Flam. Gas 1 Press. Gas	H220	GHS02 GHS04 Dgr	H220			U
001-002-00-4	aluminium lithium hydride	240-877-9	16853-85-3	Water-react. 1	H260	GHS02 Dgr	H260			

Section taken from CLP Annex VI Table 3.1
(Source: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:353:0001:1355:EN:PDF)

Self-Classification

If a supplier wishes to classify a substance that is not contained in the table of harmonised classifications, or a mixture, then they will have to **self-classify** according to **CLP** guidance on classification, published by the EU. To do this, they will have to use appropriate test data to determine what the classification should be.

Much of the information required for self-classification is currently derived from animal testing. This is a tightly regulated and highly emotive area that will be discussed later in this element. One of the aims of **CLP** is to reduce the amount of animal testing carried out by encouraging the sharing of data within specific industry groups and creating large communal databases for use in both classification and labelling (such as an extended Table 3.1 of Part 3 of Annex VI of **CLP**).

Hazard Symbols and Hazard and Precautionary Statements

Under **CLP**, classification requires the identification of **hazard symbols and hazard and precautionary statements** that will appear on the label of the substance/mixture.

Hazard symbols are standard pictograms that conform to GHS and convey the principal hazards associated with the chemical/mixture in the simplest possible terms.

Hazard and precautionary statements are short standardised statements that communicate the principal hazards and the principal control measures in words. Hazard and precautionary statements are represented by H- and P-numbers respectively, for example:

H320 - *Causes eye irritation*

P271 - *Use only outdoors or in well-ventilated areas*

We will examine labelling, hazard-warning symbols and codes in more detail later in this element.

The Health Hazard Classes

In this section, we will consider the different health hazard classifications as used in Part 3 of GHS.

Acute Toxicity

Acute toxicity refers to those adverse effects occurring following oral or dermal administration of a single dose of a substance, or multiple doses given within 24 hours, or an inhalation exposure of 4 hours.

Under GHS, acute toxicity is assessed and assigned to one of five categories,with one being the most toxic and five being less toxic. Toxicity is determined by animal testing on the basis of potential oral, dermal and inhalation toxicity. So, for example, a substance assigned a Category 1 acute toxicity - oral will have an LD_{50} of 5mg/kg bodyweight or less (i.e. in animal tests, half of the test population of animals died as a result of ingesting 5mg for each kg of their bodyweight or less). Specific label elements are determined as a result of the assessment and are shown in the following table.

	Category 1	Category 2	Category 3	Category 4	Category 5
Symbol	Skull and crossbones	Skull and crossbones	Skull and crossbones	Exclamation mark	No symbol is used
Signal word	Danger	Danger	Danger	Warning	Warning
Hazard statement: Oral	Fatal if swallowed	Fatal if swallowed	Toxic if swallowed	Harmful in contact with skin	May be harmful in contact with skin
Dermal	Fatal in contact with skin	Fatal in contact with skin	Toxic in contact with skin	Harmful in contact with skin	May be harmful in contact with skin
Inhalation	Fatal if inhaled	Fatal if inhaled	Toxic if inhaled	Harmful if inhaled	May be harmful if inhaled

Table 3.1.3 – Acute Toxicity Label Elements
(Source: www2.unitar.org/cwm/publications/cbl/synergy/pdf/cat3/ghs/ghs_en.pdf)

The two symbols, '*skull and crossbones*' and '*exclamation mark*', referred to in the table are as displayed in the diagrams.

'Danger'

It should be noted, however, that whilst category four and five substances do not attract the familiar "skull and crossbones" associated with toxic materials, these are still considered toxic and should be handled and used with caution.

Skin Corrosion and Irritation

According to GHS, skin corrosion is the production of irreversible damage to the skin; namely, visible necrosis through the epidermis and into the dermis, following the application of a test substance for up to four hours.

'Warning'

Skin irritation is the production of reversible damage to the skin following the application of a test substance for up to 4 hours.

Corrosive substances often have a high or low pH, i.e. they are acids or alkalis. Under GHS, substances classified as corrosive will be assigned the following 'corrosion' symbol.

Corrosives are further categorised into three subcategories: 1A, 1B and 1C. Subcategory 1A corrosives cause irreversible skin damage apparent less than 1 hour after the application of the chemical to the skin for less than 3 minutes.

By contrast, GHS states that skin irritation is the production of reversible damage to the skin on contact. Often, one of the key determining factors in distinguishing between a corrosive substance and an irritant is concentration.

Many acids and alkalis are corrosive in their neat or concentrated form, but only irritant in their more dilute form. As dilution increases, so the irritant effect decreases.

Substances classified as irritant will be assigned the exclamation mark symbol.

DEFINITIONS

TOXIC

Produces serious, acute or chronic ill health or death at very small or small doses.

CORROSIVE

Destroys living tissue by direct chemical attack.

IRRITANT

Causes inflammation, in particular of the mucous membranes.

Serious Eye Damage and Eye Irritation

It is not only the skin that can be affected by corrosive or irritant substances – serious eye damage can occur on exposure to corrosive substances, often as liquid splashes or corrosive gases.

According to GHS, **serious eye damage** is the production of tissue damage in the eye, or serious physical decay of vision, following application of a test substance to the anterior (front) surface of the eye, which is not fully reversible within 21 days of application.

Eye irritation is the production of changes in the eye following the application of test substance to the anterior surface of the eye, which are fully reversible within 21 days of application.

Substances that cause irreversible eye damage are assigned the same corrosion hazard-warning symbol as for corrosives. Those that cause reversible eye damage are assigned the exclamation mark symbol as for irritants.

'Corrosive'

'Irritant'

Respiratory or Skin Sensitisation

According to GHS, a **respiratory sensitiser** is a substance that will induce hypersensitivity of the airways following inhalation of the substance.

A **skin sensitiser** is a substance that will induce an allergic response following skin contact.

Some chemical agents are able to produce an allergic reaction in certain individuals. Antibodies are produced which are capable of triggering an allergic reaction each time the person is subsequently exposed to very small quantities of the causative agent. Two body systems are prone to sensitisation by chemicals:

- **Skin** – the sensitising chemical passes through the epidermal barrier, causing antibodies to be formed. This produces the symptoms associated with sensitisation dermatitis (see later in this element). Once this happens, the skin reaction will occur whenever there is further contact with the sensitising agent.

  Under GHS, skin sensitisers will be assigned the exclamation mark symbol as used for skin and eye irritation.

DEFINITION

SENSITISING

Can cause an allergic response following either single acute overexposure or repeated chronic overexposures.

- **Respiratory system** – allergic sensitisation occurring in the respiratory system results in asthma. The mechanism of occupational asthma is an abnormal immunological response to foreign material which acts as an antigen (i.e. a foreign substance which causes the body to produce antibodies). The inhalation and absorption of the antigen causes the production of specific antibodies which trigger the release of histamine, causing bronchial constriction.

  Under GHS, respiratory sensitisers will be assigned the 'health hazard' symbol:

Germ Cell Mutagenicity

According to GHS, a **germ cell mutagen** is a chemical that may cause mutations in the germ cells of humans that can be transmitted to the progeny.

'Health hazard'

Mutagens cause changes (mutations) to DNA structure in the cells of a person. The damage to DNA caused by a mutagen may possibly go on to cause cancer. DNA mutation happens constantly in the cells of the body. Most mutations are benign and of no consequence since they occur in parts of the genetic code that are not used. Occasionally, a mutation may occur in an important area. This often leads to cell death (either directly, or as a result of cancer prevention mechanisms). Occasionally, however, mutations occur in cells that have harmful effects:

- In the ordinary body cells (somatic cells) this may cause cancer.
- In the germ line cells (eggs in the ovary of a woman, or the sperm- producing cells in the testes of a man) this can lead to heritable genetic defects being passed down to offspring – this is known as germ cell mutagenicity.

The GHS labelling varies according to the category of the gem cell mutagen:

- Category 1A substances are **known** to cause heritable genetic mutations from human evidence from historical exposures.
- Category 1B substances are **believed** to cause heritable genetic mutations from strong evidence from animal studies.
- Category 2 substances are where there is some concern that they **may** cause heritable genetic mutations from evidence from animal studies.

Under GHS, all germ cell mutagens will be assigned the health hazard symbol as used for respiratory sensitisers.

Carcinogenicity

According to GHS, a carcinogen is a substance or a mixture of substances which induce cancer or increase its incidence.

DEFINITION

CARCINOGENIC

Can induce the growth of malignant cancer tumours.

Simply put, carcinogens cause cancer. A carcinogen attacks the mechanism which controls reproduction of normal cells. It causes changes in a cell's DNA, resulting in 'abnormal' cells which divide uncontrollably (and so produce growth of 'abnormal' tissue). The cells grow, spread, invade and destroy the surrounding tissue. Carcinogens evoke irreversible effects which continue after exposure to the carcinogen has ceased. The action of ordinary toxic agents usually stops when the exposure ceases, and recovery generally follows.

The effects of a carcinogenic agent will not appear for many years after exposure; periods between 5 and 50 years are given for different agents.

During this time, there is little or no warning of the eventual outcome.

With carcinogens, there is no threshold of harm and any level of exposure has the potential to cause cancer. However, in practice the chances depend on a number of factors including potency, absorption, distribution and metabolism.

Under GHS there are three categories of carcinogen, depending upon the level of available evidence suggesting that cancer can arise from exposure. The labelling varies according to the category of the carcinogen:

- Category 1A carcinogens are **known** to cause cancer from human evidence from historical exposures.
- Category 1B carcinogens are **presumed** carcinogens due to the presence of strong animal evidence of cancer causing potential.
- Category 2 carcinogens are **suspected** carcinogens for which there is insufficient human or animal evidence to place them in category 1.

Under GHS, all carcinogens will be assigned the health hazard symbol as for respiratory sensitisers and germ cell mutagens.

Reproductive Toxicity

According to GHS, reproductive toxins result in either:

- Adverse effects on sexual function and fertility in adult males or females.
- Developmental toxicity in unborn or breastfeeding children.

DEFINITION

TOXIC TO REPRODUCTION

Can cause sterility, miscarriage or birth defects.

Many organic lead compounds have been linked to increased levels of sterility, miscarriage and birth defects. Birth defects occur as a result of the chemical interfering with critical stages in the development of the child as it grows in the womb. Importantly, this is not due to mutation, as the child is genetically "normal". The drug Thalidomide is another example of a reproductive toxin (though not a workplace example).

GHS classifies reproductive toxins which damage fertility or the unborn child into three categories, 1A, 1B and 2, along similar lines as those used for germ cell mutagens and carcinogens. All three categories will be assigned the health hazard symbol under GHS, as used for germ cell mutagens and carcinogens.

(Note that no symbol is assigned to a substance which may cause harm to breastfed children (although there should be a hazard statement to this effect on the container and data sheet).)

Specific Target Organ Toxicity – Single and Repeated Exposure

According to GHS:

- **Specific target organ toxicity (single exposure)** is defined as specific, non-lethal target organ toxicity arising from a single exposure to a substance or mixture. All significant health effects that can impair function, both reversible and irreversible, immediate and/or delayed and not specifically addressed by other classifications, are included.
- **Target organ toxicity (repeated exposure)** means specific, target organ toxicity arising from a repeated exposure to a substance or mixture. All significant health effects that can impair function, both reversible and irreversible, immediate and/or delayed and not specifically addressed by other classifications are included.

MORE...

Additional information isavailable from the HSE at:

www.hse.gov.uk/chemicalclassification/index.htm

www.hse.gov.uk/chemical-classification/legal/index.htm

CLP and GHS are explained inmore detail at:

http://echa.europa.eu/home_en.asp

Some substances have toxic effects on target organs and systems. This can be as a result of a single exposure or multiple exposures over a lifetime. Human and animal evidence may indicate the potential for a substance to be toxic to a particular target organ or system.

One common example (though not a workplace one) is alcohol. Alcohol is an organic chemical which in some cultures is consumed as a drink for recreational purposes. The short-term (acute) effects depend on the concentration and quantity consumed, but usually include intoxication. This intoxication arises from a single exposure and affects the brain and nervous system (the target system). In extreme cases, a single large dose can prove fatal, although usually the body removes the toxins via the liver. Repeated exposure can result in damage such as cirrhosis of the liver (another target organ) and is also linked to some cancers.

Occupational exposure to some substances can result in a similar pattern of effects, e.g. inhalation of solvent vapours may intoxicate (targeting the brain and central nervous system) or may prove fatal. The liver may also be affected on repeated exposure.

Under GHS, substances which are target organ toxins (through single exposure or repeated exposure) are classified into categories 1 or 2 and will be assigned the *health hazard* symbol.

Aspiration Hazard

As we have already covered, some chemicals are harmful by aspiration (inhalation of a liquid directly into the lungs). Such chemicals can have very serious or even fatal consequences if aspirated.

Under GHS, this classification does not exist. However, it does exist in the EU regime under **CLP**. Under this regime, aspiration hazards will be assigned the health hazard symbol.

Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

The EU **Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)** Regulation puts duties on manufacturers and suppliers. The principal requirements are:

- Most substances manufactured or imported into the EU in quantities above one tonne per year per manufacturer must be registered with the European Chemicals Agency (ECHA).
- For most substances (termed 'phase-in substances'), provided you 'pre-registered' them, there is a long transition period for full registration, during which time you can still manufacture or import them.
- For other substances, and for those that were not pre-registered, there is no such transition period; they must be registered immediately or you cannot manufacture them or import them.
- The registration process involves submitting a dossier of information on that substance. Putting together the dossier can be a significant task but can be broken down into four stages:
    1. Gather together any existing available and relevant information on the substance.
    2. Identify what actual information is required to be submitted (the extent of information required depends on tonnages but some requirements can be waived, depending on the circumstances).
    3. Identify any information gaps; that is the difference between the information that is required to be submitted compared to the existing information that is available.
    4. Generate new information or propose further testing for filling those gaps.

One of the stated aims of the evaluation process is to eliminate unnecessary animal testing by manufacturers: proposals for further testing on animals are seen as a last resort. Article 13 of **REACH** requires that human toxicological information shall be generated wherever possible by means other than vertebrate animal testing:

- To minimise duplication, there is supposed to be data sharing between registrants.
- In simple terms, the ECHA then evaluates the data submitted by everyone on each substance and looks at its adequacy.
- In certain circumstances, the ECHA may direct the registrants to undertake the proposed further testing (including animal testing) on the substance because insufficient data is available to properly and reliably characterise its hazardous nature.
- For Substances of Very High Concern (SVHCs), **REACH** may impose a requirement for manufacturers/suppliers to gain specific authorisation prior to use of the substance. SVHCs are carcinogens, mutagens and reproductive toxins, or substances that are toxic, persistent and bio-accumulative.

- Certain substances deemed to present a very high risk may be restricted by **REACH**.
- Manufacturers/suppliers must provide to customers a Safety Data Sheet (SDS) derived from this information.

Specific Hazardous Substance Examples

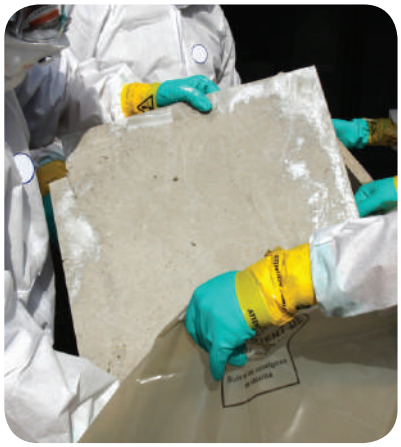
Asbestos

Asbestos is a widely-used natural mineral that, although now widely banned, is still evident in many workplaces. Typically used as an insulation and fire-resistant material, it is also a common friction lining in machinery (brakes, clutch plates, etc.).

Asbestos is associated with the development of asbestosis, lung cancer and mesothelioma:

- **Asbestosis** – a collagenous pneumoconiosis, induced when the fibres are inhaled into the lung alveoli and then migrate into the surrounding tissues. The fibrotic reactions caused by asbestosis lead to a progressive development of inelastic scar tissue and thickening of the pleural membranes.

  The main symptoms of asbestosis are breathlessness, coughing, pain between the shoulder blades or behind the sternum (breast bone).



Asbestos can still be found in many workplaces

In the later stages of the disease, lung function is markedly reduced and, with complementary heart strain, death may ensue:

- **Lung cancer** – a cancer of the lung tissue. The risk to a person working with asbestos of contracting lung cancer has been shown to be ten times that of the general population. The combined effect of smoking tobacco and working with asbestos is another well-documented factor in the development of lung cancer. In this case, the risk to the asbestos worker who smokes compared with the non-smoking general public is 90 to 1.
- **Mesothelioma** – a cancer of the plural membranes surrounding the lungs. It appears that asbestos fibres are able to migrate through lung tissue following inhalation and can have a toxic effect in adjacent tissues.
- **Diffuse pleural thickening** – thickening of the lining tissue of the lung (sometimes known as 'pleural plaques') that causes breathing difficulties.

People at risk from asbestos include those working with lagging and heat insulation materials; construction and demolition; and vehicle repair (clutch and brake assemblies).

Carbon Monoxide (CO)

A colourless, odourless gas usually encountered as a by-product of partial combustion (e.g. poorly maintained heating boiler). It is hazardous by inhalation.

During normal respiration, oxygen from the atmosphere is absorbed by the red blood cells in the blood and chemically bound to haemoglobin (a protein) so that it can be carried around the circulatory system to body tissues. Carbon monoxide interferes with this oxygen-carrying process by binding onto the haemoglobin molecule at the same place where the oxygen should be (forming a compound called carboxy-haemoglobin). This prevents oxygen transportation and can lead to death by **asphyxiation**.

Low levels of CO (0.005%) will cause a progressively worsening headache. Levels of 1.3% will cause immediate unconsciousness and death within three minutes. Note that this can occur even though oxygen concentrations are normal at 21%.

Isocyanates

Isocyanates are organic solvents used in paint-spraying (commonly referred to as two-pack paints) and foam rubber manufacture. Several different types exist:

- Hexamethylene Di-Isocyanate (HDI).
- Toluene Di-Isocyanate (TDI).
- Methane Diphenyl Isocyanate (MDI).

  Both HDI and TDI act as irritants and allergens.

- Irritant effects include inflammation of the mucous membrane of the nose and throat and bronchitis. In most cases, the symptoms and signs clear rapidly after the worker is removed from contact with the isocyanate.
- Sensitisation can occur, leading to violent recurrent symptoms, after further contact with even very low concentrations of isocyanate. Others are known to suffer from a chronic form of asthma.

All isocyanates have a very low workplace exposure limit. Asthma caused by di-isocyanates is now a recognised occupational disease qualifying for compensation.

Lead

Lead metal in its massive solid state has virtually no ability to be absorbed into the body by any of the three normal modes of entry, i.e. inhalation, ingestion or skin absorption. But, as a fume or very finely divided dust, lead inhalation becomes a serious risk as a potential mode of entry.

Lead compounds can be categorised into inorganic lead, e.g. lead oxide in lead/acid batteries, lead chromate (chrome yellow), red lead used for pigments, and organic lead, e.g. petrol anti-knock agent, lead tetraethyl:

- For inorganic lead compounds, inhalation of dusts generally poses the most serious situation. Absorption by skin contact and ingestion is limited.
- For organic lead compounds, inhalation and skin contact form the main occupational mode of entry for absorption into the body. Ingestion poses only a minor risk.

The target organs associated with lead intoxication are the central nervous system, the gastrointestinal tract, blood and blood-forming organs, exterior (straightening) muscles of the wrist or foot and the gums. Lead becomes incorporated in bone structure where it accumulates, giving it a site where it can become a cumulative toxin.

Intoxication by inorganic lead compounds leads to general symptoms related to the gastrointestinal tract, the nervous system and the blood:

- Acute intoxication, resulting in general from inhalation of high concentrations of lead fume or dust, produces nausea, vomiting and headaches. This is often followed by constipation and severe intermittent colic. If the brain becomes affected, then dullness, restlessness, tremor, convulsion or coma may develop.
- When exposure has occurred over long periods and chronic intoxication takes place, other clinical symptoms develop. The classic symptoms are headaches, anaemia, palsy and the appearance of a blue line on the gums.

Organic lead (tetraethyl lead) can have fatal consequences:

- Its absorption into the body mainly affects the central nervous system, producing restlessness, a raised level of excitement and talkativeness, muscular twitching and possible delusions, acute and violent mania.
- Fall in body temperature and a drop in normal blood pressure.
- At lower levels of intoxication, headaches, vertigo, fatigue, a sense of physical weakness, and insomnia with disturbing dreams are classic symptoms.

There is a risk of exposure to lead associated with lead smelting, lead chemical manufacture, lead/acid battery manufacture, petrol manufacture, plumbing, painting, welding.

Metal Working Fluid

Exposure to metalworking fluids can cause:

- Skin irritation or dermatitis - around 200 cases of contact dermatitis related to exposure to cutting oils and coolants are reported annually.
- Respiratory conditions - such as occupational asthma, bronchitis, irritation of the upper respiratory tract and rarely, a more serious lung disease called Extrinsic Allergic Alveolitis (EAA). Annually, at least 20 cases of occupational asthma are associated with exposure to metalworking fluids and it is thought many more cases go unrecognised. Under suitable conditions, bacteria and fungi can grow well in metalworking fluids. Inhalation of these bacteria, fungi or toxic by-products can cause irritation of the respiratory tract or flu-like symptoms, as well as making existing asthma symptoms worse.
- Cancer - in the past, the use of unrefined mineral oils led to skin cancer affecting the exposed skin, often hands and forearms. The current-day use of highly refined oils and the substitution of cancer-causing chemicals in metalworking fluids, as well as changes in work practices and improved personal hygiene, have reduced the risk of cancer.

Used Engine Oil

Potential exposure to used engine oil is a significant risk associated with motor vehicle repair. Frequent and prolonged contact may cause dermatitis and other skin disorders, including skin cancer.

Key controls that should be adopted by employers include:

- Development of safe systems of work and the use of protective clothing, such as nitrile gloves.
- Maintaining high standards of personal hygiene and cleanliness.
- Ensuring the employees do not re-use contaminated overall or keep oily rags in pockets (as the oil will seep through and affect the skin below).
- Maintain high standards of personal hygiene and cleanliness.
- The use 'barrier creams' and 'after-work' replenishing creams to replace skin oils.
- Health surveillance in the form of skin inspection or self-inspection to check for sings of dermatitis.

Silica

A component of rock commonly encountered in the mining, quarrying, pottery and construction industries, silica is hazardous by inhalation. When inhaled, respirable crystalline silica dust is deposited deep in the lungs. Over time, it causes scar tissue to form (known as silicosis – very similar to asbestosis). This progressive disease leads to breathlessness and chest pain and can prove extremely debilitating.

Inhalation of respirable crystalline silica can also lead to **Chronic Obstructive Pulmonary Disease (COPD)**, a group of lung diseases including bronchitis and emphysema. **COPD** results in severe breathlessness, prolonged coughing and chronic disability. It can be very disabling and is a leading cause of death. Around 4000 deaths are estimated annually due to **COPD** resulting from past workplace exposures.

MORE...

www.

Further information and guidance on silica dust is contained in the HSE publication INDG463 *Control of exposure to silica dust: A guide for employees*, which is available from the HSE website at:

www.hse.gov.uk/pubns/indg463.pdf

Wood Dust

Wood dust is hazardous on inhalation and causes **asthma**. Certain types of wood dust are more likely to cause asthma than others and are therefore categorised as asthmagens. Hardwood dusts can cause cancer (usually of the nose).

Again, certain types of hardwood are more strongly associated with risk of cancer and are therefore recognised as carcinogens. Workers in the woodworking industry, such as carpenters and joiners, are most at risk of exposure to wood dust, as well as those working in forestry.

International Reviews of Health Effects

As we have already seen, there is a number of different classification systems for chemicals operating worldwide. There is also a range of different systems operating in order to assess the risk posed by exposure to the chemicals. Efforts have been made to form a standardised system. One example is the production of Concise International Chemical Assessment Documents (CICADs), which are published by the International Programme on Chemical Safety (IPCS). IPCS is a joint venture between the World Health Organisation (WHO), the ILO and the United Nations Environment Programme (UNEP).

CICADs are summary documents that detail the relevant scientific information from selected national or regional chemical evaluation documents. They are thoroughly reviewed before publication to ensure accuracy. The summaries focus on the hazards and dose response arising from exposure to a specific chemical. Because scientific knowledge is constantly changing, CICADs should be considered 'up to date' at the date shown in their executive summary section.

STUDY QUESTIONS

7. What are the three basic physical states in which a chemical may be found?
8. For each of the three states, give an example of the forms in which a chemical may appear.
9. What is the difference between the inhalable and respirable fractions of an airborne dust?
10. What is the UN GHS?
11. What do we mean by the term 'toxic'?
12. How is carbon monoxide (CO) hazardous to health?

(Suggested Answers are at the end.)

Assessment and Evaluation of Risk from Hazardous Substances

IN THIS SECTION...

- Suppliers and manufacturers of chemicals have to classify, label and package chemicals according to CLP to implement the Globally Harmonised System (GHS).
- Labelling requires the application of suitable phrases and symbols.
- Safety data sheets, a legal requirement under ILO Recommendation R177 and REACH, contain 16 categories of information to allow the end user to undertake their exposure assessment.
- Several factors must be considered during this assessment:
  - Hazardous properties of the substances.
  - Type and level of exposure.
  - Duration and frequency of exposure.
  - Number of people exposed.
  - Effect of mixtures.
  - Unusual activities and emergencies.
  - Relevant Occupational Exposure Limits (OELs).
  - Effectiveness of existing controls.
  - Results of air monitoring and health surveillance.
  - Individual susceptibility.
- The assessment should be reviewed when:
  - There is reason to suspect that it is no longer valid.
- There has been a significant change in the work.

Labelling and Safety Data Sheets

As has been described earlier, legislation puts a duty on manufacturers and suppliers to:

- Classify dangerous chemicals (both substances and mixtures) using the new scientific criteria agreed under GHS according to three different criteria:
  - physicochemical properties (e.g. explosive);
  - health effects (e.g. acute toxicity); and
  - environmental effects (e.g. toxic to the aquatic environment).
- Provide information to the end user in the form of a label that will make use of new hazard-warning symbols (pictograms) agreed under GHS.
- Package the chemical safely.

CLP requires labelling to inform end users of hazards

The GHS/CLP Health Hazard Symbols

In Europe, **CLP** requires the use of standard hazard symbols on labels to aid in the communication of the hazard type. These symbols conform to GHS.

Used for substances that are **fatal** or **toxic** when inhaled, ingested or on skin contact.

Used for substances that are **harmful** (when inhaled, ingested or on skin contact), **irritant** (when inhaled or on contact with skin or eyes) or **sensitising** on skin contact.

Used for substances that are **corrosive** (to skin or eyes).

Used for substances that are **carcinogenic** (category 1A, 1B and 2), **mutagenic** (category 1A, 1B and 2), **toxic to reproduction** (category 1A, 1B and 2), **sensitising** (respiratory system), capable of **causing organ damage** (single and repeat exposures), or **represent an aspiration hazard**.

Hazard and Precautionary Statements

The regulation also requires the identification of **hazard and precautionary statements** that will appear on the label of the substance/mixture. Hazard and precautionary statements are represented by H- and P-numbers respectively, for example:

H301 - **Toxic if swallowed**.

H320 - **Causes eye irritation.**

P102 - **Keep out of reach of children**.

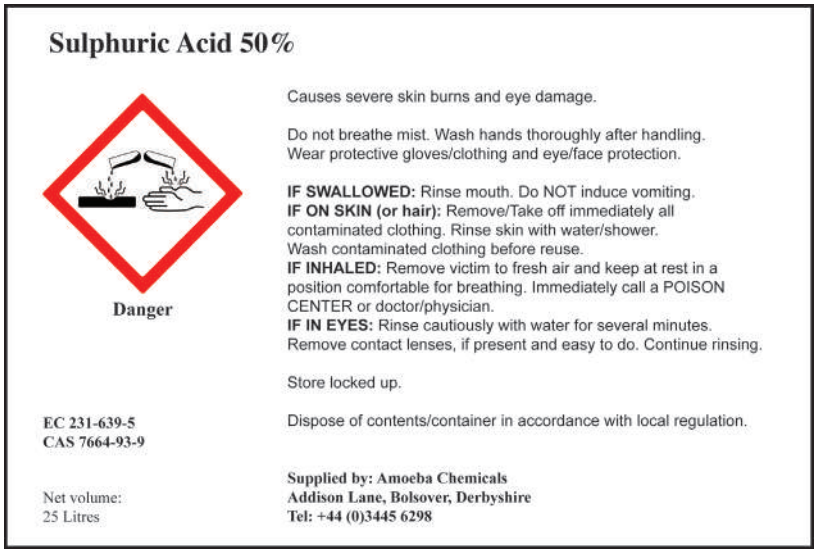
P271 - **Use only outdoors or in well-ventilated areas.**

CLP Label Elements

CLP labels must generally contain: name, address and telephone number of the supplier; nominal quantity (when made available to the general public); product identifiers (e.g. name and CAS number); hazard pictograms; signal words (e.g. 'danger' or 'warning'); hazard statements and any applicable precautionary statements (covering prevention, response, storage and disposal) and supplemental information.

Example Chemical Label

Below is an example of a label for sulphuric acid. (NB this is purely illustrative,to show the sort of information displayed.)



CLP labelling for dangerous chemicals

Safety Data Sheets (SDSs)

ILO Recommendation R177 identifies the contents of safety data sheets: "The criteria for the preparation of chemical safety data sheets for hazardous chemicals should ensure that they contain essential information...". In Europe, this is enacted through Article 31 of the **Registration, Evaluation, Authorisation and Restriction of Chemicals Regulation (REACH)**, which requires suppliers of substances and mixtures classified as dangerous for supply to provide safety data sheets (SDS, or Material Safety Data Sheets (MSDS) as they are sometimes known).

Safety data sheets must also be provided upon request in certain other cases, too.

Safety data sheets must contain information under 16 mandatory headings:

1. Identification of the substance/mixture and of the company/undertaking.
2. Hazards identification.
3. Composition/information on ingredients.
4. First-aid measures.
5. Fire-fighting measures.
6. Accidental release measures.
7. Handling and storage.
8. Exposure controls/personal protection.
9. Physical and chemical properties.
10. Stability and reactivity.
11. Toxicological information.
12. Ecological information.
13. Disposal considerations.
14. Transport information.
15. Regulatory information.
16. Other information.

For ease of recall, these sections can be summarised as:

- Supplier details (s1).
- Components and overall hazards (s2, 3).

- What to do if things go wrong:
  - First-aid measures (s4).
  - Fire-fighting measures (s5).
  - Accidental release measures (s6).
- How to stop things going wrong (s7, 8).
- Basic properties, i.e. physical, chemical, toxicological, etc. (s9, 10, 11, 12).
- How to dispose of it (s13).
- How to transport it (s14).
- Label and regulatory information (s15).
- Anything else (s16).

The safety data sheet thus provides important information relevant to the ill effects of hazardous substances, such as exposure controls, toxicological information, first aid, chemical properties and any personal protective equipment necessary. It is recommended that you obtain a copy of a safety data sheet (EU compliant) from an EU supplier/manufacturer, so that you will have a much better idea of the sort of information that is included. Suitable examples can readily be found for download from the websites of many chemical manufacturers.

Safety data sheets must be supplied (in paper or electronic form) free of charge when the substance is first provided. They must be kept up to date and revised and reissued accordingly.

In certain circumstances, **relevant exposure scenarios** must also be supplied as an appendix to the safety data sheet. As the name suggests, these are specific manufacturing/use scenarios (where exposure to the substance is likely) together with their respective control recommendations. They are produced (usually by the manufacturer/importer of the chemical substance) as part of the Chemical Safety Assessment (documented as a Chemical Safety Report) required by **REACH**.

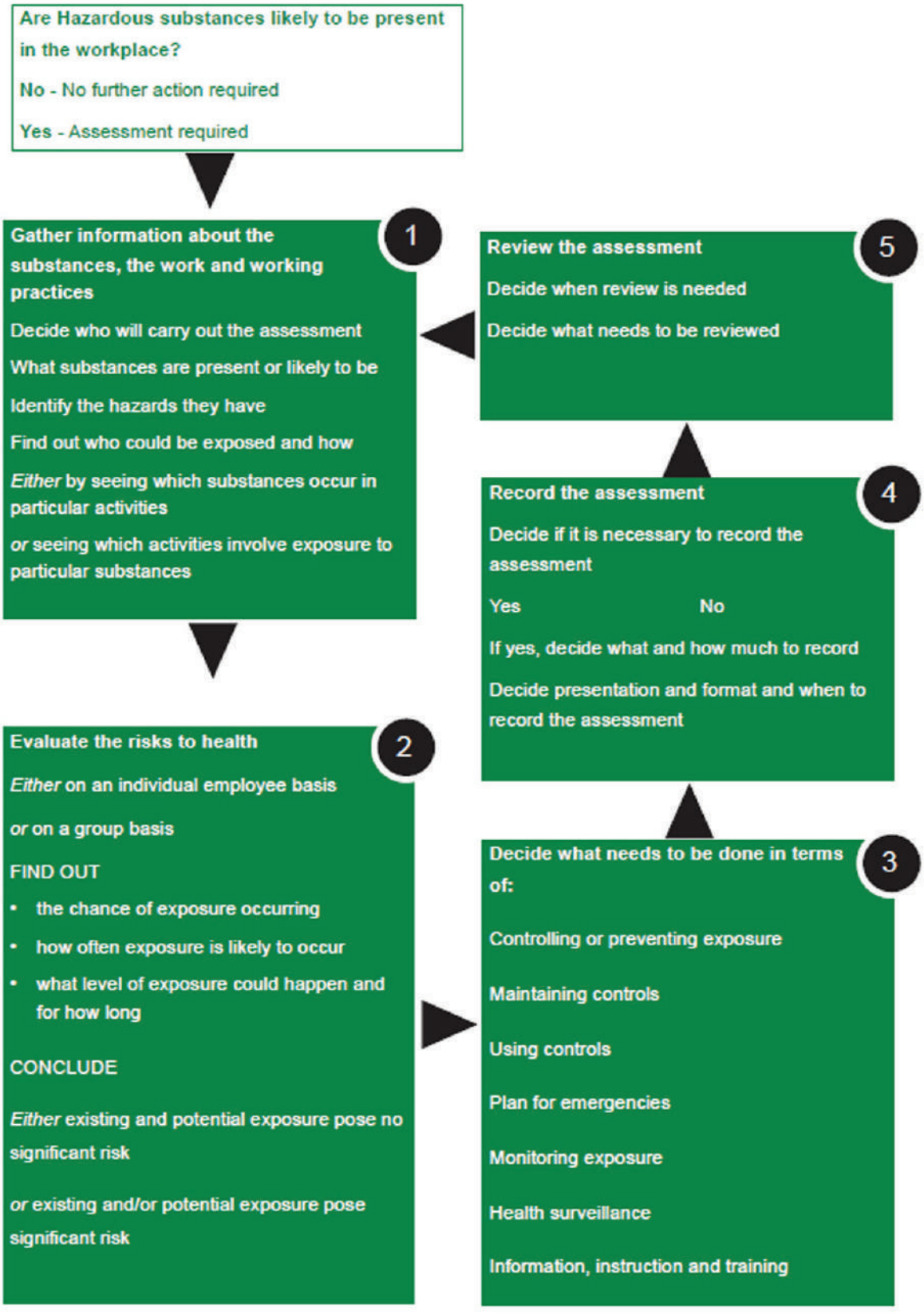
Factors to Consider when Assessing Health Risk

An employer has to carry out a suitable and sufficient risk assessment where work is liable to expose employees to substances hazardous to health. This risk assessment must be carried out before the work is undertaken and should allow the employer to identify the control measures necessary to comply with **relevant legal standards and good practice**. Those control measures must be implemented.

The assessment can be considered as a five-step process:

1. Gather information about the substances, the work and the working practices.
2. Evaluate the risks to health.
3. Decide on the control measures needed to comply with **legal standards**.
4. Record the assessment.
5. Review and update as necessary.

To be considered 'suitable and sufficient', the risk assessment must consider a range of factors that will be outlined later in this section.



A flow diagram summarising the Five-Step Approach to COSHH Assessment, adapted from HSG97 A step by step guide to COSHH assessment, HSE, 2004 (www.hse.gov.uk/pubns/priced/hsg97.pdf)

The risk assessment should be **recorded** and **reviewed** as necessary:

- When there is reason to suspect it is no longer valid.
- When there is a significant change.
- When the result of monitoring shows it is necessary.

We will now consider some of the factors that must be considered when carrying out a chemical exposure assessment, in particular during the first two steps of the process.

Hazardous Properties of the Substance

The first step in the assessment process is to gather information about the hazardous substances that are present. This must include not only substances that are brought into the workplace, but also those that are created during work activities (such as fumes from welding) or as a waste product.

Information about each hazardous substance can then be gathered from various sources, such as:

- Labels.
- Safety Data Sheets (SDS).
- Legislation, semi-legal codes and guidance (such as EH40 in UK).
- Direct from the manufacturer/supplier.
- Chemical information databases.

These information sources can then be used to identify the hazard classification of the substance (e.g. whether it is toxic or carcinogenic), the routes of entry that the substance may take and the subsequent health effects, relevant Occupational Exposure Limits (OELs) for the substances or its components, its volatility and other physical properties, etc.

Type and Level of Exposure

Gathering information about the substance and its hazardous properties is only one part of Step 1 of the assessment. Information about how the substance is actually used, stored, handled and disposed of is also vital.

One critical factor to consider is the type of exposure that might occur. This will be determined by the **physical forms** of the substance that might be present or created, and the various **routes of entry** that might then apply.

The **nature of the work activity** will play an important part here.

For example, if a raw material is in powder form then inhalation is a possible route of entry. If in liquid form then inhalation is unlikely, unless the liquid is:

- Volatile, in which case vapour will be generated at ambient temperatures.
- Heated during work activity, in which case vapour will be generated.
- Sprayed or otherwise atomised to produce an aerosol.

For the liquid form, other routes of entry might be of greater concern, such as skin contact followed by absorption or ingestion.

In some instances, the **level of actual exposure** will need to be known or estimated. This is particularly important when the substance is airborne and inhalation is of concern, since there may be an OEL relevant to the substance (see Element IB4).

The level of exposure can sometimes be estimated using knowledge of the volatility of the substance, the temperature at which it is used (or even the dustiness of a powder) and the time taken to carry out the work.

In other instances, the level of exposure will have to be measured directly using monitoring equipment. In these circumstances, other control measures will have to be taken to allow the work activity to proceed so that measurements can be taken. For example, a powder-handling process might be carried out using PPE as a control until such time as the actual level of dust exposure can be ascertained by direct measurement. The PPE might then be removed if measurements confirm that exposure levels are acceptable.

Duration and Frequency of Exposure

The duration of exposure can be a critical factor in determining the dose of substance that enters the body. This is particularly the case when the substance is airborne and inhalation is a significant route of entry. Duration of exposure can also be of concern when handling substances that can permeate the skin (for the same reason), and even when handling wet chemicals with gloves on (since some chemicals may permeate through the glove material and the gloves will have a breakthrough time; see Element IB3).

Frequency of exposure is important for several reasons:

- It can have a direct effect on dose received. For example, a 5-minute work activity that creates a vapour cloud that might then be inhaled but that is carried out once a day gives a far lower daily exposure than the same work activity repeated once every 30 minutes.
- It can influence the selection of an appropriate control method.
- For example, an exposure that occurs once a year during routine maintenance might be controlled using PPE, whereas the same exposure occurring every day would have to be controlled by other more effective means.
- Some substances are more likely to have a harmful effect following frequent exposures. For example, dermatitis is more likely following repeated exposure to wet cement.

Numbers of People

The number of people likely to be affected by the substance, either directly or indirectly, must be taken into account. This should include workers directly involved with the activity and those who might be incidentally exposed. The employer owes a duty not only to his employees, but also to employees from other organisations (e.g. contractors) and others such as visitors and members of the public.

Think about how mixing chemicals can affect health

Effect of Mixtures

If exposure is to a mixture of chemicals, how will this affect the health risk?

For example, if a work activity involves exposure to chemical A (toxic) and chemical B (irritant), how will either of these chemicals affect the hazard properties of the other, should exposure occur simultaneously?

- One compound may decrease the toxicity of another (e.g. an antidote to a poison).
- One compound may simply add to the toxicity of another (additive effect).
- One compound may enhance the toxicity of the other so that the resultant toxicity is greater than the sum of the individual toxicities (potentiation or synergy).

Note that this is very different to asking what new hazardous substance might be made if the two chemicals are mixed together and then react to form a product (e.g. acid + bleach = chlorine gas).

Unusual Activities

The assessment must take into account any unusual activities that are known to occur or that are reasonably foreseeable. This includes cleaning and maintenance work and emergencies, such as power cuts and spillages.

Note that the employer should make suitable arrangements to deal with accidents, incidents and emergencies. The arrangements required should be identified during the assessment.

Occupational Exposure Limits (OELs)

Where there is potential for exposure to a substance that has a OEL, it will be necessary to identify that limit (from the relevant legislation and guidance) so that the actual exposures that might occur in the work activity can be compared to it. This topic is dealt with in more detail in Element IB4.

Existing Controls

The assessment, like other forms of risk assessment, must reflect the real situation as it exists in the workplace. Therefore, any control measures that are already in place should be taken into account when assessing exposure.

For example, when assessing potential exposure to a hazardous powder during a weighing activity, the fact that the work is being carried out in a partial enclosure with Local Exhaust Ventilation (LEV) attached should be taken into account as this control method alone may provide adequate protection.

However, when any existing control measures are considered in the assessment, their **actual effectiveness** must be taken into account.

Particular attention must be paid to the likelihood and consequences of the failure of any existing control measures. For example, the mechanical failure of an enclosure with an LEV system attached may be a rare event (provided the system has been subject to routine planned preventive maintenance) but it could have significant consequences for those working near the enclosure. Similarly, PPE is often used as the principal control measure, but PPE is not always worn or used correctly and, if it fails, it fails to danger

Surveillance and Monitoring Results

Where there is potential for exposure to certain types of hazardous substance (e.g. flour dust or lead), the employer may be required to conduct health surveillance of exposed employees. For example, workers exposed to flour dust (a respiratory sensitiser) might undergo a periodic medical, including a lung function test to assess whether they are developing symptoms of asthma as a result of their exposure. (This topic is dealt with in more detail in the next section of this element.)

In a similar way, where there is potential for exposure to certain types of hazardous substance (e.g. carbon monoxide), the employer may be required to conduct monitoring of airborne concentrations. For example, the personal exposure of welders to welding fume might be monitored to compare actual exposures to statutory limits. (This topic is dealt with in more detail in element IB4.)

Where health surveillance and monitoring are being carried out in a workplace, the results can be useful:

- When assessing the potential for exposure to new hazardous substances (on the basis that results may indicate that current preventive or protective measures for existing substances are good or poor).
- When reviewing existing assessments.

Individual Susceptibilities

It is not only the particular properties of the chemical agent in question that determine the risk to the worker; an equally important consideration is the individual susceptibility of the worker. Various examples of this occur:

- **Atopic individuals** - some people are hypersensitive to allergens and may be more prone to asthma attacks, hay fever or eczema. This can be useful for screening out individuals from work where they might encounter sensitising substances that they are likely to be very sensitive to.

MORE...

The ILO guide on controlling chemicals can be accessed here:

www.ilo.org/wcmsp5/groups/public/@ed_protect/@protrav/@safework/documents/normativeinstrument/wcms_107823.pdf

- **Women of child-bearing capacity** - certain hazardous substances (e.g. lead and mercury) have specific effects on the unborn child. These substances will be identified with hazard statements such as:
  - **H360** – May damage fertility or the unborn child.

    In these circumstances, appropriate controls must be established by the risk assessment to ensure that harmful exposure does not occur. This may mean that a higher level of protection is afforded these individuals, or that they are excluded from undertaking work with a risk of high exposure.
- **Age** - younger workers are vulnerable to chemicals that affect the reproductive system (e.g. insecticides/ pesticides) and so may have to be given a higher level of protection or excluded from certain activities.
- **Sensitisation** - this occurs when the immune system has been exposed to an allergen (something that will produce an allergic response), remembers it and launches its defence mechanisms when the allergen re-appears. Common occupational sensitisations are:
  - Respiratory sensitisation, where occupational asthma can be caused by repeated exposure to an asthmagen (e.g. flour dust).
  - Skin sensitisation, where secondary or allergic dermatitis occurs as a result of repeat exposures to a skin sensitiser (e.g. gluteraldehyde).

Sensitisation can occur in any individual irrespective of health, age or atopy.

For example, a common sensitisation is allergic dermatitis in construction workers due to exposure to cement.

Where an individual is known to be sensitised to a substance, they must be protected from further exposures as this may trigger a sensitisation reaction and make the condition worse.

Review of the Assessment

The assessment should be reviewed whenever there is reason to suspect that it is no longer valid or where there has been a significant change in the work to which the assessment relates.

Examples include:

- After an incident, such as fire or spillage.
- After the results of monitoring.
- As a result of health surveillance.
- When new information on risks is available.
- After a significant change in the workplace or work method.

STUDY QUESTIONS

13. What is the purpose of Risk/Safety Phrases and Hazard/Precautionary Statements and where can they be found?
14. Identify the information that must be included on a safety data sheet.
15. What factors should be considered when assessing risks to health?
16. What specific personal factors affect the hazard/risk to individuals from chemical agents?

(Suggested Answers are at the end.)

The Role of Epidemiology and Toxicological Testing

IN THIS SECTION...

- Epidemiology and toxicology are two branches of medical science that have allowed the recognition and classification of chemical health hazards to occur.
- Epidemiological studies look at the prevalence and spread of disease in populations. Many epidemiological studies follow cohorts of people over periods of time. Three such types of study are the case-control study, the prospective cohort study and the retrospective cohort study.
- Animal testing of chemicals often involves acute toxicity testing (such as the fixed dose procedure used for classification). These studies have their limitations.
- Alternatives to animal testing include in vitro testing using bacteria, such as the Ames test for mutagenicity, and predictive modelling, such as QSAR and grouping and read-across methods.
- One of the key tools of toxicology is the dose/response curve that demonstrates the relationship between the dose of chemical administered and the ill-health response that occurs.
- Dose/response curves can be used to derive three important characteristics of a chemical; LD_{50}, LC_{50} and the NOAEL.

Use of Epidemiology and Toxicological Testing in Classification

The classification of chemicals into their various categories of hazard is based largely on the scientific study of their toxic effects. This information is based on hard scientific data gathered in research facilities around the world. Much of this information has been gathered by animal testing, some using other investigative techniques that will be outlined later.

Epidemiological studies have, on occasion, revealed a link between a particular chemical and ill health in humans. Classic examples of this are asbestos and lead in petrol. Increases in the prevalence of ill health, first noticed by health professionals, triggered toxicological investigation that confirmed epidemiological result; there was a causal link between exposure and disease. Legislation ensued.

This approach to the classification of chemicals has been successful in identifying and quantifying the nature of thousands of substances over time.

DEFINITIONS

EPIDEMIOLOGY

The study of the patterns of ill health in populations.

TOXICOLOGY

The study of the adverse effects of chemicals on living organisms and the symptoms, mechanisms, detection and treatment of those effects.

In this way, toxicology and epidemiology complement one another as approaches to studying the ill-health effects of exposure to chemicals and substances. Whilst toxicology data is the principal tool used in the classification of chemicals, epidemiology still has a role to play in identifying overlooked links between exposure and ill health.

Human Epidemiology

Epidemiology is concerned with the distribution of a particular occupational disease and the search to identify the various factors that may be involved. A number of different types of study are available. We will consider three of the main studies that are conducted over a period of time (referred to as longitudinal studies).

CASE STUDY

An Early Example of Epidemiology

In the summer of 1854, cholera broke out in London, UK, being particularly severe in the slums around Soho. Dr John Snow used the opportunity to carry out the first true epidemiological investigation into the spread of a disease. Cholera victims suffer from severe diarrhoea and vomiting, with death typically occurring after a few days and very high mortality rates.

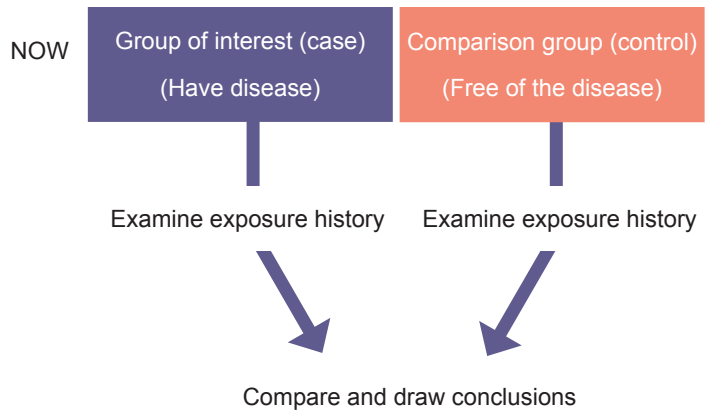
During the course of the epidemic, Snow plotted the household of every death in the area around Soho. By plotting the incidence of deaths onto a map he was able to demonstrate that the nodal point was the Broad Street pump. This led to his conclusion that the water from this pump was responsible for the cholera outbreak.

Snow persisted in his theory, despite opposition from many eminent scientists of the time who believed that miasmatic gases rising from the foul smelling open sewers and the Thames were responsible for the deaths. He was eventually successful in having the Broad Street Pump disabled, whereupon the local outbreak stopped.

The Case-Control Study

This type of study is retrospective, beginning with a definition of a group of cases (people with the disease) and relating these (along with controls – people without the disease) to the past exposure history. The main drawback of this type of study is obtaining accurate exposure history, which may need to go back as far as 40 years.

With the case-control study, the investigation compares a group of individuals who have the disease or condition with another group who does not. The comparison is made with respect to past characteristics of both groups and, of course, the outcome is known.



Case-control study

The case-control method may be used, for example, to investigate the frequency of asbestos workers who have respiratory problems or lung disease against a control group drawn from the general population. It is quicker and less expensive than a **prospective (or follow-up) cohort study** (see below) and is often used as the first step to see if there may be an association between a suspected cause and a known effect. It is also useful in investigating a disease of low prevalence. Unfortunately, **case-control studies** are generally less informative than prospective studies and spurious associations are likely to occur.

Prospective Cohort Study

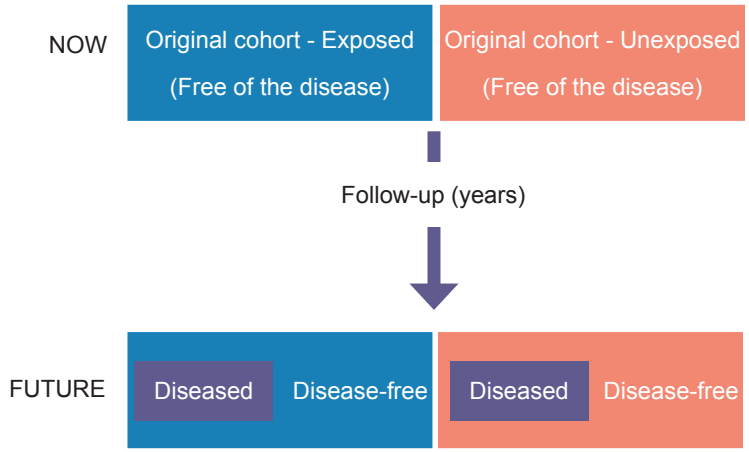
This method is **prospective** (following the group forward in time) and avoids the problem of tracing exposure history retrospectively, as with the **case-control study**.

A **prospective cohort study** is a specific type of **follow-up study** where a population is defined in advance for exposure characteristics, followed for a period of time and then the outcome measured. These studies are designed to observe incidence of occupational ill health and should, naturally, extend over a period of time longer than that required for the outcome to develop.

Such studies are used to determine whether there is an association, for example, between exposure to asbestos (the cause) and the incidence of lung cancer (the effect) and uses two groups (cohorts) of subjects:

- Exposed.
- Unexposed (the control group).

The incidence of lung cancer is then calculated for each group and if significantly more people suffer in the exposed group then there is strong evidence for cause and effect.



Prospective cohort study

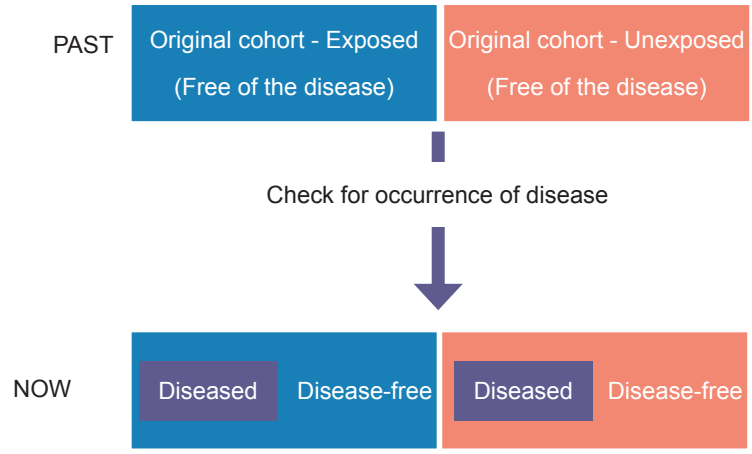
Prospective cohort studies are concerned with the relationship between the cause, as evidenced by the history and nature of the exposure, and the effect, i.e. the presence of the disease.

Prospective cohort studies provide a more accurate account of exposure related to deaths or disease and a direct estimate of the risk associated with the causal factors.

However, it may be necessary to wait many years for the development of the disease (mesothelioma might take as long as 40 years to manifest itself) and some of the cohort may be lost over the period of study.

Retrospective Cohort Study

Here, the population is selected based on past exposure records. It is very similar to the prospective cohort study, except that an historic cohort is assembled; that is, we create the cohort from historical records. The current outcomes of that exposure are then examined and investigated for both exposed and unexposed groups. It is, of course, much faster than the prospective method, because the 'follow-up' period has already occurred in the past!



Retrospective cohort study

Limitations of Epidemiology

The main problems of epidemiological studies include:

- The 'healthy worker' effect, whereby the control group has a different health status compared with the cases to be studied (pre-employment health screening has the effect of excluding less healthy individuals and consequently raising the general health of employed persons in comparison to those not in work).
- A poor response rate which reduces the sample size and its statistical significance.
- A high turnover of study populations.
- The latency period between exposure and effect, which is longer than the study period.
- Poor quality of health affects data and/or exposure data.
- No effect of exposure noted, which may be a consequence of a poor or small study population.

Toxicological Testing

Animal Testing

Toxicity tests tend to share certain basic principles. They usually involve exposing experimental animals to the test substance under controlled conditions. The relevant test methods are described within the **Test Methods Regulation** (EC 440/2008). The animal test methods include tests for:

- **Acute toxicity** – testing for the short-term onset of effects following a single exposure by various routes, such as oral (ingestion), inhalation, dermal (i.e. skin), dermal irritation/corrosion and eye irritation/corrosion.
- **Skin sensitisation** – testing for potential for contact dermatitis.
- **Repeated dose (28 days) toxicity** – testing for the medium-term onset of effects following multiple exposures by various routes, such as oral, inhalation and dermal.
- **Sub-chronic repeated dose (90 days) toxicity** – testing for the longer- term onset of effects following multiple exposures by various routes, such as oral, inhalation and dermal.
- **Chronic toxicity** – testing for the long-term onset of effects following lifetime multiple exposures by various routes, such as oral, inhalation and dermal.
- **Mutagenicity** – testing to determine if the substance has the ability to cause genetic damage and the potential to induce cancer.
- **Carcinogenicity** – if mutagenicity tests prove positive, the animal is subjected to lifetime exposure to the substance and, at post-mortem, an examination is carried out to detect tumours.
- **Reproductive toxicity** – to examine the effect of the substance on the development of the embryo and foetus to identify gross anatomical abnormalities.

These are just a selection of the many test categories.

One of the main types of toxicity tests is described as follows.

Acute Toxicity Tests and the Fixed Dose Test

Acute toxicity tests are designed to determine the effects which occur within a short period after dosing. There are various types of acute test, one of the most important of which is the fixed dose test for determining hazard classification.

The **fixed dose procedure** is considered more humane than classical LD_{50} testing. Far fewer test animals are used in the procedure. It is described in **Test Methods Regulation** (EC 440/2008).

The test substance is administered orally to test animals at one of four dose levels – 5, 50, 300 and 2000mg/kg, using a sample of animals. The animals are observed for 14 days.

The actual test is preceded by a 'sighting' or 'range-finding' study to help determine the starting dose for the main study. In this, the dose is administered to single animals sequentially – with 24 hours between administering the next highest dose to the next animal. The dose is increased by successive orders of magnitude, in factors of ten, in order to establish the range of toxic effects. The more refined main study can then be carried out.

The initial test dose should be chosen to identify toxicity but without mortality occurring. The test determines what is called the discriminating dose – the dose which causes evident toxicity, but not mortality, and which must be 5, 50, 300 or 2000mg/kg. The result is then compared with regulatory criteria in order to classify the chemical toxicity.

Advantages of Animal Testing

There are many advantages to animal testing; for example, it:

- Does not rely on exposing people to chemicals, thereby preventing human disease and suffering.
- Can be quicker and cheaper than epidemiological studies on human populations.
- Provides good-quality information about the effects of exposure to certain chemicals that could not be determined by other types of study, such as in-vitro studies.
- Allows the long-term effects of exposure to low doses to be studied, replicating the actual types of exposure that workers might experience at work.

Animal testing has many advantages, including providing good-quality information about exposure effects

Limitations of Animal Testing

These studies are not without their limitations:

- Responses vary between species, so the application to humans may be questionable.
- Testing on animals clearly raises ethical questions and should be avoided where possible.
- Additionally, diseases like cancer may have a number of contributing factors (e.g. lifestyle).
- These studies may take a long time and be expensive.

Alternatives to Animal Testing

In-Vitro Studies

Toxicology tests that can be done in vitro (this means in a test tube, or on a petri dish) rather than in vivo (in a living animal) have the advantage of being relatively quick and cheap. These types of test make use of bacteria, yeast, or cell or tissue cultures grown outside of a living animal to test the toxic effects of chemicals. In these types of test cells are

grown in a culture medium containing nutrients and are then subjected to testing. The way that the cells respond to and metabolise the test chemical can be studied by observing cell growth and behaviour, and analysing the chemical composition of the growth medium and the cells themselves.

One good example of this sort of test is the **Ames test** for mutagens:

- The test makes use of a strain of bacteria that have defective **histidine** gene. This gene is normally responsible for the production of histidine inside the bacteria. However, in the defective gene, one single mutation has knocked out the gene's function.
- Histidine is an amino acid. If the bacteria cannot make or get histidine then they die.
- The bacteria are normally grown in a medium that contains histidine (since they are unable to make it for themselves).
- When the test is conducted, the bacteria are mixed with the chemical that is being tested.
- They are then plated out to grow in medium **without** histidine.
- If the bacteria grow then they must have made their own histidine. The only way this can have occurred is if the defective histidine gene was mutated back to the active version. The chemical is a **mutagen**.
- If the bacteria die then the defective histidine gene has not been changed back to its active form. The chemical is not a mutagen.

Predictive Studies

One of the methods used to attempt to predict the possible toxic properties of a substance is to assume that chemically-related substances will show similarities in toxic properties. This method is known as **grouping and read-across**. This type of study – making use of known information about a related, similar chemical – where the way that the known chemical interacts with human metabolism, is well understood. The similarities are used to make predictions about the toxicity of the new substance. These predictions then have to be tested in vitro or in vivo to ensure that they are correct. This can eliminate or significantly reduce the need for animal testing.

An alternative is to use a predictive method that models the structure of the chemical in question and attempts to predict molecular shape, bonds, activity and how the chemical will interact with human biochemistry. This type of study method, known as **Quantitative Structure-Activity Relationship (QSAR)**, makes use of computer-based modelling of the three-dimensional structure of the chemical to make predictions about toxicity and the dose/response relationship. QSAR makes use of the very large databases of information on known chemicals and human biochemistry. Like read-across, QSAR is quicker and cheaper than most forms of in vivo testing and epidemiological study.

The Dose/Response Relationship

Toxic substances have very different effects on organisms, including the minimum level at which an effect is detectable, the sensitivity of the organism to small increases in dose, and the level at which the harmful effect (most significantly, death) occurs.

Such factors are indicated in the dose/response relationship, which is a key concept in toxicology:

In order to define a dose/response relationship, we must specify the particular effect, e.g. death, and also the conditions under which the effect is obtained, e.g. length of time after administration of the dose.

DEFINITIONS

DOSE

The amount per unit body mass of toxic substance to which the organism is exposed.

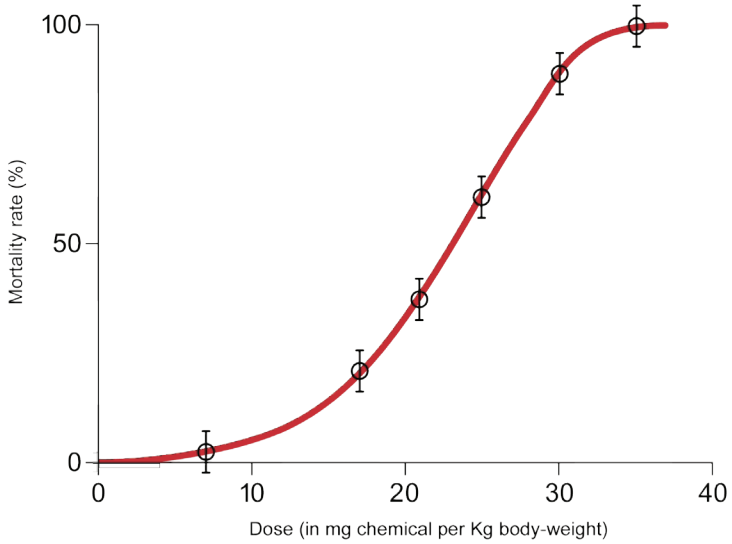
RESPONSE

The resultant effect.

If we consider a specific example, we can see that:

- At low doses, no organisms will show a response, i.e. they all live.
- At higher doses, all organisms show a response, i.e. they all die.
- In between, there is a range of doses over which some organisms die and others do not.

It is possible to plot a graph of dose against response (see example below).



Dose/response curve

The S-shape is typical of a dose/response curve. In the graph shown above:

- At zero dose, none of the test animals die.
- At 10mg/kg less than 5% of the test animals die.
- At 40mg/kg 100% of the animals die.

By extrapolating from the 50% mortality point, we can see that the dose of chemical predicted to kill 50% of the test population is 23mg/kg.

This point is referred to as **LD_{50} – Lethal Dose 50%**.

You should appreciate that LD_{50} is not an exact value and in recent years there has been much discussion as to its usefulness and necessity in toxicology. The LD_{50} values may vary for the same compound between different groups of the same species of animal.

However, the value is of use in comparing how toxic a substance is in relation to other substances. The following table gives examples of LD_{50} values for a variety of chemical substances.

LD_{50} Values

Compound	LD_{50} (mg/kg)
Ethanol	10,000
DDT	100
Nicotine	1
Tetrodotoxin	0.1
Dioxin	0.001
Botulinus toxin	0.00001

An alternative figure often referred to in toxicology data is **LC_{50}**. This refers to **Lethal Concentration 50%** and is the concentration of an aerosol that, when inhaled, killed 50% of the test population.

The S-shaped dose/response curve can be further analysed mathematically to determine doses that have a higher or lower probability of fatality. The determination of LD_{90} from the dose/response curve, for example, enables estimation of the dose that will kill the majority (i.e. 90%) of a sample of animals.

Remember that the LD_{50} classification is only a very rough guide to relative toxicity. It tells nothing about sublethal toxicity and the data is only strictly valid for the test population, e.g. rats and the route of exposure, e.g. ingestion. The LD_{50} tells us nothing about the shape of the dose/response curve on which it is based. It is possible for two chemicals to have the same LD_{50} but one may have a much lower lethal threshold and kill members of the exposed population at concentrations where the other has no effect.

The use of the classical LD_{50} testing method has declined with the use of fixed dose testing (see later).

One significant use of the dose/response curve is it allows for the identification of the dose below which no effect or response is measurable. This is often called the **threshold dose** and can be clearly demonstrated with responses such as lethality. This concept of a threshold dose for the toxic effect is an important one and implies that there will be a dose at which the response does not occur in any member of the population. The term for this is the **No Observed Adverse Effect Level** (**NOAEL)**. The NOAEL is important for setting Occupational Exposure Limits (OELs), which are designed to represent a level of exposure at which there is no evidence of harm (see Element IB4).

Testing for **carcinogenic potential** is more complex since there is no simple dose/response relationship. It is not possible to assign a dose below which it can be said that the exposure is safe. There is no threshold below which cancer does not occur: it must be assumed that any exposure to carcinogenic substances has the possibility of an adverse effect and it is then necessary to estimate the **risk** of cancer at various doses.

STUDY QUESTIONS

17. Explain the difference between the case-control epidemiological study and the prospective (follow-up) cohort study.
18. Describe an example of a retrospective cohort study.
19. Outline the range of toxicity tests that might need to be carried out on a substance.
20. Explain the methodology and purpose of the fixed dose acute toxicity test.
21. Describe a test that can be used to detect genetic mutation.
22. Explain what is meant by the term "dose/response relationship".
23. Sketch a dose/response curve and use the curve to explain the terms "LD_{50}" and "LD_{90}".

(Suggested Answers are at the end.)

Summary

The Human Anatomical System - the Routes of Entry and Defensive Responses

We have described how:

- The respiratory system consists of the upper respiratory tract and lungs and its prime function is the delivery of oxygen into the bloodstream.
- The digestive system consists of a continuous tract through the body where ingestion, digestion, absorption and excretion of foodstuffs take place.
- The circulatory system consists of the heart, blood vessels and blood and is responsible for the continuous transportation of all of the chemicals essential for life.
- The nervous system is made up of the central nervous system (brain and spinal cord) and the peripheral nervous system (which controls motor functions).
- The skin is an organ made up of the epidermis and dermis and is the primary barrier between the body and the environment.
- The eye is a delicate sense organ used to detect light; similarly, the nose provides a sense of smell.
- Chemicals gain entry to the body by four principal routes of entry: inhalation, absorption through the skin (pervasion), injection through the skin and ingestion. Aspiration and entry at the eye or ear are other possible routes.
- The health effects of chemicals can be described as local or systemic and often involve specific target organs and target systems.
- The body has innate and adaptive defence mechanisms to protect it from attack and damage.
- The respiratory system has a series of defences to combat dust inhalation: the sneeze reflex, nasal filtration, the mucociliary escalator, macrophages and the inflammatory response.

Identification, Classification and Health Effects of Hazardous Substances

We have examined how:

- The three physical states of matter are solid, liquid and gas. Within these states, chemicals can take different forms, such as dust, fibres, fume, mist and vapour. The physical form of a chemical influences the possible routes and methods of entry into the body.
- Inhalable dust is all dust that can be breathed into the nose and mouth. Respirable dust is dust that can be inhaled deep into the lungs.
- The United Nations have implemented a **Globally Harmonised System of Classification and Labelling of Chemicals (GHS)**, which aims to standardise the laws governing the classification and labelling of chemicals globally, with the principle "one chemical – one label worldwide".
- Suppliers and manufacturers of chemicals have to classify, label and package chemicals according to EC **Regulation no. 1272/2008 Classification, Labelling and Packaging of Substances and Mixtures Regulation (CLP)** in line with GHS.
- Harmonised classification and labelling information is available for many substances in Table 3.1 of Part 3 of Annex VI of **CLP**.
- Where these tables do not apply, the supplier must classify and label according to **CLP**.
- Standard health hazard classes are used to classify the health effects of chemicals according to GHS. They are: acute toxicity, skin corrosion, skin irritation, serious eye damage, eye irritation, respiratory sensitisation, skin sensitisation, germ cell mutagenicity, carcinogenicity, reproductive toxicity, specific target organ toxicity (single and repeat exposure) and aspiration hazard.

- In Europe, the EU **REACH** Regulation requires that suppliers/manufacturers register chemicals that they manufacture or supply in quantities of one tonne or more per year with the European Chemicals Agency (ECHA).
- Specific workplace examples of hazardous chemicals include asbestos, lead, carbon monoxide, isocyanates, metal working fluids, used engine oil, silica and wood dusts (both hard and soft wood).

Assessment and Evaluation of Risk from Hazardous Substances

We have described how:

- Suppliers and manufacturers of chemicals have to classify, label and package chemicals according to **CLP** to implement the Globally Harmonised System (GHS).
- Labelling requires the application of suitable phrases and symbols.
- Safety data sheets, a legal requirement under **REACH**, contain 16 categories of information to allow the end user to undertake their exposure assessment.
- Legislation and good practice require the employer to carry out an assessment when employees are liable to be exposed to hazardous substances.
- Several factors must be considered during this assessment:
  - Hazardous properties of the substances.
  - Type and level of exposure.
  - Duration and frequency of exposure.
  - Number of people exposed.
  - Effect of mixtures.
  - Unusual activities and emergencies.
  - Relevant Occupational Exposure Limits (OELs).
  - Effectiveness of existing controls.
  - Results of air monitoring and health surveillance.
  - Individual susceptibility.
- The assessment should be reviewed when:
  - There is reason to suspect that it is no longer valid.
  - There has been a significant change in the work.

The Role of Epidemiology and Toxicological Testing

In particular, we have described how:

- Epidemiology and toxicology are two branches of medical science that have allowed the recognition and classification of chemical health hazards to occur.
- Epidemiological studies look at the prevalence and spread of disease in populations. Many epidemiological studies follow cohorts of people over periods of time. Three such types of study are the case-control study, the prospective cohort study and the retrospective cohort study.
- Animal testing of chemicals often involves acute toxicity testing (such as the fixed dose procedure used for classification). These studies have their limitations.
- Alternatives to animal testing include in vitro testing using bacteria, such as the Ames test for mutagenicity, and predictive modelling, such as QSAR and grouping and read-across methods.
- One of the key tools of toxicology is the dose/response curve that demonstrates the relationship between the dose of chemical administered and the ill-health response that occurs.
- Dose/response curves can be used to derive three important characteristics of a chemical; LD_{50}, LC_{50} and the NOAEL.

Exam Skills

QUESTION

(a) **Outline** the following toxicological terms:

(i) LD_{50}; **(2)**

(ii) LC_{50}. **(2)**

(b) **Outline** the advantages and disadvantages of using animal studies to investigate whether a substance used at work may be carcinogenic to humans. **(6)**

Approaching the Question

Now think about the steps you would take to answer the question:

Step 1: Read the question carefully.

Step 2: Consider the marks available. In this question there are two marks for each part of (a) so it is expected that you produce a short written answer for these parts, whereas part (b) is worth six marks about advantages and disadvantages so you should aim for around seven/eight different pieces of information and the question should take around 15 minutes.

Step 3: Highlight the key words. In this case this might look like this:

(a) **Outline** the following toxicological terms:

(i) **LD_{50}**; **(2)**

(ii) **LC_{50}**. **(2)**

(b) **Outline** the advantages and disadvantages of using animal studies to investigate whether a substance used at work may be carcinogenic to humans. **(6)**

Step 4: Read the question again to make sure you understand it and have a clear understanding of the two terms. (Re-read your notes if you need to.)

Step 5: The next stage is to develop a plan – there are various ways to do this. A common approach for part (b) is to outline the advantages and disadvantages between the studies.

Your answer must be based on the key words you have highlighted. So, in this case, we need to outline advantages and disadvantages.

Step 6: Now have a go at the question. Hint – animals to humans is an important factor! Remember that the question calls for you to "outline" – this is very important if you want to gain good marks.

When you have finished have a look at the following comments and guidance.

Suggested Answer Outline

(a) (i) LD_{50} relates to a single oral or dermal dose that results in the death of 50% of a test population. LD_{50} is measured in terms of milligrams (or grams) per kilogram body weight.

(ii) LC_{50} is an inhaled concentration sufficient to kill 50% of a test population in a fixed period of time and is measured in milligrams (or grams) per cubic metre of air.

(b) A list of advantages could include the following:

- Avoiding human exposure to the substance and hence avoiding harm to humans.
- They are faster than human (epidemiological) studies.
- You can argue it is more ethical than using epidemiological methods.
- It could be argued that animals provide the best study models as they relate more closely to humans.

Disadvantages could include the following:

- Difficulty in extrapolating data from animals to humans, due to size, body factors, etc. varying the dose/response.
- Animal studies are expensive to undertake.
- It could also be time-consuming.
- Public opinion against testing.
- Ethical considerations of testing.
- Testing on one substance doesn't consider the combined (synergistic) effects of other products humans use, possibly affecting results.
- Does the test actually produce any effect in the animal - "no observed effect level"- does this mean no effect in humans?

Example of How the Question Could be Answered

(a) (i) LD_{50} is a measurement that relates to the amount of an oral or dermal dose that was given to the animals that resulted in 50% of the test sampling dying. The units are in terms of milligrams/kg of body weight.

(ii) LC_{50} is a measurement that relates to the inhaled concentration that is capable of 50% death rate. The units are in terms of milligrams/m^3 of air.

(b) ***Advantages***

Animal testing avoids the need to test substances on humans. Such tests are much quicker to carry out than human epidemiological studies and may prevent the unnecessary deaths of humans. Animal biology is similar to that of humans, which makes the test results relevant, while in vivo animal testing is a better way to detect cancers than in vitro methods, such as Ames testing.

Disadvantages

Although there are similarities between animal and human biology, animals may still react differently to humans in specific exposure situations, which may render the results less accurate than expected. Despite the potential benefits of animal testing in preventing harm to humans, there are still strong public feelings against this type of experimental work, and in order to carry out such work, humanely animal testing becomes very expensive and time-consuming, and there are strict regulations to comply with. Data from such testing needs to be interpreted carefully because no observed effect in animals does not necessarily mean there will be no effect in humans. In addition, humans and animals are of different sizes, therefore it may prove difficult to extrapolate the dose required to that relevant to a workplace situation.

Reasons for Poor Marks Achieved by Candidates in Exam

- Demonstrates a lack of understanding of the terms LD_{50}, LC_{50}.
- Is not written in the required "outline" format.

Element IB3

Control of Hazardous Substances

Learning Outcomes

Once you've read this element, you'll understand how to:

1. Explain the principles of prevention and control of exposure to hazardous substances (including carcinogens and mutagens).
2. Outline the specific requirements for working with asbestos and lead.
3. Explain the uses and limitations of dilution ventilation and the purpose and operation of local exhaust ventilation, including assessing and maintaining effectiveness.
4. Explain the effectiveness of various types of Personal Protective Equipment (PPE) and the factors to consider in selection of PPE.

Contents

Prevention and Control of Exposure to Hazardous Substances

IN THIS SECTION...

- A simple hierarchy of controls is as follows:
  - Eliminate exposure, following these steps:
    - Cease use of the hazardous chemical.
    - Substitute for a less hazardous alternative.
    - Implement an alternative process.
  - Control exposure, through:
    - Good design and installation (through total enclosure of the process, segregation of the process from workers, modification of the process to reduce exposure potential, implementation of Local Exhaust Ventilation (LEV) – with or without partial enclosure – and the use of general ventilation).
    - Implementing work systems and practices to minimise the numbers of people exposed, restrict access to the processes, restrict the duration of exposure and provide for cleaning and decontamination, maintenance of controls, and safe storage/disposal of materials.
    - The use of PPE, good hygiene practices, welfare facilities, warning signs and emergency arrangements.
- Additional control measures must be implemented to prevent exposure to carcinogens and mutagens.

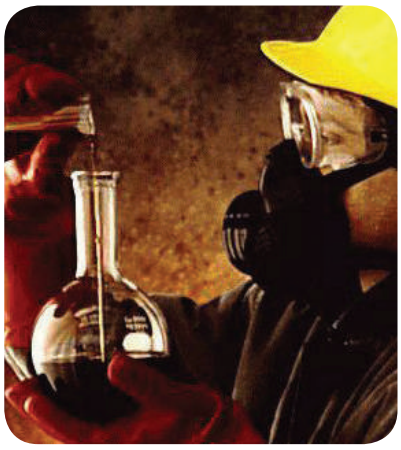
Introduction

The ILO has produced two codes of practice that cover the control of hazardous substances in the workplace:

- **ILO Code of Practice – Safety in the Use of Chemicals at Work**, particularly Chapters 6.4 and 6.5.
- **ILO Code of Practice – Ambient Factors in the Workplace**, Chapter 4.3.

Elimination of Exposure

The most effective method of control for hazardous substances is to **eliminate** their use altogether. Whilst it is not always possible to achieve in practice, consideration should first be given to the elimination of either the hazardous chemical, or the process that requires it. Obviously, a manufacturer of lead acid batteries may struggle to eliminate the lead or the acid from the process!



Elimination of substance use is the most effective method of control

In attempting to completely eliminate the use of a substance or the production of it in the workplace, options include:

- Changing the **method of work** so that the operation that involves exposure is no longer necessary:
  - For example, buying timber of the correct size for product assembly eliminates the need to generate hazardous concentrations of wood dust from cutting and sanding operations.
- Modifying a **process** so that a hazardous by-product or waste material is no longer produced:
  - For example, treating an acidic by-product with alkali at the last stage of a manufacturing process neutralises the waste so that it is no longer a corrosive substance.

- Substituting a **non-hazardous substance** that presents no risk to health:
  - For example, screen-printing using a solvent-based ink exposes operators to solvent vapour. By using a water-based ink instead, exposure to the solvent is completely eliminated.

If the chemical can't be eliminated then the next best option is to **substitute** it for a substance that is less hazardous. This could be a less hazardous form of the same chemical or an entirely new substance with a lower hazard classification (e.g. irritant rather than corrosive). So, for example, a manufacturer using a dusty powder which is harmful by inhalation might substitute this for a pelletised form of the same chemical, which would have less potential to generate dusts and would thus reduce the risk of inhalation.

Analysing the process may identify activities that produce harmful substances. **Changing the work method** may minimise or suppress the generation of the substance. For example, where a paint-spraying process is generating harmful solvents, brush-painting rather than spraying will considerably reduce the level of airborne contaminant.

The ill-health effects arising from exposure are often related to the duration of exposure as well as the concentration of the substance. **Reducing exposure time** can minimise the dose. As a general principle, the cumulative dose should be reduced to as low a level as possible by organising the work pattern to provide periods of nil exposure. Another method is job rotation, where the exposure of any particular individual is reduced by sharing the dose with other workers.

Methods of Control

We will now look at each of the following methods of controlling exposure in turn:

- Good design and installation practices.
- Work systems and practices.
- Personal protection.

Good Design and Installation Practices

When designing a process, it is important that good design and installation practices are considered at the outset. When assessing an existing process, an evaluation must be made to ensure that the standards implemented at the time of installation meet the current requirements and that any improvements required are identified.

Total Enclosure

Total enclosure or containment is an effective control, since no-one can then be exposed to the hazard. For example, total enclosure of a process that generates dust or fumes will prevent the escape of airborne contaminants that could be inhaled by operators in the vicinity. When an area has been totally isolated, it may still be necessary to access equipment or material within that area. Robotically-controlled, remote-handling systems may be used, allowing access without disturbing the substance hazardous to health and potentially exposing operators.

Segregation of the Process

Keeping people away from the process and its hazards is another effective method of controlling exposure. This can be achieved by storing the substances and carrying out the process in separate areas of the plant, away from other workers and processes.

Process Modification

In some cases, the process itself can be modified so that the release of hazardous substances is minimised. If the chemical is harmful when airborne, using techniques to minimise the generation of dusts or vapours will reduce the exposure potential, for example:

- Applying paint with a roller or brush rather than spraying.

- Adding materials to a vessel via a sub-surface addition pipe (known as a 'dip leg'), rather than splash filling from the top.

ILO Code of Practice – Ambient Factors in the Workplace also states that controls should be implemented to limit the area of contamination in the event of spills and leaks, which could be achieved by including drip trays and bunds (containment walls) around tanks, pumps and vessels (with the provision of spill kits considered in 'emergency arrangements').

Local Exhaust Ventilation (LEV)

Local Exhaust Ventilation (LEV) is an example of an engineering control; an airborne substance is extracted from the workplace at the point of generation. This can be achieved through implementing partial enclosures around the source of the contamination (where it isn't possible to totally enclose the process) and extracting the contaminants away from the workers, or using LEV units which can be adjusted so that the point of extraction is close to the point of generation. This will be covered in detail later.

Dilution Ventilation

Dilution ventilation is another engineering control, sometimes known as 'general ventilation'. The airborne substance is allowed to escape into the workplace, but then air changes dilute the concentration down to an acceptable safe level.

Again, this will be explained in detail later.

Work Systems and Practices

Minimise Numbers Exposed

Reducing the number of people exposed to a particular hazardous substance is a sensible control measure in all circumstances.

However, there may be instances where it is particularly important to restrict exposure to certain individuals only. For example, where the substance:

- Is carcinogenic, mutagenic or toxic to reproduction.
- Is a sensitising agent to which certain individuals might be more susceptible.

Restrict Access

Minimising the number of people exposed might have to be done by segregating parts of the workplace where the substance is to be stored, used and handled and restricting access to authorised people only.

Reduce Exposure Duration

By reducing the length of time a worker is exposed to a chemical, the overall exposure dose can be reduced. This is most commonly achieved through controls such as job rotation, whereby workers only work with the substance for a short period of time before being moved onto another part of a process, with the result that more workers are exposed but to a lower dose of the chemical.

Reduced exposure duration can be done through job rotation

Cleaning Regimes

It is important to ensure that contaminated surfaces are regularly cleaned to prevent the accidental transfer of chemicals throughout the work area. Work surfaces, walls, floors and handles might require regular cleaning to remove contaminants.

Maintenance

Where engineering controls are provided, it is important to ensure that they are used, and used correctly. For example, adjustable LEV must be set at the correct distance from the emission point and – more importantly – turned on! This may require regular workplace inspections to ensure controls are in place.

When engineering controls such as LEV are installed it is essential that these are maintained in good working order. At national level, there may be legislation or guidance requiring the maintenance of such systems at prescribed frequencies. This type of thorough maintenance will require the full testing of the extraction system to ensure that it is working at its design parameters and that contaminants are being transported away from the workers.

Storage and Transportation of Chemicals

It is important to ensure that chemicals are stored and transported safely within the workplace. The quantity of hazardous substances stored in the work area should be restricted, often to the quantity that is required within one shift. These substances should be stored in cabinets or other suitable storage containers, in labelled, leak-proof vessels. Where flammable materials are used, a suitable fire-resistant cabinet should be used for the internal storage of the chemicals.

Incompatible materials must be segregated to prevent chemical reactions – incorrectly storing materials that have subsequently leaked has resulted in devastating chemical plant fires. Warehouses may therefore need to be segregated into separate, isolated storage areas.

Whilst transporting chemicals care should be taken to ensure that leaks and spills are minimised. It may be possible to transfer large quantities of chemicals in bulk from delivery tankers into large storage tanks and, via pipework, into the process vessels. Where materials are charged from drums or bags, transport should be carried out in a controlled manner and consideration given to the engineering controls required at the point of addition to the process (e.g. LEV extraction systems).

Disposal

Hazardous chemicals must be correctly disposed of in accordance with local legislation. Usually this will require the material being stored in sealed containers and sent for treatment (to reduce the hazard or to process it into another useable form) or disposal at licensed waste disposal facilities.

Personal Protection

So far the controls we have considered are 'safe place' controls which would protect the workforce as a whole. In some instances it is also necessary to implement 'safe person' controls to protect individual workers.

Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) is a commonly used control measure for hazardous substances. It may be used as the only control, or it may be used in combination with other procedural and engineering controls. Usually, PPE should only be considered as an option when all of the other measures outlined above have been considered and applied and where it is necessary to further reduce the exposure to an acceptable level.

Common types of PPE used to control exposure to hazardous substances include:

- Respiratory Protective Equipment (RPE).
- Gloves and gauntlets.
- Eye and face protection.

RPE is used to control substance exposure

These are discussed in more detail later in this element.

Prohibition of Eating/Drinking/Smoking

It is usual practice to prohibit eating (including the chewing of gum and tobacco), drinking and smoking in potentially contaminated areas of the workplace in order to prevent accidental ingestion of chemicals. This will also require controls to ensure that the designated rest/eating areas are maintained free from contamination through the strict observance of decontamination and changing regimes on leaving the workplace. For example, it is common practice for pharmaceutical workers to change out of potentially contaminated workwear into clean clothing before entering the office or canteen areas to prevent transfer of contaminants.

Hygiene Facilities

Facilities must be provided for washing to remove contamination – this includes hot water, soap and drying facilities but showers may also be required. Where workwear may become contaminated, changing facilities must be provided together with a clean area to store personal clothes. Finally, contaminated workwear should not be taken home to be laundered – a facility for this should be provided in the workplace.

Signs and Notices

Warning signs and notices should be used to alert workers and visitors to the potential presence of hazardous chemicals. These should be of the correct format to meet any national requirements.

Emergency Arrangements

The risk assessment should address not only the control measures needed to minimise exposure during normal use, but also foreseeable emergencies, including spillages.

The escape of large quantities of a hazardous substance may require the evacuation of the premises and the surrounding area (which may include domestic properties) and then liaising with the emergency services.

Depending on the nature of the substance, spillages can lead to very high exposures of vapours and a greatly increased fire risk, especially with volatile organic chemicals. Suitable PPE is therefore essential for workers required to deal with a spillage. This has significant implications for the selection and maintenance of PPE and the training and supervision of the users.

First-aid provision is an important element of any emergency plan.

Environmental damage, such as leakage into a watercourse, should also be addressed. Spill kits should be prepared to deal with spillages; different kits may be needed depending on the substances involved.

MORE... www.

The **ILO Code of Practice – Ambient Factors in the Workplace** is available from the ILO website at:

www.ilo.org/safework/info/standards-and-instruments/WCMS_107729/lang--en/index.htm

Information on the control of exposure to hazardous substances is available from the HSE at:

www.hse.gov.uk/coshh/index.htm

The ACoP and Guidance on the **Control of Substances Hazardous to Health Regulations** (L5, 6th edition) is also available at:

www.hse.gov.uk/pubns/priced/l5.pdf

Additional Control Measures for Carcinogens and Mutagens

Additional control measures must be adopted where it is not reasonably practicable to prevent exposure to carcinogens or mutagens. These are:

- Totally enclosing the process and handling systems, unless this is not reasonably practicable.
- The prohibition of eating, drinking and smoking in areas that may be contaminated by carcinogens.

- Cleaning floors, walls and other surfaces at regular intervals and whenever necessary.
- Designating those areas and installations that may be contaminated by carcinogens or mutagens and using suitable and sufficient warning signs.
- Storing, handling and disposing of carcinogens or mutagens safely, including using closed and clearly labelled containers.

STUDY QUESTIONS

1. Outline the hierarchy of control for exposure to hazardous substances, as outlined in the **ILO Code of Practice – Safety in the Use of Chemicals at Work** and the **ILO Code of Practice – Ambient Factors in the Workplace**.
2. What are the further measures necessary to control exposure to carcinogens and mutagens?

(Suggested Answers are at the end.)

Specific Requirements for Working with Asbestos

IN THIS SECTION...

- Asbestos causes several serious ill-health conditions: asbestosis, lung cancer, mesothelioma and pleural plaques.
- Chapters 5 to 11 of the ILO Code of Practice – Safety in the Use of Asbestos outline the controls that should be implemented when working with asbestos.
- The general methods of control which should be employed include elimination of exposure, or reduction to the lowest possible level through the use of engineering controls, such as enclosure and LEV extraction.
- Where exposure can't be controlled to an acceptable level, respiratory protective equipment and personal protective equipment should be used.
- Plant and equipment should be cleaned so as to remove contamination from surfaces.
- Asbestos-containing materials should be stored in secure bags clearly labelled with the recognised asbestos-warning labels. This applies to products as well as wastes.
- Asbestos materials should be transported in secure containers.
- Disposal should be via an approved waste disposal site and disposal contractors should be supervised.
- Health surveillance should be carried out before workers begin asbestos work, at regular intervals and on ending employment, in order that their health status is monitored.
- Workers (including those who implement asbestos controls) should be trained in the hazards, risks and controls associated with asbestos exposure.
- Lead is a toxic metal that can cause damage to the central nervous system.
- Control of exposure to lead often requires biological monitoring (taking blood or urine samples) as a form of health surveillance and the observation of action levels and suspensions levels for concentrations of lead in blood and urine.
- Different levels of protection are necessary for young persons and women of reproductive capability.

Asbestos Health Risks

Asbestos is a generic name given to a collection of naturally-occurring minerals that have been used extensively as fire-resistant building and lagging materials. Though the use or importation of asbestos has been banned in many (but not all) countries around the world, the material was widely used before that date and so many buildings, structures and articles will contain asbestos.

The three principal mineral forms of asbestos are blue (more correctly known as crocidolite), brown (amosite) and white (chrysotile). The naming of asbestos by colour as an easy way of referencing the type of mineral is usual. However, the appearance of asbestos incorporated into an Asbestos-Containing Material (ACM) cannot normally be used as an indication of the type of asbestos present. Crocidolite may be 'blue' asbestos, but it may not appear blue when observed in an asbestos containing material. The actual type can usually only be determined by technical analysis.

Working with asbestos

Historically, asbestos has been incorporated into many building parts, such as roofs (asbestos cement), ceilings (ceiling tiles), walls and ceilings (in fire breaks), floors (floor tiles), pipes (downpipes), decorative plasters (artex) and insulation (pipe lagging). It may also be found as asbestos rope or gaskets in old equipment such as furnaces, chemical pipework, or boilers. It is also a common friction lining in machinery (brakes, clutch plates, etc.).

Asbestos is hazardous by inhalation. Four forms of disease are associated with asbestos exposure (see Element IB2).The symptoms of these diseases do not become apparent until years after exposure has occurred (10-15 years for asbestosis and 30-40 years for mesothelioma). Though asbestos use is now banned or seriously restricted in most countries, it remains a serious health risk as it is still present in many buildings. Any work on existing structures where asbestos is present involves the potential to disturb it. Demolition, refurbishment, installation and even minor repair work can expose workers to asbestos by inhalation.

Control of Asbestos

The **ILO Code of Practice – Safety in the Use of Asbestos** is a guidance document which seeks to:

- Prevent the risk of occupational exposure to asbestos.
- Prevent harmful effects arising from asbestos dust exposure.
- Provide reasonably practicable control procedures.

It is also highly likely that there will be national legislation governing the use and control of asbestos materials, which would take precedence over this guidance in the workplace.

The CoP calls for the formation of a competent regulatory authority, who should be notified of all work with asbestos-containing materials which is likely to generate dusts.

General Preventive Measures

The first control proposed is the replacement of Asbestos-Containing Materials (ACMs) with non-asbestos alternatives, which should be selected on the basis that they are harmless or less harmful. The primary consideration should be the associated health hazards of the replacement materials.

Methods of Control

All efforts should be made to eliminate the exposure of workers to asbestos or reduce it to the lowest possible level.

Engineering controls should include:

- Process separation, automation or enclosure.
- Bonding asbestos fibres with other materials to prevent dust generation.
- General ventilation of the working areas with clean air.
- Local ventilation of processes, operations, equipment and tools to prevent dust dissemination (ventilation is covered in more detail later in this element).
- Use of wet methods where appropriate.
- Separate workplaces for certain processes.

Work practices should be implemented where it is possible that asbestos dust may be generated. These include:

- The use and maintenance of engineering controls.
- Damping of asbestos materials before handling.
- Regular cleaning of work areas to remove contamination.
- Proper use of PPE.

Control Programme

Each employer should establish a written control programme which includes:

- A description of each operation in which airborne asbestos is emitted, including the:
  - Processes and machinery used.
  - Materials handled.
  - Control devices.
  - Number of exposed workers.
  - Job responsibilities of each worker.
  - Operating procedures.
  - Maintenance practices.
- A description of the specific means for controlling exposure to asbestos dust.
- Engineering plans, safety data sheets, study reports or other relevant technical information.
- Air monitoring data on the efficiency of control measures.
- A description of the work practices or administrative controls needed.
- A detailed schedule for implementation of the control programme.

Design and Installation

The materials, processes and equipment should be designed so that asbestos exposure is eliminated or reduced to the lowest practicable level. Such controls include segregating the asbestos operations from the rest of the process to reduce the potential for asbestos dust to accumulate.

Direct handling of asbestos-containing materials should be avoided and, where practicable, the process should be totally enclosed and operated at negative pressure (using an internal exhaust) which will prevent the release of fibres. In practice this would usually require the construction of a "tent" with a filtered extraction system ensuring that the enclosure remains at negative pressure. Workers would enter this area via an air lock and would be decontaminated on leaving.

Dust emission and worker exposure should also be measured in order to demonstrate that the required standard of control has been achieved.

Removal and bagging of ACM
Note the protective clothing and the use of RPE

Where total enclosure is not practicable, LEV should be provided and maintained. However, this must be subject to strict controls to ensure that the extraction systems are designed and used correctly, with regular performance checks implemented to ensure efficient operation of the LEV.

General Ventilation

General ventilation should be ensured to provide a clean supply of air to replace air extracted from the workplace. The exhausted air must be filtered thoroughly and not returned to the workplace unless strict controls are in place to check and assure the air quality and levels of asbestos contamination.

Personal Protection

Respiratory Protection

Respiratory Protective Equipment (RPE) should only be used as a temporary or emergency measure and not as an alternative to a technical control or when workers are likely to exceed exposure limits. In these instances workers should be informed and required to wear the RPE, whilst employers should supervise to ensure its correct use. Provision and maintenance of RPE should be without cost to the employee.

There is a number of types of RPE available, including half mask air-purifying respirators, positive pressure systems and breathing apparatus – this should be selected giving consideration to the maximum concentration of airborne asbestos likely to be encountered, together with comfort and fit.

Workers using RPE should be trained in its use and maintenance, and the RPE should be regularly cleaned, checked, maintained and stored in an appropriate container.

Protective Clothing

Protective clothing should be provided when there is a potential for workers' own clothing to be contaminated. It should completely cover workers' own clothing and should also cover the head. Where protective clothing is reusable, separate locker rooms should be provided to segregate clean clothing from contaminated workwear, with vacuum cleaners provided to carry out decontamination of clothing at the entrance to the locker area. Respirators should remain on during the decontamination process. Shower or washroom facilities should be provided between the "dirty" and "clean" locker areas to fully remove contaminants, and personal clothing only put on in the clean locker room. Appropriate, competent laundering facilities should be provided by the employer for the contaminated workwear and the washing of such items at home strictly prohibited.

Cleaning of Plant and Premises

Employers should ensure that, as far as is practicable, work premises remain clean and free from asbestos contamination and waste. This cleaning should be carried out by methods which prevent dust generation, e.g. vacuum cleaning, and at a time when no other workers are present. The vacuum-cleaning equipment used for cleaning and decontamination of workwear must be fitted with appropriate filters to prevent fibre release, collection bags should be disposable and provision made for safe containment of a burst bag.

Packing, Transport and Storage

The CoP provides detailed guidance on the packing of asbestos materials for storage and transport. In summary, any asbestos materials should be packed in impermeable bags, clearly marked with an approved asbestos warning and constructed so as not to degrade or release fibres. They should be stored in an area not exposed to the elements which may damage the bags through weather damage or UV (ultraviolet) degradation. Additional controls should be implemented when transporting materials to ensure that the bag contents are not released or bags damaged, although provision should also be made for the repair of damaged bags.

Waste Disposal and Collection

Wastes should be collected into appropriate impermeable bags or containers in a way that prevents the release of asbestos dusts. This will depend largely on the type of material to be disposed of, e.g. during large-scale stripping operations it may be practical to place plastic sheeting on the floor which can be folded over and sealed to contain the materials for disposal. In any instance, the wastes should be sealed, isolated and identified as wastes containing asbestos materials. The bags should be stored and transported as we have previously covered.

Whilst the CoP also provides detailed guidance on the final disposal of asbestos waste and details landfill controls to be implemented, again this is likely to be covered in national legislation. The key requirement is that employers should ensure that any waste disposal site is capable of accepting asbestos wastes.

Use of Specialist Contractors

Work on asbestos-containing materials should always be done by competent people using appropriate work methods and precautions.

Many national governments have a system of licensing:

- Contractors for higher-risk work (where risk of exposure is significant) must be licensed.
- The client must check the competence of specialist contractors to ensure that they are licensed to undertake work with asbestos.
- Lower-risk work can be done without a licence.

Personal Protection and Hygiene

Workers who transport, collect or dispose of asbestos wastes should be equipped with suitable PPE and any contaminated vehicles or equipment decontaminated by a dustless method, such as vacuum cleaning.

Supervision

Adequate controls to supervise asbestos contractors should be implemented.

Supervision of the Health of Workers

Asbestos workers should be subject to health surveillance – this should take the form of an initial examination before starting work with asbestos (i.e. on recruitment or before assignment to an asbestos role) and at periodic intervals. On leaving employment, an examination should also be carried out to determine the state of health at the point of finishing work. Health surveillance records should be confidential and retained by the physician.

Information, Labelling, Education and Training

The CoP recognises that there is a link between cigarette smoke and asbestos in asbestos workers who also smoke, resulting in a greatly increased risk of bronchogenic (lung) cancer (this is an example of a synergistic effect – see Element IB2). It is therefore important that workers are made aware of this specific risk if they will potentially be exposed to asbestos dust in the workplace.

All asbestos-containing materials should be labelled with recognised warning labels using an appropriate symbol. Shown here is an example of the label used in the UK – other countries will use their own labelling systems.

All workers should receive training when starting employment and on a regular, ongoing basis to inform them of the potential sources of asbestos dusts, potential health effects, the risks associated with asbestos and smoking and control methods. This should be delivered in an appropriate manner using a variety of media. All personnel involved in the management of asbestos and prevention of disease should also be trained, including managers and safety professionals. Occupational health physicians employed to carry out surveillance should also be appropriately trained.

Example of an asbestos warning label

Source: INDG223 Managing asbestos in buildings: a brief guide, HSE, 2012 (www.hse.gov.uk/pubns/ indg223.pdf)

Lead

As a fume or very finely divided dust, lead inhalation becomes a serious risk as a potential mode of entry; **organic lead** can have **fatal** consequences (see Element IB2).

Control of Exposure to Lead

Control of exposure to lead is best illustrated by examining the regulatory regime in the UK as an example. In the UK, the control of lead is subject to the **Control of Lead at Work Regulations 2002 (CLAW)**.

These Regulations require the employer to:

- Carry out a suitable and sufficient risk assessment.
- Introduce control measures to eliminate or reduce exposure.
- Prohibit eating, drinking and smoking in contaminated areas.
- Maintain control measures.
- Carry out air monitoring.
- Carry out medical surveillance.
- Provide information, instruction and training.
- Develop procedures to deal with accidents, incidents and emergencies.

The Regulations state that:

- The risk assessment must identify when an employee's risk of exposure to lead is significant. Significant in this context means:
  - exposure is over half the Occupational Exposure Limit (OEL) for lead; or
  - there is a substantial risk of ingestion of lead; or
  - they come into contact with lead that can be absorbed through the skin.
- Control measures will only be considered adequate provided the relevant OEL has not been exceeded.
- Medical surveillance must be conducted for all employees where:
  - Their exposure to lead is liable to be significant.
  - Their blood-lead or urinary-lead concentrations exceed one of the given values.
  - A doctor certifies that they must be under medical surveillance.

The medical surveillance requirements under **CLAW** require not only that a medical examination is undertaken but also create a statutory requirement for **biological monitoring**. This means that blood and urine samples have to be taken routinely for all employees identified with significant exposures.

The subject of biological monitoring is explained in Element IB4.

It is worth pointing out here, though, that two different types of biological limit value exist for lead:

- **Action level** – above which the employer must take steps to reduce employee exposure.
- **Suspension level** – above which the employer must remove the employee from further lead exposure if informed to do so by the doctor.

MORE...

The **ILO Code of Practice – Safety in the Use of Asbestos** is available from the ILO website at:

www.ilo.org/safework/info/standards-and-instruments/WCMS_107843/lang--en/index.htm

The Asbestos Essentials website contains a series of task sheets that explain how to undertake some of the more common non-licensed asbestos work activities safely and includes a flowchart that distinguishes notifiable non-licensed work - see:

www.hse.gov.uk/pubns/guidance/a0.pdf

There is a range of useful documents available from the HSE, including L143 *Managing and working with asbestos* (2nd edition), which applies to all asbestos work and, in particular, that which disturbs or is liable to disturb asbestos-containing materials, available at:

www.hse.gov.uk/pubns/priced/l143.pdf

There is also an HSE microsite for asbestos which provide lots of useful information:

www.hse.gov.uk/asbestos

It is also worth noting that, under **CLAW**, different action and suspicion levels exist for:

- **Women of reproductive capacity** – this means any woman who is physically and medically capable of becoming pregnant.
- **Young persons** – any 16 or 17 year old.
- **Any other employee** – everyone else.

STUDY QUESTION

3. Name three diseases associated with asbestos exposure.

(Suggested Answer is at the end.)

Ventilation

IN THIS SECTION...

- Dilution ventilation is an alternative form of engineering control where the airborne concentration of a substance is kept to acceptable levels by changing the air volume (passively or with fans).
- Local Exhaust Ventilation (LEV) systems work by removing contaminated air at the point of generation and are made up of five basic parts: hoods, ducts, air cleaner, fan and discharge.
- LEV can be classified into three types, depending on the nature of the hood: enclosing, receiving and capturing.
- Other elements of the LEV system have to be carefully designed and selected to ensure correct and efficient operation.
- A range of air-cleaning devices can be used to remove contaminant from the captured air before discharge. Bag filters, cyclones, electrostatic precipitators and scrubbers are typically used for particulates; and tower scrubbers, incinerators and charcoal filters for gas and vapour.
- LEV systems capture contaminant from a specific zone adjacent to the inlet hood. If contaminant is generated by work outside of this capture zone then the contaminant will not be efficiently drawn into the LEV system.
- LEV systems must be subjected to thorough examinations and tests to ensure their ongoing effectiveness.
- This thorough examination comprises a three-stage process:
  - Stage 1 – visual examination of the system.
  - Stage 2 – quantitative assessment of performance by measuring parameters such as face velocity, transport velocity and static pressure. Devices such as anemometers, pitot tubes and manometers are used to measure these parameters.
  - Stage 3 – qualitative assessment of performance using dust lamps or smoke to visualise air movement.
- The resulting Report of Thorough Examination and Test must be interpreted and acted upon.

Introduction

We have already seen that the hierarchy of control measures available to prevent exposure to hazardous chemicals includes:

- Elimination of the substance or replacement with less toxic substances.
- Engineering controls, such as total enclosure and ventilation systems.
- Personal Protective Equipment (PPE).

Although elimination of the substance (e.g. by change of work method) or replacement of the substance with a less hazardous one are preferred options, in practice engineering controls and/or PPE are the measures most widely employed.

Replacement of hazardous chemical with less toxic ones helps prevent exposure to harm

Examples of commonly used engineering controls include:

- Dilution ventilation
- Local Exhaust Ventilation (LEV).

The third part of this element looks at these ventilation controls.

Dilution Ventilation

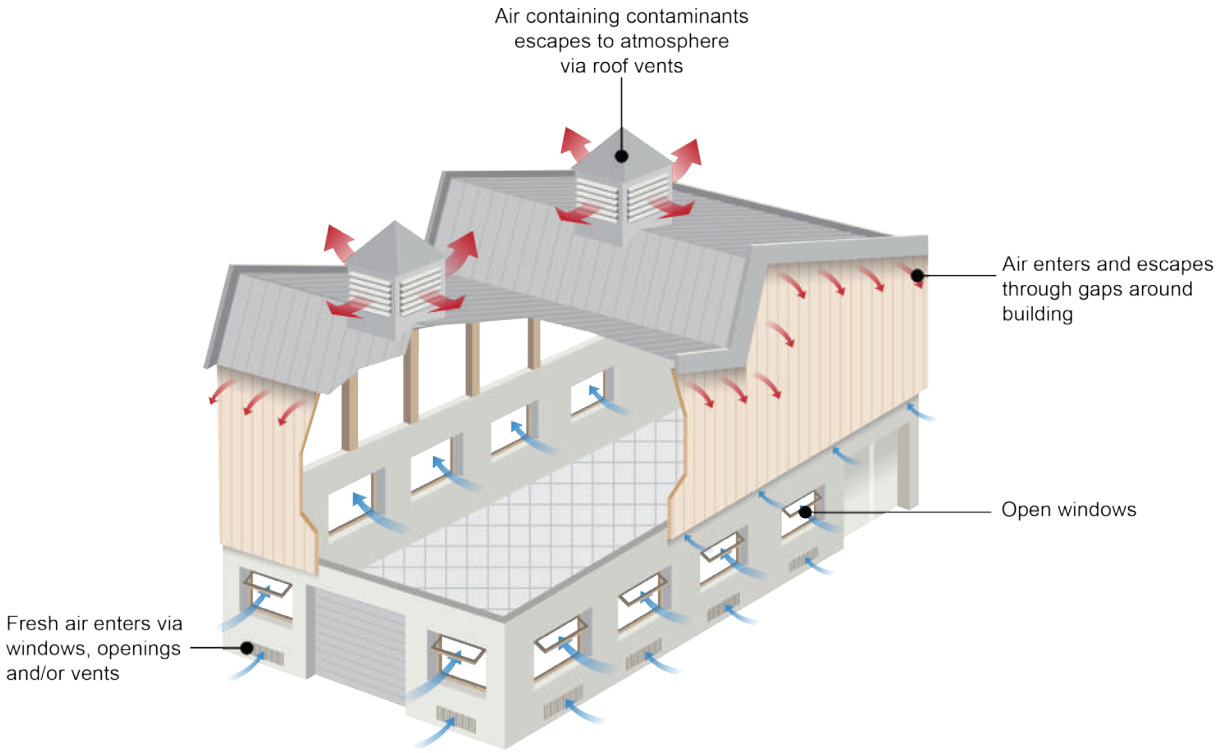
Dilution ventilation operates by simply diluting the contaminant concentration to an acceptable level. This is achieved by efficiently changing all of the air in a workplace over a given period of time, i.e. air changes per hour.

Dilution ventilation is sometimes achieved using a **passive** system, where natural air movement in a room or building is used. With **active** systems, workplace air is extracted by the use of fans set in the walls or roof.

These systems remove gaseous contaminants (sometimes fumes) and have two main applications; these are to:

- Reduce the concentration of a contaminant to below the occupational exposure limit.
- Keep the concentration of a flammable substance to below its lower explosive limit.

Where both a harmful and flammable substance is encountered, e.g. propanone (acetone), then achievement of the first objective will also control the second.



Passive dilution ventilation

Dilution ventilation has fairly limited use as an effective control strategy in occupational hygiene. However, it can be used with reasonable success, provided the contaminants conform, where applicable, to the following:

- The OEL of the harmful substance is high.
- The vapour pressure of any liquid hazardous substances is low, i.e. it has a low evaporation rate.
- The rate of formation of a gaseous product is slow.
- Operators are not in close contact with the contamination generation point.
- A hazardous substance is carried swiftly away from the operator, e.g. by hot gases.

When contaminants are to be removed from a workplace using dilution ventilation, two important criteria have to be considered:

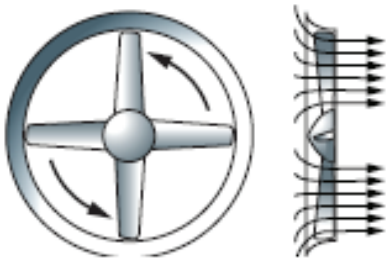
- The first is the **rate of contaminant generation** and hence the number of air changes per hour required.

  Relevant factors involved in contaminant generation of vapour from liquid include the:

  – Vapour pressure and potential to evaporate at the operating temperature of the system.
  – Surface area of the liquid surface in contact with the workplace air.
  – Potential increased surface area, e.g. contact adhesives generate vapour at a much greater rate after they have been spread over a surface.
- The other criterion is the **position of the extraction fans.**

The important factor that controls the positioning of the extraction fan unit is the density of the contaminant. The vapour density of many common solvents is greater than one (1), therefore they tend to layer over the lowest floor area in the workplace. For such conditions, fans should be positioned in the walls at a low level. Where there is a fire hazard, e.g. in the use of ethoxyethene (ether), the motors of the fans should be flameproofed to at least a zone 1 classification, i.e. an area where an explosive mixture is likely to occur during normal working.

Where the density is less than one (1), the contaminant will rise; for this situation, the fan must be positioned high on the workplace walls or in the roof. Simple propeller-type fans are used for dilution ventilation systems, as illustrated in the figure.



Propeller fan

Source: HSG258 Controlling airborne contaminants at work – A guide to Local Exhaust Ventilation (LEV), HSE, 2011 (www.hse.gov.uk/pubns/priced/hsg258.pdf)

A major problem in setting up an efficient dilution ventilation system is the formation of **dead areas**. These are areas in the workplace which, owing to the airflow pattern produced by the extraction fan and the inlet of make-up air, remain dormant and so the air is not changed. Dead areas can be detected by the use of smoke tracer tubes. A high density of smoke will remain in the unventilated areas.

A secondary problem with dead areas is that they can move from one position in the workplace to another. Such moves can be produced by changing inlet for the make-up air, i.e. in cold weather, the inlet may be spread over the workplace via the cracks in windows and doors. In hot weather, indiscriminate opening of doors and windows will produce a quite different flow pattern. Moving the position of machinery or workbenches can also cause the same problem. To help reduce the problem, controlled air make-up inlets can be constructed.

Where large quantities of air are being used to carry out the dilution process then consideration must be given to recycling heat losses from the workplace. It can be achieved by using heat exchange systems whereby make-up air is heated by the exhausted air.

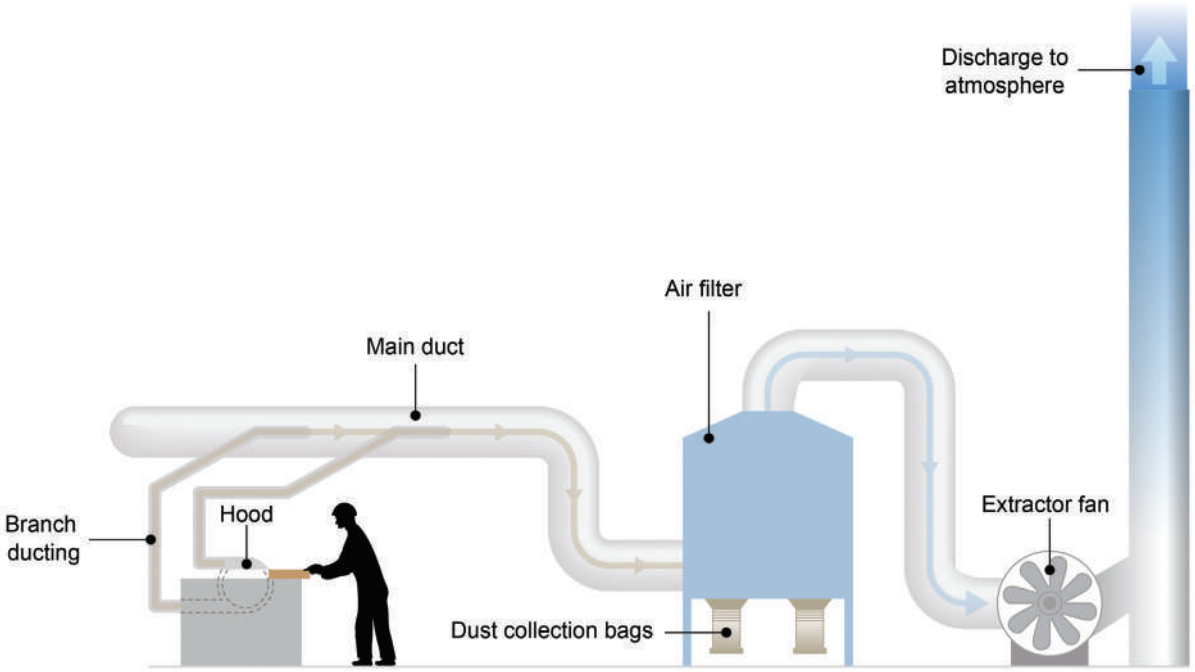
Local Exhaust Ventilation (LEV)

Local Exhaust Ventilation (LEV) operates by removing contaminated air at the point of generation and ducting it away from work areas. The contaminated air might then be cleaned and is then exhausted to atmosphere.

In general, a local exhaust ventilation system is made up of five main parts:

- **Hood(s)** – to collect airborne contaminants at, or near, where they are created (the source).
- **Ducts** – to carry the airborne contaminants away from the work area.
- **Air cleaner** – to filter and clean the extracted air.
- **Fan** – to deliver 'suck' to the hood.
- **Discharge** – for the safe release of cleaned, extracted air into the atmosphere.

A typical system is shown below.



A typical LEV system

LEV systems can be very small, such as those fitted to hand tools, or very large, such as a walk-in paint-spray booth. Various types and sizes of LEV systems are illustrated in the following figures.

On-tool extraction - soldering iron

On-tool extraction - hand sander

Fixed capturing hood

Moveable capturing hood

Small booth

Walk-in booth

Source: INDG408 Clearing the air - A simple guide to buying and using Local Exhaust Ventilation (LEV), HSE, 2008 (www.hse.gov.uk/pubns/indg408.pdf)

Hoods

LEV systems are often classified according to the type of hood used to receive the contaminant. Though hoods come in a wide variety of types these can be classified into three main categories; enclosing hoods, receiving hoods and capturing hoods.

- **Enclosing Hood**

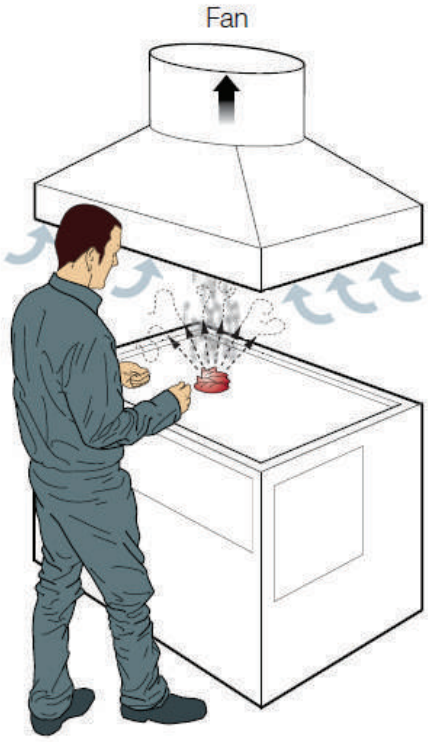
  These are the most effective hoods. A full enclosure is where the process is completely enclosed, e.g. a glove box. A partial enclosure contains the process with openings for material and/or operator access, e.g. walk-in booths and fume cupboards.

- **Receiving (Receptor) Hood**

  The process usually takes place outside the hood. The hood receives the contaminated air, which has a speed and direction that is usually process-generated. This speed and direction is taking the contaminated air into the hood. Hoods can be fixed or moveable. A canopy hood over a hot process is an example of a receiving hood.

An enclosing hood

Source: HSG258 Controlling airborne contaminants at work – A guide to Local Exhaust Ventilation (LEV), HSE, 2011 (www.hse.gov.uk/pubns/priced/hsg258.pdf)



A receiving hood

Source: HSG258 Controlling airborne contaminants at work – A guide to Local Exhaust Ventilation (LEV), HSE, 2011 (www.hse.gov.uk/pubns/priced/hsg258.pdf)

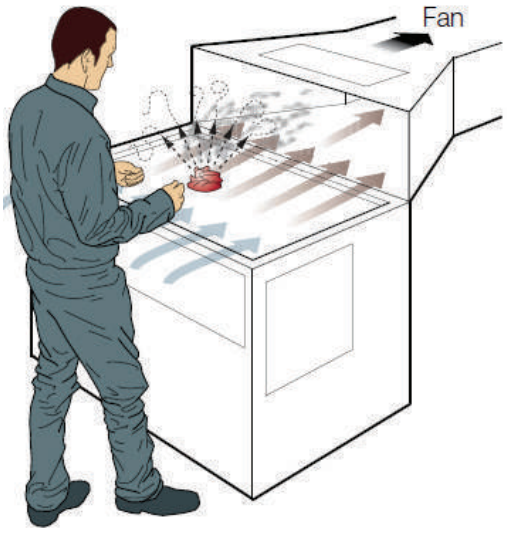
- **Capturing (Captor) Hood**

  The process, source and contaminant cloud are outside the hood. The hood has to generate sufficient airflow to 'capture' and draw in the contaminated air. Hoods can be fixed or moveable. This is the most common type of LEV hood.

Within these three categories, there are many different types of design to suit different workplace applications and types of contaminant.

Some general principles can be applied to LEV hood design:

- Enclose the source of the contaminant as much as possible as this increases LEV effectiveness significantly.
- Position the hood as close as possible to the contaminant source and in a way to take advantage of the speed and direction of the contaminated air.
- Match the hood size to the process and contaminant cloud size.
- Keep the contaminant cloud away from the worker's breathing zone; inhalation of contaminated air must be minimised.
- Minimise eddies within the hood.
- Make sure the hood is comfortable to use and practical for the way the worker actually does the job.
- Trial and test LEV before putting into full use.



A capturing hood
Source: HSG258 Controlling airborne contaminants at work – A guide to Local Exhaust Ventilation (LEV), HSE, 2011 (www.hse.gov.uk/pubns/priced/hsg258.pdf)

Ducting

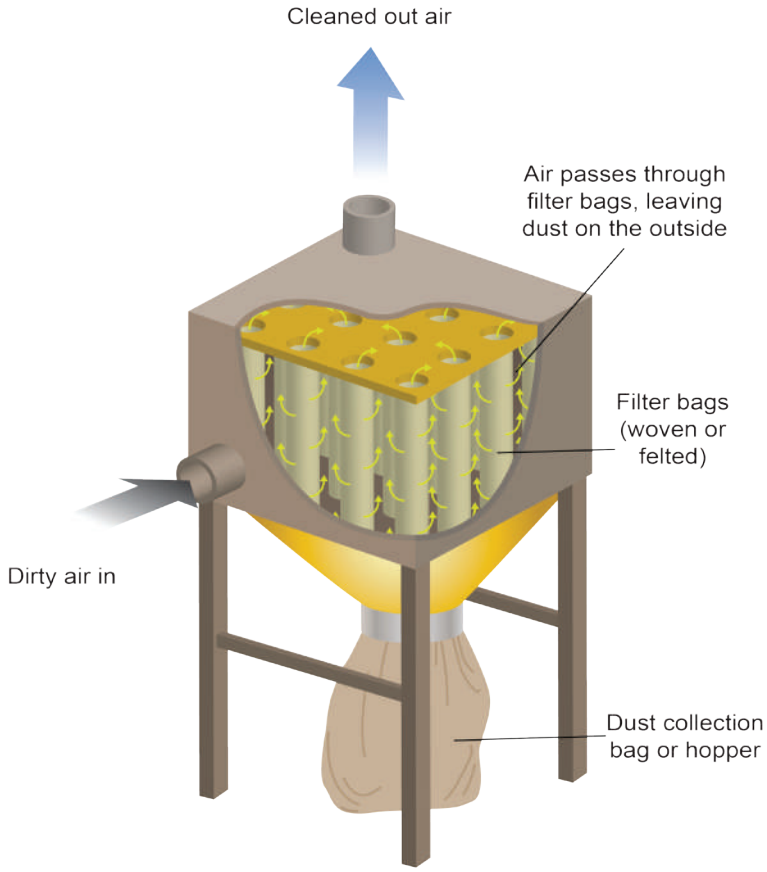
Ducting should be as straight as possible. Where bends or joins are required, gentle bends and acute angle joins are good practice. Ducting should be well supported and care taken to see that where solids are extracted, airflow is sufficient to prevent deposition of solids, which might cause the system to collapse. Access ports should be provided to allow for regular cleaning.

Examples of good and bad duct design
Source: HSG258 Controlling airborne contaminants at work – A guide to Local Exhaust Ventilation (LEV), HSE, 2011 (www.hse.gov.uk/pubns/priced/hsg258.pdf)

The design of the junction on the left allows air to flow smoothly down both ducts and meet with minimal turbulence. The design on the right has a right angle T junction which will cause turbulence as the two airstreams meet.

Filter or Purifying System

It is important that the appropriate system is used especially if neutralising toxic gases. For particulate solids, physical methods of separation are required, such as cyclones or bag filters. Care must be taken to see that the correct type of filter is used (e.g. cyclones are not suitable for very fine particles). Owing to the dynamic nature of cyclones and the resultant generation of static electricity, the potential for dust explosions can be high.



A Bag Filter - one of the simplest filtration methods used in LEV systems

Source: HSG258 Controlling airborne contaminants at work – A guide to Local Exhaust Ventilation (LEV), HSE, 2011 (www.hse.gov.uk/pubns/priced/hsg258.pdf)

Ideally, the air cleaner will remove contaminants to well below any relevant WEL or other OEL. Total removal of the contaminant is rarely possible.

There is a wide variety of cleaning devices suitable for different applications. The choice of device use depends on many factors, the most important of which is the nature of the contaminant.

The most common group of air cleaning devices is **paricle collectors.** These fall into four types:

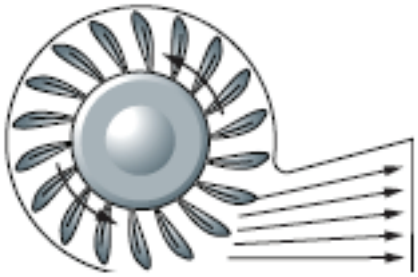
- **Fabric filters** – which use socks or bags to filter out the particulates in much the same way as a bag-style domestic vacuum cleaner does.
- **Cyclones** – cone-shaped collectors that use centripetal force to spin particles out of the contaminated airflow (as used in a Dyson vacuum cleaner).
- **Electrostatic precipitators** – that give particles an electrostatic charge and then attract them out of the airstream using plates with the opposite charge.
- **Scrubbers** – where the particles are wetted and then washed out of the airstream.

The alternative group of air-cleaning devices are **gas and vapour collectors**. These fall into three main types:

- **Destruction** – where the gas and vapour is destroyed by burning or thermal oxidation.
- **Tower scrubbers** – where the contaminated air is passed through a vertical column containing a matrix through which water is passed – this removes the contaminant from the airstream.
- **Recovery** – where the gas or vapour is filtered out (often using activated charcoal filters) and can then be reclaimed.

Ventilation Fans and Motors

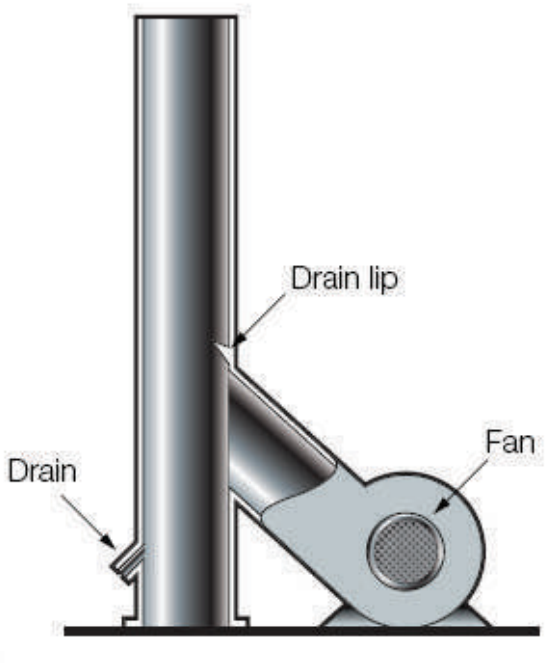
It is important that the correct type of fan is installed to suit the design of the ventilation system. The capacity of the fan motor is important; it must have sufficient power to cope with normal working but have sufficient margin to deal with overload situations. Centrifugal fans, as shown in the following figure, are typically used in LEV systems.



A centrifugal fan
Source: HSG258 Controlling airborne contaminants at work – A guide to Local Exhaust Ventilation (LEV), HSE, 2011 (www.hse.gov.uk/pubns/priced/hsg258.pdf)

Discharge to Atmosphere

Extracted air must not re-enter buildings unless the contaminant has reached negligible concentrations. Discharged air must leave the discharge duct at a high enough speed to make sure it is dispersed. Discharge is normally via a 'stack'.



Typical stack design
Source: HSG258 Controlling airborne contaminants at work – A guide to Local Exhaust Ventilation (LEV), HSE, 2011 (www.hse.gov.uk/pubns/priced/hsg258.pdf)

Extracted air must not re-enter buildings after discharge unless the contaminant has reached negligible concentrations. The position of the discharge point (exhaust stack) and the velocity and direction of the discharged air are therefore important.

Buildings have a boundary layer of air around them where eddies occur. If the discharged air is exhausted into this boundary layer then contaminated air can be re-circulated back into the building. Therefore, tall stacks are preferred.

There may be building control and planning issues associated with the building of tall stacks. There may also be local and regional environmental legislation that will apply to any pollutants released from the LEV system into the environment.

Source Strength, Capture Zones and Capture Velocity

Worker exposure depends on many things, including source strength and the distance from the source. Source strength is the combination of the volume rate of release of the contaminant cloud, the cloud volume, shape and speed, and the concentration of the contaminant.

Two important characteristics of any LEV system are the capture zone and the capture velocity. The capture zone is the area around the inlet to the LEV system that the system is extracting contaminated air from. Capture velocity is the velocity required at a contaminant source to overcome the movement of the contaminant cloud and draw it into the hood. Fast-moving contaminant clouds are very difficult to control with a capturing hood. They normally require a partial enclosure or receiving hood.

Example capture velocities are given below.

Contaminant cloud release	Example of process	Capture velocity range, m/s
Into still air with little or no energy	Evaporation, mist from electroplating tanks	0.25 to 0.5
Into fairly still air with low energy	Welding, soldering, liquid transfer	0.5 to 1.0
Into moving air with moderate energy	Crushing, spraying	1.0 to 2.5
Into turbulent air with high energy	Cutting, abrasive blasting, grinding	2.5 to >10

Based on table from HSG258 Controlling airborne contaminants at work – A guide to Local Exhaust Ventilation (LEV), HSE, 2011 (www.hse.gov.uk/pubns/priced/hsg258.pdf)

Since the actual velocity achieved at a capturing hood is determined by the shape of the hood, the rate of airflow into it and the distance from the inlet at which the velocity is measured, it is important that the capture velocity for a contaminant is known so that the correct specification of capturing hood can be determined.

The pictures illustrate how distance away from the hood influences the amount of contaminant captured.

The dust produced has a particular capture velocity above which it will be drawn into the LEV, but below which it will not be effectively extracted.

As the working zone (where the chisel is being used, in the previous example) moves away from the LEV hood, so the actual velocity of air achieved in that zone drops. The area indicated by the yellow dotted line is the capture zone inside which the dust will be effectively extracted.

Capture velocity is not normally measured as a part of routine LEV testing, since it is a property of the contaminant and forms a part of the initial design specification for the LEV.

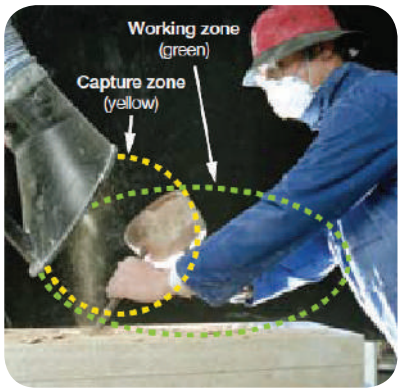
LEV Thorough Examinations

A new LEV system should be carefully examined and tested as part of the commissioning procedure to ensure it is able to meet its design specification:

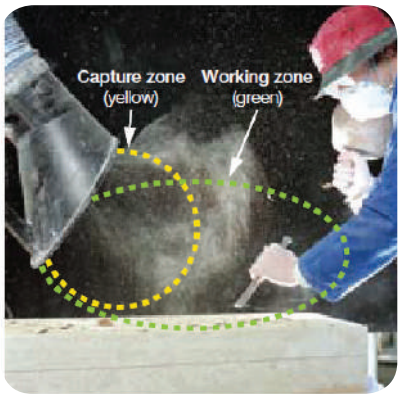
- All hoods should be examined in detail to ensure they effectively capture or contain the contaminant. This may be done by using smoke generation to follow the airflow around a hood or by taking airflow measurements.

- Manometers (pressure gauges) or U-tubes (see later) can be used to measure static pressures at hoods or enclosures. They can also be used to measure pressure drops across filters or air-cleaning plant. The measurements will confirm the suitability of airflow distribution and agreement with the design specification.
- Where the LEV system is designed to extract dust, it should be checked for duct velocity to ensure that ducts will remain free of dust settlement.
- The air-cleaning plant and fan should also be checked for compliance with the design specification.

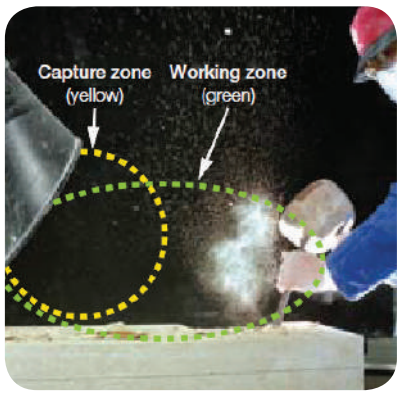
These measurements will also form a basis on which performance is assessed during routine checks and **statutory examination and testing**.



Effective



Partly effective



Ineffective

Based on extract from HSG258 Controlling airborne contaminants at work – A guide to Local Exhaust Ventilation (LEV), HSE, 2011

(www.hse.gov.uk/pubns/priced/hsg258.pdf)

Legal Requirements

There may be specific legislation that requires the routine thorough examination and test of LEV systems. In the UK regime, for example, the **Control of Substances Hazardous to Health Regulations 2002 (COSHH)**, requires the thorough examination and test at least once in every 14 months. Similar basic requirements for inspection and testing of LEV are contained in the **Control of Lead at Work Regulations** (14 months) and the **Control of Asbestos Regulations** (6 months).

For certain processes, such as blasting of metal castings, a more frequent examination interval may be specified.

The examination and test is to ensure that the control measures continue to perform as originally intended.

The statutory thorough examination and test must be carried out by a competent person. This is usually an external contractor but can be an engineer working for the employer (LEV owner). Competent in the context of an LEV test engineer may mean possessing qualifications through recognised accrediting institutions or authorities, such as British Occupational Hygiene Society (BOHS), Chartered Institution of Building Service Engineers (CIBSE) or the associated Institute of Local Exhaust Ventilation Engineers (ILEVE). There is a UKAS accreditation scheme for LEV Thorough Examination and Test (TExT) that can also be used as proof of competence.

Three Stages to Carrying Out Testing

Stage 1 – Visual Inspection of LEV

LEV systems have to be maintained in efficient working order. One of the ways in which the performance of an LEV system can be checked is by visual inspection. This gives a qualitative indication of performance.

A **visual inspection** of an LEV system might include examination of:

- All external parts of the system for damage, wear and tear.
- Internal duct and hatch seals.
- Filter material and any built-in filter pressure gauges.
- Filter cleaning devices to ensure they work properly.

- Water flow and sump in a wet scrubber.
- Monitors and alarms fitted to the system.
- The fan and associated drive mechanism, e.g. fan belt.

In particular, indications of ineffectiveness are looked for, such as:

- Deposits of settled dust in and around the LEV hood.
- Excessive system vibration or noise.

The exact nature of any visual inspection carried out as a check on LEV would vary, depending on the type of LEV, the frequency of the check and the competence of the person carrying it out. For example, a machine operator might be tasked with carrying out a daily visual check of the external parts of a system prior to use.

During a **statutory thorough examination** of LEV, the first stage of the process would be a visual examination of all of the above matters.

Stage 2 – Measuring Technical Performance

Quantitative methods are used to measure the technical characteristics of the LEV system for comparison against its design specification.

Type of contaminant	Indicative transport velocity, m/s
Gases and non-condensing vapours	No minimum value
Condensing vapours, fume and smoke	Up to 10
Low or medium density, low moisture content dusts (plastic dust, sawdust), fine dusts and mists	Up to 15
Process dust (cement dust, brick dust, wood shavings, grinding dust)	Around 20
Large particles, aggregating and damp dusts (metal turnings, moist cement dust, compost)	Around 25

Transport Velocity

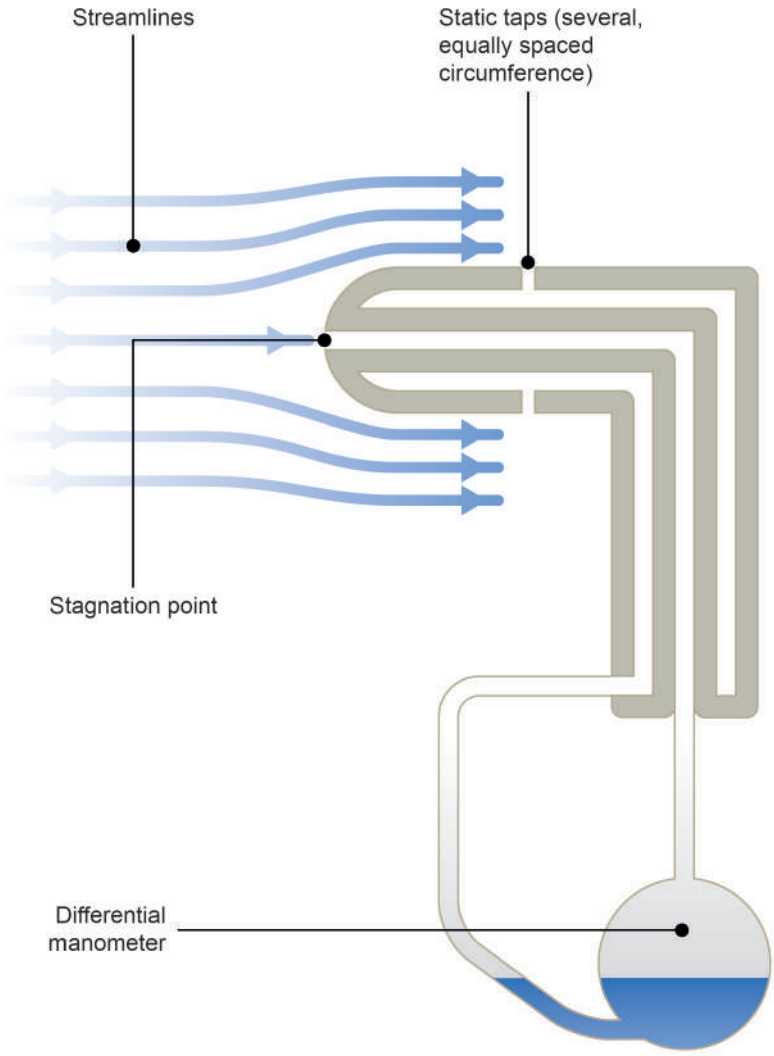
Transport velocity is the air velocity required to convey particles and prevent deposition in ducts. LEV will often have a transport velocity (or duct velocity) stated in its specification most particularly when it is used to extract dust, fumes or fibres.

The transport velocity is an important parameter to measure because, if the airflow velocity in ductwork falls too low, particles will no longer be transported through the system and will be deposited in the duct. Example transport velocities are given in the following table.

Airflows in ducts can be measured using the same equipment and technique as for face velocity. The main problem is inserting the anemometer into the duct.

Another device that provides a useful alternative due to its small size is the **pitot tube**. This is a device that measures velocity pressure inside the ventilation system, i.e. the pressure caused by the movement of air in the duct. The reading is then converted to velocity using a simple formula.

The measuring head consists of two concentric tubes, one facing and one at right angles to the airflow. The tubes are connected to each side of a manometer and so measure the pressure difference between the static pressure in the duct and that generated by the airflow.



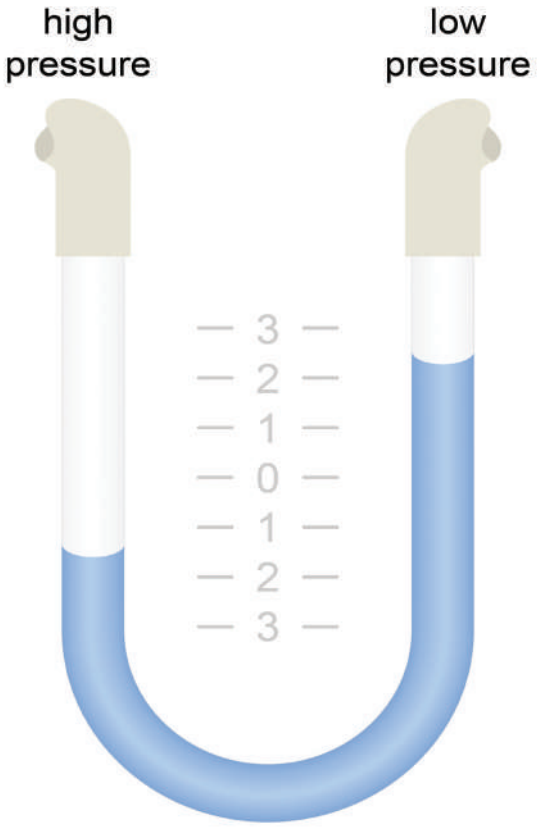
Pitot tube

Static Pressure

Static pressure is the air pressure, measured perpendicular to the airflow direction, i.e. the difference between inside and outside air pressure. Static pressure is frequently used in the specification of all types of LEV and is routinely measured as one of the indicators of performance.

Static pressure is measured using a pressure gauge, of which there are several types, such as:

- **Manometer** - a device that measures pressure by displacing a column of liquid in a **U-shaped tube**. The manometer is calibrated so that liquid displacement can be related to actual static pressure. A point to note is that the manometer always measures a pressure difference. If the end of the manometer is open, it measures pressure relative to atmospheric pressure. If the manometer is connected across a filter, it will measure a pressure drop, which gives some indication of the obstruction to the airflow across the filter and therefore how blocked the filter might be.



U-tube manometer

- **Diaphragm gauge** - which gives a reading on a dial as a result of direct pressure on a diaphragm.

  In addition to all of the parameters detailed above, the characteristics of the **fan** (such as speed of rotation) can also be used to quantify performance.

  The ultimate proof of satisfactory performance of any exhaust ventilation system is that it maintains an acceptable work environment where atmospheric concentrations of airborne contaminants are kept below occupational exposure limits. Consequently, **periodic air monitoring** or even continuous monitoring will confirm that effective protection is being maintained and will identify signs of deterioration so that remedial action can be taken before harm occurs.

Face Velocity

Face velocity is the average velocity of air at the open front face of a hood or booth. LEV will often have a face velocity stated in its specification.

Face velocity is measured using an **anemometer**.

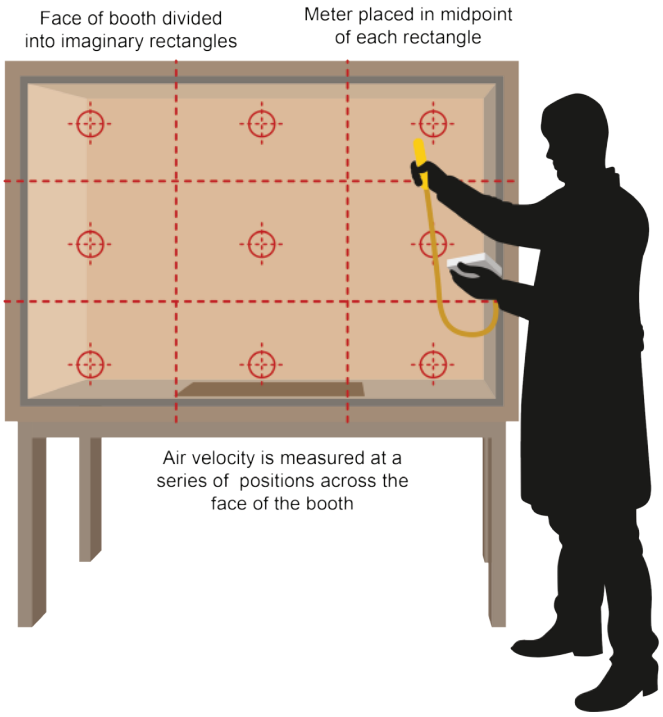
Three types of anemometer are typically used:

- The **rotating vane anemometer** is like a small windmill, usually between 25 and 100mm in diameter and enclosed in an annular shroud.
- The **heated head anemometer** relies on the airflow to cool a sensitive head which consists of a hot wire, thermocouple or thermistor. The degree of cooling is related to the air velocity. A cowl is used to direct the airflow across the head, which is usually quite small.

- The **deflecting vane anemometer** (or **swinging vane anemometer**) features a moving element consisting of a pointer and a vane mounted on a taut-band suspension. The vane is able to swing inside an air chamber, where its movement creates very little friction. The flow through the anemometer is created by the velocity pressure at the point being measured. This type of anemometer is able to operate without batteries or a power source.

The method of measuring face velocity is:

- The face of the inlet is divided up into an imaginary grid of dimension 100 to 150mm square.
- The air velocity is measured at the centre of each imaginary rectangle on the face of the inlet and the results noted on a sketch.
- Readings can be averaged and each reading compared to the average to note the degree of variation.
- Variations over 20% of the average indicate that the airflow distribution is uneven and requires adjustment.



Measuring face velocity using an anemometer

Stage 3 – Assessing Control Effectiveness

Qualitative techniques are used to assess the effectiveness of the LEV system. These often involve the visualisation of air movement using different techniques.

Dust Lamp (Tyndall Illumination)

Most dust particles are too small to be seen with the naked eye, particularly those which are inhalable or respirable.

So, under normal lighting conditions, it is difficult to detect a dust cloud visually.

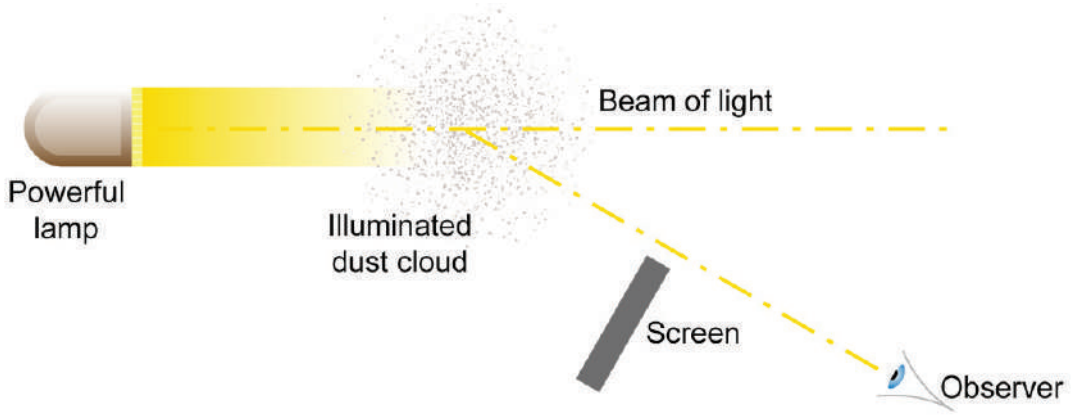
The Dust Lamp (or Tyndall lamp) is a device that allows dust particles to be visualised. This allows identification of:

- A dust emission which is taking place.
- The behaviour and direction of the dust cloud, in order to determine whether it is likely to enter a worker's breathing zone.

The principle of this technique is based on the phenomenon that most of us have observed when a strong shaft of sunlight enters a room and suddenly we can see clouds of house dust particles that were not visible before. The light beam is reflected from the dust particles and makes them readily visible (known as the Tyndall effect).

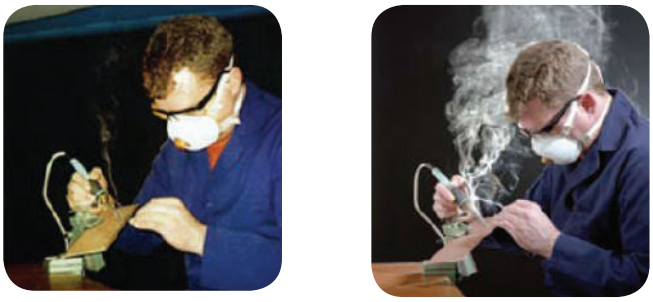
The method of use is:

- A powerful parallel-beamed light, supported on a tripod, is used to illuminate the suspected dust cloud.
- The dust cloud is viewed from a direction slightly oblique to the main light beam and a screen is used to shield the image of the lamp itself (see diagram).
- The dust cloud can be observed directly or photographed.



Illumination of a dust cloud using the Tyndall Effect

Although no numerical measurements are made, the equipment enables us to observe exactly how and where the dust is generated. Its main use is to see how well extract ventilation systems are working and what effect any changes to the system have if unsatisfactory capture is observed.



Photographs of a soldering operation

Source: HSG258 Controlling airborne contaminants at work – A guide to Local Exhaust Ventilation (LEV), HSE, 2011 (www.hse.gov.uk/pubns/priced/hsg258.pdf)
Left - normal workplace lighting conditions
Right - with Tyndall illumination
Note how the tiny respirable particles in the metal fume are made visible by the dust lamp

Smoke

Smoke can be artificially produced and released into a work area to visualise air movement and to simulate the movement of particles. Smoke can be produced from pellets, smoke tubes or smoke generators.

- Smoke tubes produce a small amount of smoke as a single cloud. Some produce an acidic mist. They are often useful for testing smaller hoods.

- Smoke generators can produce variable amounts of smoke for prolonged periods. They use oil, propylene glycol, etc. that can leave residues. They are usually unsuitable where smoke detectors are fitted, unless these can be isolated. Smoke generators have many uses, including assessing the effectiveness of large enclosing hoods.
- Smoke pellets produce a moderate amount of smoke for a short period. They are inappropriate with flammable substances nearby. They are useful for testing canopies and flues.

Report on LEV Testing

Following the test, the examiner will stick a label on each hood of the LEV system detailing when it was tested and when it should be re-tested. Red FAIL labels are stuck to hoods that fail to pass the test. The examiner must record information on each test and pass this to the employer.

Records must be kept for five years.

For LEV, the following information must be kept as a record of each thorough examination and test:

- Name and address of employer responsible for the plant.
- Identification and location of the LEV plant, process, and hazardous substance concerned.
- Date of last thorough examination and test.
- Information about the LEV plant which shows:
  - Its intended operating performance for controlling the hazardous substance.
  - Whether the plant continues to achieve the same performance.
  - If not, the repairs required to achieve that performance.
- Methods used to make the above judgments, e.g. visual pressure measurements, airflow measurements, dust lamp, air sampling and filter integrity tests.
- Date of examination and test.
- Name, designation and employer of person carrying out the examination and test.

Interpretation of Reports

During the interpretation of reports, there is a number of general issues that should be checked, to see whether:

- An appropriate strategy and method of sampling has been used.

  Standard strategies and methods are published by the HSE and other authorities (such as the World Health Organisation (WHO)). Where these exist, they must be adhered to in order to ensure the scientific and legal validity of any result obtained.

- The equipment used was appropriately maintained, certificated and calibrated.
- The assessment was carried out at a place and time that would give results representative of real workplace conditions (this requires an understanding of the types and patterns of work that the engineer may not have a full appreciation of).
- The results have been correctly evaluated against the correct legal standards. These can be checked by reference to relevant documents, such as **legislation and international standards**.

LEV Roles and Responsibilities

There are several key roles relevant to LEV systems and it is important that each party recognises their role and the responsibilities that go along with it, with regards to LEV systems:

- **LEV owner** – this will be the party who owns and operates the LEV system. This is normally the employer in charge of the workplace or work activity that is using the LEV system.

- **LEV supplier** – this will be the party or parties who design and then install the LEV system for the owner. LEV systems must be designed to meet the specific needs of the work activity. They will, therefore, be designed to a specification. Installers must ensure that LEV systems are built to the design specification and they must then commission the LEV system to ensure that it achieves the intended specification in terms of performance.
- **LEV service provider** – this is the test engineers (or company) responsible for examining and testing the LEV system, either for commissioning purposes or for routine statutory thorough examination and test purposes.

All of the above parties must be competent to fulfil their roles and they must communicate and co-ordinate their activities to ensure the LEV system is designed, installed, commissioned and maintained in safe and efficient working order.

Inevitably, there may be an overlap of roles, e.g. the 'LEV owner' may also be the 'LEV service provider'; a company owning and operating several LEV systems might carry out their own internal inspection, testing and maintenance.

STUDY QUESTIONS

4. Explain what is meant by dilution ventilation and comment on its value as a measure to control contaminants.
5. Explain why it is important to monitor the performance of an LEV system.
6. Describe why a manometer might be used to measure the pressure drop across the filter in an LEV system.
7. State the information to be included in a report of thorough examination and test of an LEV system.

(Suggested Answers are at the end.)

Personal Protective Equipment

IN THIS SECTION...

- Personal Protective Equipment (PPE) is commonly used to control exposure to hazardous substances.
- Under the relevant regulations, PPE must be suitable (appropriate, ergonomic, correct fit, CE-marked) and compatible with other PPE worn.
- Respiratory Protective Equipment (RPE) is commonly used to control inhalation of airborne contaminants.
- RPE can be categorised into two main types: respirators and Breathing Apparatus (BA).
- Respirators come in many different forms but can be generally classed as half-mask, full-face or powered. Different variations of each type can give protection against both particulates and gases.
- Breathing apparatus also comes in many forms, but can be classed as fresh air hose, compressed airline or self-contained.
- The level of protection offered by RPE is indicated by the Assigned Protection Factor (APF), a measure of the ratio of contaminant inside to outside the face-piece.
- The APF can be used in combination with contaminant concentrations and WELs to indicate the degree of protection offered by an item of RPE and hence its suitability.
- When selecting RPE, the following factors must be considered:
  - Atmosphere and substance-related factors, such as potential for oxygen deficiency.
  - Task and work area-related factors, such as work rate and duration.
  - Wearer-related factors, such as fit/comfort and acceptability.
- Most items of RPE require some form of face-fit test to ensure that an adequate seal exists between the item and the wearer's face.
- Skin is often protected from hazardous chemicals using clothing such as gloves.
- Gloves must be carefully selected to ensure their suitability. Several characteristics of gloves need to be understood to make an informed choice; breakthrough time, permeation rate and degradation rating.
- Reference should also be made to the relevant standard.
- Eye protection, in the form of safety spectacles, goggles and face shield, is also frequently used to give protection from hazardous substances and must be carefully selected with reference to relevant standards.
- When selecting skin and eye protection, the following factors must be considered:
  - Substance-related factors, such as compatibility with the chemical against which protection is required.
  - Task-related factors, such as duration of operation and breakthrough times.
  - Wearer-related factors, such as fit/comfort and acceptability.

Introduction

Personal Protective Equipment (PPE) is commonly used as a control measure where workers are at risk of exposure to hazardous substances.

In the following section, we examine three different types of PPE that are particularly relevant to hazardous substances: Respiratory Protective Equipment (RPE), skin protection and eye protection.

PPE is a common control measure

Respiratory Protective Equipment (RPE)

The use of Respiratory Protective Equipment (RPE) to prevent the inhalation of harmful airborne contaminants constitutes an extensive subject in its own right, so here we shall concentrate on the various types of respiratory protection available and the factors affecting selection. An important point to note about respiratory protection is that there are two fundamentally different types:

Respirators use filters to remove contaminants from the air being breathed in. They can be either:

- non-powered respirators – relying on the wearer's breathing to draw air through the filter; or
- powered respirators – using a motor to pass air through the filter to give a supply of clean air.

The main issues affecting choice of respirator are:

- The suitability of the purifying medium, i.e. filtration of dust particles and absorption of gases and vapours.
- How well it purifies the air, i.e. efficiency and protection factor.
- Leakage of contaminant into the respirator, i.e. face fit and seal.

- **Breathing Apparatus (BA)** supplies pure respirable air from an uncontaminated source (such as an air cylinder).

  The main issues affecting choice of BA are:

  - Ergonomic matters arising from the work and location of use.
  - The duration of use.

  Respirators and BA are available in a range of styles, dividing into two main groups:

- **Tight-fitting face-pieces** (often referred to as masks) rely on having a good seal with the wearer's face. These are available as both non-powered and powered respirators and BA.

  A face-fit test should be carried out to ensure the RPE can protect the wearer.

- **Loose-fitting face-pieces** rely on enough clean air being provided to the wearer to prevent contaminant leaking in (only available as powered respirators or BA). Examples are hoods, helmets, visors, blouses and suits.

DEFINITIONS

PERSONAL PROTECTIVE EQUIPMENT (PPE)

"...means all equipment (including clothing affording protection against the weather) which is intended to be worn or held by a person at work and which protects him against one or more risks to his health or safety, and any addition or accessory designed to meet that objective."

The UK's **Personal Protective Equipment at Work Regulations 1992**

SUITABLE

- It is appropriate for the risks involved, the conditions where it will be used and the duration of time over which it will be worn.
- It takes account of ergonomic factors and the health of the user.
- It fits the user.
- It controls specific risk without increasing overall risk.
- It is CE marked and complies with any relevant standards (in accordance with the **Personal Protective Equipment Regulations 2002**).

Types of Respirator

Half-Mask Respirator

This type of face mask covers the nose and mouth only, leaving the eyes exposed. Half-mask respirators can be subdivided into two types:

- particle filters, and
- gas filters.

The simplest form of half-mask respirator is the **disposable half-mask type**. This consists of a piece of filtering material worn over the nose and mouth and secured by twin elastic headbands. A flexible metal strip enables the user to bend it over the bridge of the nose to fit. A typical example is illustrated in the illustration.

Disposable half-mask – particle filter

Source: HSG53 Respiratory protective equipment at work – A practical guide, HSE, 2013 (www.hse.gov.uk/pubns/priced/HSG53.pdf)

The simple structure is designed to provide a cheap, disposable unit. They are light to wear, permit ease of breathing and speech, do not interfere excessively with vision and can be worn with eye protection but are only designed to protect against particles. **Disadvantages** are that:

- An adequate face-fit test (see later) cannot be carried out.
- The face seal cannot be fully achieved over beards.
- It can be uncomfortable to wear due to moisture build-up on the filter material.
- Used respirators may need a safe disposal procedure.

Other types of **half-mask respirators** are made with a flexible rubber or plastic face-piece which covers the nose and mouth, fitted with a replaceable **cartridge filter** to remove the airborne contaminant. Filters are available to protect against particles and gas/vapour.

Some respirators have a single cartridge, others have twin cartridges. The respirator is strapped to the head with adjustable headbands. Exhaled air is released through non-return exhaust valves.

See the following illustration.

Re-usable half-mask – particle filter

Re-usable half-mask – gas/vapour filter

Source: HSG53 Respiratory protective equipment at work – A practical guide, HSE, 2013 (www.hse.gov.uk/pubns/priced/HSG53.pdf)

A worker wears a half-mask respirator to seal asbestos lagging around a pipe

Face seal is achieved in good quality respirators by the use of a pneumatic cushion around the outer edge. As with disposable respirators, beards and unshaven faces reduce face-fit efficiency.

Cartridge-type half-mask respirators can be used for protection against particles or gas and vapour, so cartridges are colour-coded by manufacturers to help reduce the possibility of their incorrect use. Manufacturers also provide charts to indicate the correct type of cartridge for specific hazards.

Owing to the quite substantial structure of half-mask respirators and the cartridge protection system, breathing is not easy, speech communication is reduced and vision is slightly impaired, especially in twin-cartridge types.

MORE...

Simple guidance on respirators aimed at employees is contained in the UK HSE pocket card INDG460 *Is your mask protecting you?* which is available at:

www.hse.gov.uk/pubns/indg460.pdf

Another issue with the use of cartridge filters is not knowing when their working life has ceased.

Full-Face Respirator

This type of face mask covers the nose and mouth in a face-piece and has a visor with full-face seal to completely enclose the eyes and much of the face.

Full-face respirators can be subdivided into two types:

- particle filters, and
- gas filters.

They have replaceable cartridges and the face-piece is secured to the head by a set of flexible, adjustable headbands. Wide vision is provided in most modern face masks by a large tough Perspex visor.

Full-face mask – particle filter

Full-face mask – gas/vapour filter

Source: HSG53 Respiratory protective equipment at work – A practical guide, HSE, 2013 (www.hse.gov.uk/pubns/priced/HSG53.pdf)

The main reason for choosing a full-face respirator over a half-mask respirator is that the former offers eye and face protection. There will be various work scenarios where this might be necessary, e.g. when the work activity involves exposure to an irritant vapour or dust that will irritate the eyes and cause tear production (which in turn will cause the nose to run – not great when wearing a respirator of any type). Alternatively, it might be necessary to protect the eyes simply from nuisance dust.

One of the most significant drawbacks with all of the above respirators is that, in order to draw air in through the filter, the wearer has to breathe in. This creates negative pressure inside the face-piece. Any leaks (due to poor face-fit or damage) will allow contaminated air inwards because of this negative pressure.

Powered Respirators

With this type of respirator, air is pumped into the face-piece, so alleviating the problem of negative pressure. This positive air pressure also reduces user fatigue and allows longer work periods between rests.

There are **two main designs** for the system:

- **Masks** - full- or half-masks connected directly or by flexible tube to a centrifugal pump, which draws air through a filter.
- **Helmets** - with a wide-vision, high-impact visor secured to the head by a harness and chin strap. The system is loosely sealed by a fabric skirt around the neck and over the shoulder. A motorised fan set in the helmet or on a belt draws contaminated air through a filter. The motors are usually powered by re-chargeable batteries.

Powered mask

Powered helmet

Source: HSG53 Respiratory protective equipment at work – A practical guide, HSE, 2013 (www.hse.gov.uk/pubns/priced/HSG53.pdf)

Types of Breathing Apparatus (BA)

Breathing Apparatus (BA) can be classified into three general categories.

Fresh Air Hose BA

Fresh air hose BA can be described as a breathing apparatus that provides a supply of **unpressurised** fresh air from an uncontaminated source. The user is connected to a fresh air supply by an air hose of up to 20 metres and draws air through by breathing effort. The system is not self-contained, so it enables work to be carried out over an indefinite period, provided it is only a short distance from fresh air.

Fresh air hose breathing apparatus

Source: HSG53 Respiratory protective equipment at work – A practical guide, HSE, 2013 (www.hse.gov.uk/pubns/priced/HSG53.pdf)

The apparatus usually consists of a full-face mask with a short length of wide-bore hose joined to a metal elbow, secured to a waist belt. The wire-reinforced air hose is connected to the elbow and the free end secured in uncontaminated air. Breathing air down the length of hose can be difficult (especially if it is kinked). This can be overcome to a degree using fan-assisted face masks or powered hoods.

Compressed Airline BA

Compressed airline BA is similar in design to fresh air systems but the respirable air comes from a compressed air source. The compressed air supply may be from a cylinder or from a compressor. Cylinders are often mounted on a trolley and provide a mobile supply unit. Air from compressors is more usual in static situations where it can be piped around a site with outlet connectors at convenient points.

As the supply uses higher pressures than fresh air systems, much smaller and longer supply hoses can be used, up to 80 metres for some. The airline can be connected via a pressure-reducing valve to full or half face-piece respirators, hoods, coverall suits or protective visors. Positive pressure helps to reduce work-rate fatigue and the ingress through leaks of harmful airborne contaminants.

Powered helmet

Source: HSG53 Respiratory protective equipment at work – A practical guide, HSE, 2013 (www.hse.gov.uk/pubns/priced/HSG53.pdf)

A very important safety control for compressed airline systems is the purity of the air. Filters must be incorporated into the system to prevent contamination from dusts, toxic and corrosive gases, and vapours. The filters must be situated to control flow of air to the user and for control of air into the inlet of a compressor unit.

Compressed airline systems give complete respiratory protection in dusty, toxic and oxygen-deficient atmospheres.

There are two types of respirator design for compressed airline systems:

- The **constant flow BA**, which receives a continuous flow of air from the supply. Any air not used for respiration is exhausted from the face-piece. This system is used only where there is a compressor supply considered to be inexhaustible. It cannot be considered a very economical way to use compressed air.
- The **demand flow BA**, which is a very economical system in that respirable air only flows into the mask when the user inhales.

Self-Contained BA (SCBA)

Self-Contained Breathing Apparatus (SCBA) provides air or oxygen to the user from cylinders or some other form of container which is carried in a harness on the user's chest or back. The system provides respiratory protection in toxic, corrosive, dusty and oxygen-deficient atmospheres (see following figure).

Demand valve breathing apparatus

Source: HSG53 Respiratory protective equipment at work – A practical guide, HSE, 2013 (www.hse.gov.uk/pubns/priced/HSG53.pdf)

There are three main types of self-contained breathing apparatus, classified mainly on the basis of duration of use:

- Escape SCBA

  This is an open-circuit system consisting of a compressed air cylinder at about 200 bars, fitted with a pressure gauge and a reducing valve. Some models have an on/off control valve: others are controlled by demand valves. Air is fed via a short airline to an ori-nasal face-piece set in a full face-piece which incorporates a wide-vision visor. Respiratory air supply is controlled by a demand valve which allows airflow when the user inhales. Exhaled air is vented via an exhalation non-return valve. Most systems operate with positive pressure in the face-piece so that ingress of the contaminated atmosphere is prevented. Many face-pieces incorporate a speech diaphragm to improve communication.

  Most escape breathing apparatus sets operate for ten minutes; hence the common name **ten-minute escape sets**. Longer-duration units are available for specific purposes. Most escape sets incorporate a warning whistle to indicate that the cylinder has reached about one-third of its capacity. Except for disaster situations, e.g. fire or explosion, escape sets should always be used with atmospheric monitoring devices, set to provide warning when the contaminant has reached a certain concentration. The escape set can then be put on and an escape made in an orderly manner. Where escape sets are used for disaster situations, their capacity should be checked daily; when used as back-up emergency equipment, they should be issued in a state of readiness.

- General SCBA

  Again, using compressed air cylinders, this is designed to work in hazardous atmospheres for periods of 40 minutes or so at normal working rates. It has an open-circuit system with equipment similar to an escape set, but the cylinder (sometimes two) is mounted on a special harness backpack. The cylinders have an on/off control and a pressure-reducing valve which supplies positive-pressure air to the face mask at all times. Respiratory airflow is controlled by inhalation via a demand valve. A pressure gauge connected to the high-pressure outlet is positioned on the front of the cylinder harness so the user can check the cylinder capacity during operation. A warning whistle is always provided. It operates automatically at a pre-set, low-level pressure.

  Where breathing apparatus sets are used for rescue purposes, the cylinders are attached to full safety harnesses that allow the users to be lowered into or pulled from shafts, tanks or restricted spaces.

A fire-fighter wearing self-contained breathing apparatus

- Re-circulating SCBA

  Re-circulating BA (or re-breathers) provides longer duration use. Some units can last up to three hours. They have a closed-circuit, regenerative respiratory breathing system supplied either by oxygen from a cylinder or from a liquid oxygen container.

The general principle of operation is that exhaled air (which contains less oxygen than normal respirable air (21%), but still has quite a high oxygen concentration (>17%)) is not lost to atmosphere through a non-return valve (as is usual). Instead the exhaled breath is scrubbed clean of carbon dioxide (CO_2). The CO_2 free air is then 'sweetened' with oxygen (from a cylinder) to bring the oxygen concentration back up to normal respirable concentration (21%). This reclaimed air is then resupplied back to the user. In effect, the same volume of air is 're-breathed' many times.

Selection of RPE

Many factors have to be taken into account when choosing RPE. The main factors are:

- Atmosphere-/substance-related factors.
- Level of protection required and the Assigned Protection Factor (APF).
- Task and work-related factors.
- Wearer-related factors.
- Quality-related factors.

Atmosphere-/Substance-Related Factors

Where the risk is very serious (e.g. with chemicals that are toxic by inhalation), the concentration of the hazardous agent inside the face-piece must be reduced to 'as low as reasonably practicable' (and at least below the WEL). Accordingly, RPE with the highest protection factors must at least be considered. However, it may not be reasonably practicable to use RPE with the highest available assigned protection factor (see below) because of its other limitations.

For example, when removing asbestos lagging from pipes, the primary means of controlling airborne asbestos concentrations is by using damping down. To control residual fibre concentrations, it is not advisable to use airline-breathing apparatus (even though it offers very high protection) because the line may become entangled in the pipework too easily. Self-contained breathing apparatus is also not practical because it is bulky and will not allow enough time to complete the job. A powered full-face type respirator may be the best choice here; it offers a good level of protection for residual airborne concentration and also takes account of the restrictions of the job (high work rate, obstacles, etc.).

Where there is a risk of oxygen deficiency, the use of filtering respirators is inappropriate – breathing apparatus that assures a fresh supply of clean air is the only acceptable solution. Respirators are not recommended for use in confined spaces, as, once the filter is exhausted, the wearer will be exposed to the contaminant until they are able to leave the confined space.

Filter Selection

Filtering respirators are intended to remove specific contaminants from the atmosphere – as a result of this, the wearer will not be protected if the wrong filter cartridge is selected. Examples of filter types include:

- Particulates.
- Acid gases.
- Organic (solvent) vapours.
- Ammonia.

These will, however, differ between manufacturers and, in some cases, filters are available which cover a combination of contaminants.

Level of Protection Required and the Assigned Protection Factor (APF)

For respiratory protection, the measure of its ability to protect the respiratory system is given by its **Assigned Protection Factor (APF)**, which is the ratio of the concentration of contaminant in the working atmosphere to the measured concentration within the face-piece when the equipment is in use.

The ratio can be represented as follows:

$$\frac{\text{Concentration of atmospheric contaminant}}{\text{Concentration of contaminant in the face-piece}}$$

The higher the ratio, the better the level of protection.

APFs represent levels of protection that can be realistically achieved under working conditions if the wearers are correctly trained and supervised and if the equipment is correctly fitted and functioning properly.

The following table gives general values for the types of equipment we have discussed here. Remember that these values are indicative only; the actual APF will depend on manufacturer, filter type, etc.

The following table gives general values for the types of equipment we have discussed here. Remember that these values are indicative only; the actual APF will depend on manufacturer, filter type, etc.

PF required	Respirators						Breathing apparatus		
	Half-mask, particle filters	Half-mask, gas filters	Full face mask, particle filters	Full face mask gas filters	Powered (fan-assisted) masks	Powered (fan-assisted) hoods	Fresh air hose	Constant flow airline BA	Demand valve BA
4	FFP1, FMP1, P1		P1						
10	FFP2, FMP2, P2	FF gas, FM gas, Gas	P2		TM1	TH1		LDH1	
20	FFP3, FMP3, P3			Gas	TM2	TH2		LDH2, LDM1, LDM2, Half-mask	
40			P3		TM3	TH3	Full face mask, Hood	LDH3, LDM3, Hood, Full mask	
200								Sult	
2000									Airline, self-contained

Source: based on HSG53 respiratory protective equipment at work – A practical guide, HSE, 2013

The protection factor is not absolute, but gives a relative ability to provide protection. If a respirator has an APF of 10 and it is used in a contaminant concentration of 100ppm, then the user would be subjected to respirable air containing 10ppm of contaminant. If the APF is 5 and the concentration of contaminant 50ppm, then the respirable air would still contain 10ppm of contaminant. The protection provided by each piece of equipment is the same.

You must of course aim to reduce the concentration of the contaminant within the face-piece to at least below the applicable OEL.

TOPIC FOCUS

USING APF TO CHOOSE RPE

Using the protection factor as the basis for a choice of RPE requires knowledge of the:

- Acceptable concentration of the contaminant that can be inhaled, based on the OEL for the contaminant.
- Actual or likely concentration of the contaminant in the work area.

The workplace exposure limit is used in conjunction with the actual atmospheric contaminant concentration to calculate an APF value.

For example, if the OEL for a harmful vapour was 20ppm and the highest concentration of atmospheric contamination was 160ppm, then:

$$APF = \frac{160ppm}{20ppm} = \mathbf{8}$$

This means that a suitable type of RPE with a minimum APF of 8 would be needed just to achieve the OEL inside the face-piece. In practice, you may impose a further safety factor to achieve better control. Thus, for example, selecting RPE with an APF of 20 would give a good level of protection.

When selecting RPE, the APF is a primary concern. However, the variety of different types of respirator and BA available, many of which have a number of different APF values assigned, can make the selection process confusing.

As a consequence, authorities such as the UK HSE have published guidance on the selection of RPE. The HSE Guidance HSG53, sets out the following process:

MORE...

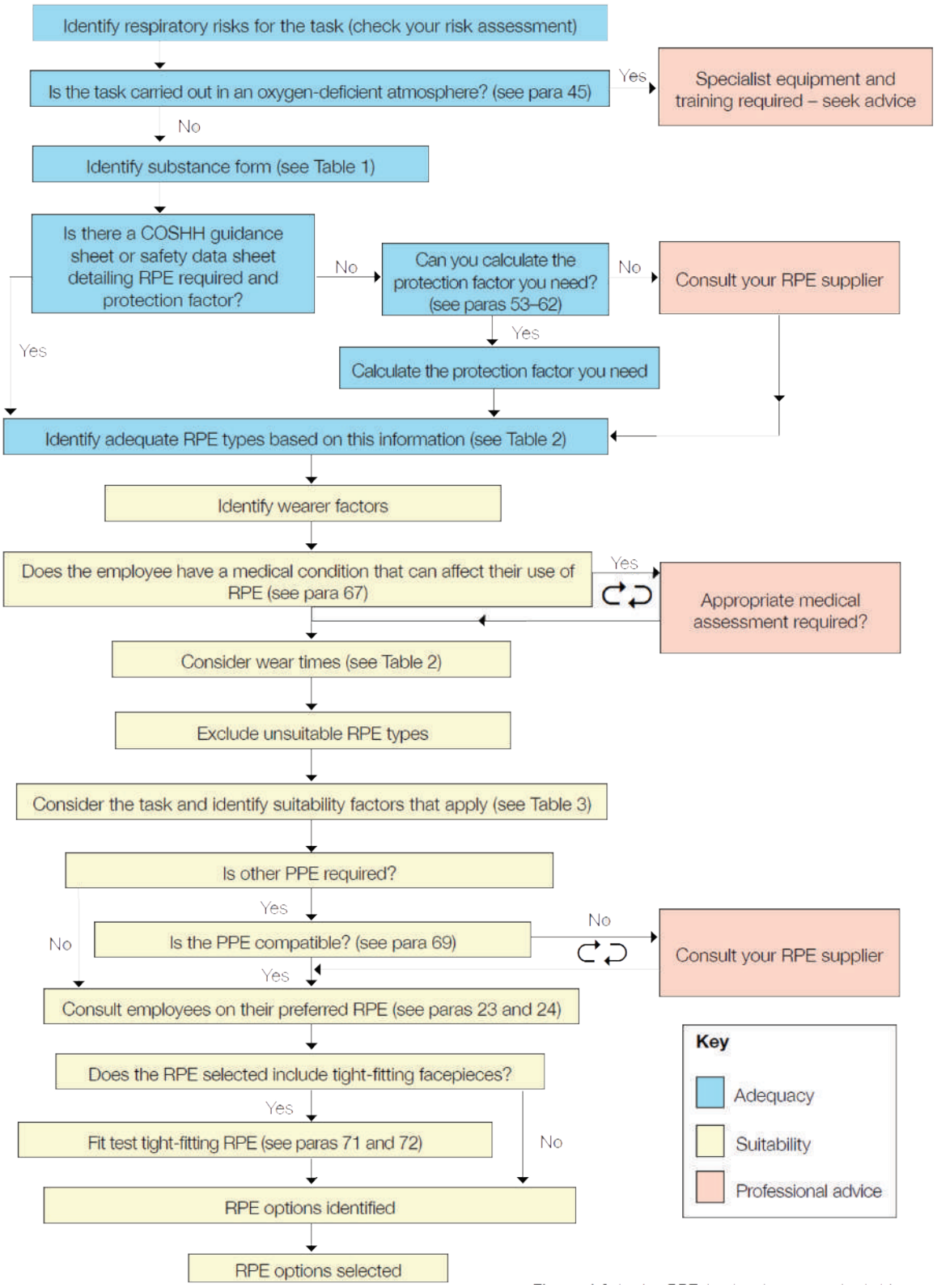
www.

L25: *Guidance on the Personal Protective Equipment Regulations 2002*

HSG53: *Respiratory protective equipment at work*

Both are available from the HSE website at:

www.hse.gov.uk/pubns



Selecting RPE that is adequate and suitable

Source: HSG53 Respiratory protective equipment at work – A practical guide, HSE, 2013 (www.hse.gov.uk/pubns/priced/HSG53.pdf)

Task and Work-Related Factors

Whilst we have considered the capabilities of the RPE, other work-related factors should also be considered:

- **Work rate** – RPE can be hot and heavy to wear (especially in the case of SCBA), so workers who are working at a high rate will become fatigued if wearing RPE for a prolonged period of time. Care should be taken to select the most appropriate type of RPE for the task; e.g. airstream helmets/visors will provide a stream of cool, filtered air over the face of the wearer, which can be cooling in a hot environment.
- **Duration** – the use of RPE can be fatiguing and so workers may not be able to work for extended periods of time in RPE without rest breaks.
- **Temperature/humidity** – the use of RPE in hot and humid conditions can accelerate fatigue, so selection of RPE which provides a supply of cool, filtered or purified air is preferable.
- **Vision** – where clear, unobstructed vision is required, it may be preferable to opt for a full-face respirator rather than a half-mask respirator with goggles due to the tendency of goggles to mist over. Filters on respirators may impede the workers' view of a task during close work. It is advisable to allow workers to select from a range of RPE options in order to ensure that they have clear vision.
- **Communications** – using RPE restricts the ability to communicate. Where communication is essential, such as in the fire service, radio communications devices can be obtained to use within the BA sets.
- **Mobility and space constraints** – where workers are required to be highly mobile, the RPE must not hinder their movement. The use of airline systems may therefore be inappropriate due to the potential for the airline to snag or restrict movement, and SCBA may prove too bulky or heavy in some circumstances. However, the use of respirators may also be inappropriate if the contaminants involved make breathing apparatus necessary.
- **Tools** – where tools are used, they must be able to be used freely without impacting upon the RPE. For example, airlines may be damaged by cutting equipment.
- **Explosive atmospheres** – work in potentially explosive atmospheres must be carried out using equipment suitably rated for this task.

Battery power packs worn by the operator must be protected so that they can't ignite a flammable vapour. Compressors may need to be located outside of the flammable area with only the airline entering the work area. Communications equipment must also be suitable for use within flammable atmospheres.

Wearer-Related Factors

An employer can select the best RPE in the marketplace, but it is rendered useless if the operators refuse to wear it or are unable to use it. The following factors should be considered:

- **Fit and comfort** – people have differently shaped faces, so what feels comfortable on one person might not be comfortable on another. Providing a choice of RPE to the workers may help to overcome some reluctance in using the equipment.
- **Beards** – beards prevent the wearer from obtaining an adequate seal around the face, so it may be necessary to prohibit the wearing of beards which impinge upon the seal, or to prohibit a person with a full beard from working in an area where RPE is necessary.
- **Spectacles** – the wearing of spectacles can impair the seal on a full-face respirator or BA set as the spectacle legs pass through the seal to hook over the ears. Special BA spectacles can be obtained which are inserted into the visor rather than hooked over the ears, allowing a seal to be obtained.
- **Face marking** – whilst not harmful, RPE can cause red marks due to the pressure applied to the face. If this is a problem, alternative styles of RPE may alleviate this issue.
- **Compatibility with other PPE** – half-mask respirators may be incompatible with other PPE, such as goggles and visors, in which case the use of a full-face respirator may be more acceptable. RPE also requires a tight fit to the head, so it may be incompatible with some head coverings worn for religious reasons.
- **Medical conditions** – due to the demands placed upon the wearer, users of RPE may need to undergo medical examinations in order to ensure that they are physically fit enough to undertake the work.

Quality-Related Factors

RPE is safety-critical equipment and therefore good quality is essential. In order to ensure quality, RPE must becompliant with the relevant national and international standards, such as European EN standards.

Face-Fit Test

It has been conclusively demonstrated by research that the stated protection factor for respiratory protection may not be reached in practice. This is due largely to the poor face-fit of many respirators, especially half-mask types. Owing to mass production, a generalised fit is made in the hope that pneumatic or rolled edge seals will make a better fit around anomalous facial structures.

In an effort to improve effectiveness, the face-fit test was introduced. It is only applicable to those types of RPE that rely on a tight fit of the face-piece to the wearer's face for effective performance, e.g. filtering face-piece, half-mask, full-face mask, etc. It does not apply to the loose fitting types, such as powered hoods/blouses, which don't rely on a tight fit but instead rely on high airflow rates through the face piece. There are basically two types of fit-testing: qualitative and quantitative. Each has a number of methods from which to choose.

- **Qualitative** fit-testing is a simple pass/fail subjective assessment of leakage around the face seal and can be conducted very easily by the user. These are only suitable for filtering face-piece and half-mask respirators and are not considered suitable for full-face respirators. Methods here include: use of a bitter or sweet-tasting aerosol or use of odour compounds.
- **Quantitative** tests provide a direct numerical measurement of fit (called a 'fit factor') and are recommended for full-face masks. Methods here include: laboratory chamber; portable fit-test device (working on the basis of either a particle counter or controlled negative pressure).

Skin and Eye Protection

There are many situations where hand protection in the form of gloves or gauntlets is used occupationally. Such items can provide protection against a range of hazards such as high and low temperatures, chemicals and rough handling work.

Skin Protection

When safety gloves are being selected for use, it is very important to choose the material of construction which is designed to give protection against the particular hazard. Where chemicals are handled, suppliers will provide a good guide as to the type required. Glove resistance charts are often available (see the following example).

Chemical	Natural Rubber	Neoprene	Nitrile	Normal PVC
Ethanoic acid	E	E	E	E
Nitric acid (up to 50%)	NR	NR	NR	G
Benzene	NR	F	G	F
Diesel fuel	NR	F	G	F
Wood preservatives	NR	G	G	F

Key to ratings:
E - excellent
G - good
F - fair
NR - not recommended

You will note in the table the wide variation in suitability of differing materials for the chemical listed.

Glove manufacturers use three technical terms to characterise the chemical resistance properties of gloves:

- **Breakthrough time** - the time a chemical takes to permeate through the glove material and reach the inside. Permeation is a process by which a chemical can pass through a material without going through pinholes or pores or other visible openings. This tells you how long you can use a glove for.
- **Permeation rate** - the amount that then permeates through. The higher the rate the more of the chemical will move through the glove. Choose a low rate.
- **Degradation rating** - some chemicals can destroy the glove material. It may get harder, softer or may swell. Degradation indicates the deterioration of the glove material on contact with a specific chemical. Choose gloves with an excellent or good degradation rating.

A laboratory worker uses nitrile gloves to prevent contact with chemical reagents being handled in a fume cupboard

For rough work, not involving contact with chemicals, and for hot/cold protection in the temperature range 10°C to 150°C, terrycloth gloves provide good protection and are comfortable to wear. Leather gloves are more durable but less comfortable to use unless the fit is very good. Leather gloves/gauntlets are good for high temperatures, while for very low temperatures (-10°C to -80°C) special low thermal conductivity fabrics with good flexibility have been developed.

Various practical issues arise with hand protection:

- **Loss of dexterity and tactile sensation** is a considerable problem for some operators. In the chemical industry, the use of gloves for dispensing from small containers (below 0.5 litre) is not recommended, except for very hazardous materials such as phenol, bromine or hydrofluoric acid. It is considered that loss of dexterity is a greater risk in terms of spillage than not providing gloves. If spillage does occur, then the ability to wash quickly reduces the risk to very small limits. However, in some cases, ultra-thin gloves are available which offer limited protection against the chemicals being used and retain good dexterity.
- **Local heating of hands**, with resulting sweating and opening of the skin pores, provides ideal conditions for chemicals to cause corrosive burns and to be absorbed into the body following skin contact. Loss of protection through pin holes which are not easily seen is a common way for materials to enter the gloves. The time taken to remove contaminated gloves can also reduce the effectiveness of first-aid treatment.
- Another possible way in which harmful materials can enter gloves results from their **removal during a hazardous operation**. Removal usually occurs as a result of the operator seeking a little respite from the discomfort of their use.

These must all be considered when making a selection.

Barrier creams can be used to protect the hands against dermatitis. They are particularly useful where non-hazardous wet chemicals are in use where the constant wetting of the hands creates the dermatitis risk. They may also provide protection where a high level of dexterity is needed and the risk from the hazardous material is low.

Antiseptic hand creams are useful for post-exposure when used as part of a good hygiene regime.

Eye Protection

Protection is required from hazards that which can cause damage to the eyes, such as impact from flying particles; dust; chemical splashes; molten metal; mists, sprays and gases; welding; non-ionising radiation; and laser light.

Work activities should be assessed to identify such hazards, then the level of risk estimated to allow the correct type of protection to be selected. The risk assessment should include not only persons directly in the process or activity, but also any other persons who may be at risk.

Listed below are the principal types of processes or activity that could present risks to the face or eyes and where appropriate protection would be required:

- Handling or coming into contact with acids, alkalis and corrosive or irritant substances.
- Working with power-driven tools where chippings are likely to fly or abrasive materials be propelled.
- Working with molten metal or other molten substances.
- Welding operations where intense light or other optical radiation is emitted at levels liable to cause risk of injury.
- Working on any process using instruments that produce light amplification or radiation.
- Using any gas or vapour under pressure.

Before eye protection is used, it is vitally important that the hazard is fully understood. The protection chosen must provide full protection against the hazard to which the eyes are exposed. You must remember that not only are the eyes vulnerable to direct frontal attack from radiation, projectiles or liquids, but the same problem exists, although to a lesser degree, by attack from the sides of the eyes. Liquids can splash up the cheeks and run down from the forehead. Thus highlighting the importance of understanding the potential hazard that you have to control.

Factors Affecting Choice of Type of Protection

Various forms of eye protection are available, depending on the type of hazard encountered, and are grouped in the following general classifications:

- **Spectacles** fitted with side pieces.
- **Goggles**, which provide full eye enclosure and are secured by a flexible headband.
- **Face visors** which provide both eye and face protection. They are secured by an adjustable head frame or may be fixed to a safety helmet.

The design will depend upon the hazard they are used to combat.

Spectacles

Spectacles can be used where there are low risks from radiation, solid projectiles and liquids:

- For **radiation**, the lenses will be specially designed to absorb the problem radiation, i.e. ultraviolet or infrared. Such spectacles are used by glassblowers as they are light and comfortable, as well as provide adequate protection. Models are marketed for welding but they would only be suitable for infrequent or small-scale welding operations.
- Where **solid projectiles** are encountered, e.g. for machinists, chippers or grinders, the spectacle lenses are specially toughened to withstand impact. Although they are comfortable to wear, their effectiveness depends upon fit. On many faces, there are unprotected areas under the eyes and over the bridge of the nose, which reduces the protection factor considerably.
- For **liquids**, spectacles provide limited protection and should be used only where the potential risks are low. They can be used for general chemical laboratory purposes, where the risks are often fairly low. Where the risk level is increased, then spectacles should be replaced or supplemented with a high grade of eye protection. Spectacles provide the least of the problems associated with eye protection, i.e. reduction in visual field, misting and becoming dirty or scratched.

Where safety spectacles provide adequate protection, the use of sight-corrected or prescription lenses becomes a consideration. The provision of prescription lenses for employees is a useful area where management can show a positive concern for eye protection.

Goggles

Goggles can provide almost complete protection for the eyes from all the potential hazards that occur from radiation, projectiles and liquids. The effectiveness of the protection usually depends on the fit under the eyes and over the bridge of the nose. The basic design of goggles consists of a one-piece, clear visual section in front of the eyes surrounded by a safe, flexible frame which seals across the forehead, around the temple and the cheekbone and over the bridge of the nose. This structure effectively protects the eyes by containing them within their own secure environment. It also allows operators to wear their own prescription spectacles under the goggles. This does cause a small problem in that the side seal over the temples is reduced.

Vision is more restricted than with spectacles and misting over of the eyepiece becomes a problem.

Goggles
Source: L25 Personal protective equipment at work (2nd ed.), HSE, 2005 (www.hse.gov.uk/pubns/priced/l25.pdf)

Where goggles are worn to combat harm from projectiles, the frame is often perforated to help ventilation and reduce misting. Where radiation or liquids are the problem, special bubble cap ventilators have been designed, which allow airflow but prevent ingress of liquids or radiation. You should note that the differing designs are required to protect against specific hazards. Hence the need for an adequate understanding of the hazard and for effective supervision to check that the correct type of protection is being worn.

Face Shield/Visor

For some operations, e.g. welding and handling harmful liquids, not only the eyes require protection but also the face and forehead. Face shields are able to satisfy this need. Where corrosive liquids are involved, the shield forms a wide curved screen and gives effective protection from splashes. Welding visors are more complex in that they are constructed of a non-transparent visor with a lens section set into the structure. The lens can be changed according to the type of welding operation. Arc welding or cutting up to about 100 amperes will use a different filter from that required when 300 amperes are used. The different lenses are required to deal with the varying intensity of radiation and the differing type of wavelength spectrum produced.

Face shield
Source: L25 Personal protective equipment at work (2nd ed.), HSE, 2005 (www.hse.gov.uk/pubns/priced/l25.pdf)

The **European Standard**, BS EN 166:2002 - *Personal Eye Protection. Specifications*, lays down specification requirements for eye protection against certain hazards. This standard must be used when selecting eye protection and the protection chosen must be CE-marked to this standard. Alternatively, commercial suppliers of eye protection should be familiar with the standard and able to give advice.

Selection of Skin and Eye Protection

Many factors have to be taken into account when choosing PPE. These can be categorised into four main groups:

- Substance-related factors.
- Task-related factors.
- Wearer-related factors.
- Quality-related factors.

Substance-Related Factors

Substance-related factors include the:

- Type of protection required – the type of protection selected must reduce the risk from a particular hazard. To choose the right type of equipment, it is important to have a full understanding of the hazard under consideration. For example, before protective footwear is selected for use in a chemical environment, the corrosive or solvent nature of the chemicals encountered must be known, so that the chosen footwear is not made from materials that will be adversely affected.
- Level of protection required – the PPE chosen must be able to reduce the hazard to an acceptable level. When choosing gloves or gauntlets, the level of protection provided by the item will be indicated by the quality; for example, the item may have a quality mark (such as the European CE mark). However, the level of protection actually required by the nature of the work may call for a more qualitative judgment.

Task-Related Factors

Task-related factors include:

- **Duration of work** – PPE may only be able to resist chemical 'attack' for a limited period of time (known as the 'breakthrough' time) so consideration must be given to the duration of work which will be undertaken, as this will affect the length of time the PPE is exposed to the chemical substance. Compatibility and breakthrough charts from the manufacturer will indicate the length of time the PPE can be exposed to the chemical.
- **Dexterity and durability** – sometimes, the most durable PPE may not be the most appropriate for a task. Gloves affect the dexterity of the wearer; the thicker (or more durable) the glove, the greater the impact on dexterity. Therefore there may be occasions where using thinner gloves may be preferable and safer.
- **Gloves and gauntlets** – though the terms are sometimes used interchangeably, gloves are shorter and end at the wrist, whereas gauntlets are longer and cover the forearm to the elbow. If there is a risk of contamination of the forearm, gauntlets should be selected.

Wearer-Related Factors

One of the key failings of PPE is that it can be used incorrectly, or indeed not used at all! Users must be trained in the correct use and fitting of PPE, but if wearer-related factors are considered at the selection stage, the potential for misuse can be reduced:

- **Fit** – in order to achieve the necessary level of protection for any PPE, it is important that it fits the user correctly. The correct fit of an item of PPE can often be determined by asking the wearer to subjectively determine whether it fits or not.
- **Compatibility** – the PPE chosen must not interfere with or impede the use of other PPE that also has to be worn at the same time. Consequently, it is necessary to assess the various situations under which the PPE will be used to ensure that it will be compatible with all the other items that might foreseeably be worn.
- **Personal issues** – PPE must be selected with the individual in mind. There may be many reasons why certain PPE is not suitable for a particular individual. There may also be instances where the requirements of the workplace run contrary to the ability of individuals to wear certain PPE. In these circumstances, the individual may be excluded from certain areas/processes or prohibited from entering the workplace.

The PPE chosen must not interfere with the use of other PPE

- **Wearer acceptability** – the effectiveness of an item of PPE is ultimately determined by whether or not users actually wear it. If the equipment is uncomfortable or interferes with the user's ability to work then, irrespective of its cost or efficiency, it will be bypassed.

  Wearer acceptability can be improved by involving workers, or their representatives, in the selection process. This consultation will give end users the opportunity to voice their opinion and assist in the selection procedure. This can often be best achieved by selecting a set of items that provide the required level of protection and then involving workers in trials so that they can then choose the item they think is most suitable.

- **Management commitment** to the use of PPE must be seen to be positive. Management must show clear leadership by using PPE at all appropriate times. They must also provide adequate resources for PPE provision. This may mean buying higher-quality items rather than the cheapest available and ensuring that replacement stocks are always kept.
- Clear and consistent **supervision** of the use of PPE must be demonstrated.

Quality-Related Factors

As with RPE, any PPE purchased must be of a sufficiently high quality to offer the desired level of protection. There are international quality standards that can be used when purchasing PPE, such as the European EN standards.

Storage and Maintenance of PPE

Provision must be made for the safe storage of PPE away from sources of contamination – after all, PPE that is coated with contaminants on the inside is not going to be an effective form of protection for the wearer! It is common practice to provide a locker or storage area for PPE and RPE.

PPE must be maintained in safe working order. The level of maintenance will be determined by the item, manufacturer's recommendations and the conditions of use. Many items of PPE are designed to be used once and then disposed of; this would not entail any maintenance. In other instances, items have to be periodically examined to determine their condition and some level of dismantling, cleaning and/or replacement of parts may have to take place. For safety-critical items, such maintenance should be carried out according to schedules and records of the maintenance must be kept. All those involved in maintenance activities must be competent.

Though usually issued to individuals and not shared, there are some circumstances where PPE might not be issued on a personal basis (e.g. in the case of SCBA) and, in these instances, good standards of hygiene must be assured through disinfection of the face mask.

RPE must be cleaned, disinfected and thoroughly examined periodically. Records of such inspections and disinfections should be maintained. Maintenance should be in accordance with the manufacturer's recommendations, but typical maintenance checks for RPE include:

- Checking face seals and replacing them if necessary.
- Checking airflow (this may involve checking inlet valves for respirators or air supply to BA sets).
- Checking respirator filters are in date.

Training Requirements

If workers are to use PPE effectively, they have to be provided with information, instruction and training. In particular, they will need to know:

- What the risks are that the PPE can give effective protection against (including limitations).
- How and when the PPE should be used.
- How and when to clean, inspect, maintain or replace the PPE.
- Requirements for storage of the PPE.

Failure to provide this in a comprehensible form will result in poor (and perhaps even dangerous) practices developing.

Since different items of PPE will have different training requirements, it may be sensible for the employer to take this into account when selecting PPE in the first place. If two items of PPE give the same level of protection, but one is more complex and will require considerably more training resources, then it might be better to choose the simpler option.

STUDY QUESTIONS

8. When choosing PPE for the workforce, what factors should the employer consider when determining its suitability?
9. What is meant by compatibility in relation to PPE?
10. Describe the fundamental difference between respirators and breathing apparatus.
11. Identify the advantages of a powered clean-air respirator over a conventional canister-type respirator.
12. What factors would you consider when choosing eye protection?
13. Identify three possible problems associated with wearing protective gloves.

(Suggested Answers are at the end.)

Summary

Prevention and Control of Exposure to Hazardous Substances

We have described how:

- A simple hierarchy of controls is as follows:
  - Eliminate exposure, following these steps:
  - Cease use of the hazardous chemical.
  - Substitute for a less hazardous alternative.
  - Implement an alternative process.
- Control exposure, through:
  - Good design and installation (through total enclosure of the process, segregation of the process from workers, modification of the process to reduce exposure potential, implementation of
  - Local Exhaust Ventilation (LEV) – with or without partial enclosure – and the use of general ventilation).
  - mplementing work systems and practices to minimise the numbers of people exposed, restrict access to the processes, restrict the duration of exposure and provide for cleaning and decontamination, maintenance of controls, and safe storage/disposal of materials.
  - The use of PPE, good hygiene practices, welfare facilities, warning signs and emergency arrangements.
- Additional control measures must be implemented to prevent exposure to carcinogens and mutagens.

Asbestos and Lead

We have described how:

- Asbestos causes several serious ill-health conditions: asbestosis, lung cancer, mesothelioma and pleural plaques.
- Explained the controls that should be implemented when working with asbestos. These are specified in the ILO Code of Practice – Safety in the Use of Asbestos and include:
  - Elimination of exposure.
  - Use of engineering controls.
  - Respiratory Protective Equipment (RPE) and Personal Protective Equipment (PPE).
  - Cleaning of plant and equipment to remove contamination.
  - Safe storage, transport and disposal.
  - Health surveillance.
  - Training.
- Lead is a toxic metal that can cause damage to the central nervous system.
- Control of exposure to lead often requires biological monitoring (taking blood or urine samples) as a form of health surveillance and the observation of action levels and suspensions levels for concentrations of lead in blood and urine.
- Different levels of protection are necessary for young persons and women of reproductive capability.

Ventilation

We have examined how:

- Dilution ventilation is a form of engineering control where the airborne concentration of a substance is kept to acceptable levels by changing the air volume (passively or with fans).
- Local Exhaust Ventilation (LEV) systems work by removing contaminated air at the point of generation and are made up of five basic parts: hoods, ducts, air cleaner, fan and discharge.
- LEV can be classified into three types depending on the nature of the hood: enclosing, receiving and capturing.
- Elements of the LEV system have to be carefully designed and selected to ensure correct and efficient operation.
- A range of air-cleaning devices can be used to remove contaminants from the captured air before discharge. Bag filters, cyclones, electrostatic precipitators and scrubbers are typically used for particulates; and tower scrubbers, incinerators and charcoal filters for gas and vapour.
- LEV systems capture contaminants from a specific zone adjacent to the inlet hood. If a contaminant is generated by work outside of this capture zone then the contaminant will not be efficiently drawn into the LEV system.
- LEV systems must be subjected to thorough examinations and tests to ensure their ongoing effectiveness
- This thorough examination comprises a three-stage process:
  - Stage 1 – visual examination of the system.
  - Stage 2 – quantitative assessment of performance by measuring parameters, such as face velocity, transport velocity and static pressure. Devices such as anemometers, pitot tubes and manometers are used to measure these parameters.
  - Stage 3 – qualitative assessment of performance using dust lamps or smoke to visualise air movement.
- The resulting Report of Thorough Examination and Test must be interpreted and acted upon.

Personal Protective Equipment (PPE)

We have described how:

- Personal Protective Equipment (PPE) is commonly used to control exposure to hazardous substances.
- Respiratory Protective Equipment (RPE) is commonly used to control inhalation of airborne contaminants.
- Respiratory protective equipment can be categorised into two main types: respirators and Breathing Apparatus (BA).
- Respirators come in many different forms but can be generally classed as half-mask, full-face or powered. Different variations of each type can give protection against both particulates and gases.
- Breathing apparatus also comes in many forms, but can be classed as fresh air hose, compressed airline or self-contained.
- The level of protection offered by RPE is indicated by the Assigned Protection Factor (APF), a measure of the ratio of contaminant inside to outside the face-piece.
- The APF can be used in combination with contaminant concentrations and WELs to indicate the degree of protection offered by an item of RPE and hence its suitability.
- When selecting RPE, the following factors must be considered:
  - Atmosphere and substance-related factors, such as potential for oxygen deficiency.
  - Task and work area-related factors, such as work rate and duration.
  - Wearer-related factors, such as fit/comfort and acceptability.
- Most items of RPE require some form of face-fit test to ensure that an adequate seal exists between the item and the wearer's face.
- Skin is often protected from hazardous chemicals using clothing such as gloves.

Summary

- Gloves must be carefully selected to ensure their suitability. Several characteristics of gloves need to be understood to make an informed choice; breakthrough time, permeation rate and degradation rating.
- Reference should also be made to the relevant standard.
- Eye protection, in the form of safety spectacles, goggles and face shield is also frequently used to give protection from hazardous substances and must be carefully selected with reference to relevant standards.
- When selecting skin and eye protection, the following factors must be considered:
  - Substance-related factors, such as compatibility with the chemical against which protection is required.
  - Task-related factors, such as duration of operation and breakthrough times.
  - Wearer-related factors, such as fit/comfort and acceptability.

Exam Skills

QUESTION

A welder undertakes work in an open plan workshop.

Outline the factors to be considered when selecting suitable Respiratory Protective Equipment for this work. **(10)**

Approaching the Question

- Read the question carefully – there is clear information here for you! It can be daunting if you haven't encountered the specific task or activity mentioned, but don't panic or let it put you off answering this type of question, this might be straightforward for you to answer.
- Consider the marks available this time – it is likely that for 10 marks the examiner would want to see 10 factors. As you haven't specifically been asked for 10 feel free to give a couple of extra points to increase the likelihood of gaining full marks.
- An outline plan for this might include:
  - Health issues with welding.
  - Exposure routes.
  - Location issues.
  - People using RPE, what you should consider about them.
  - Tasks involved.
  - Equipment available.
  - RPE issues – storage, training, maintenance, face fit.

Suggested Answer Outline

The examiner would expect you to identify 10 (remember, there are 10 marks available) of the following factors:

- Those to do with the substances emitted (welding fume): intrinsic health hazard (irritant/toxic, etc.), concentration in the air, volatility, particle size, applicable OELs, level of protection required (APF), choice of filter type and whether half/full-face or with respirator or BA.
- Those to do with the task/activity: type, duration (wear time), frequency, rate of the work; effort required; existing control measures in place (e.g. LEV); environment (humidity, temperature); requirements for communications, mobility.
- Those to do with the individual: fit/comfort (facial hair, face markings, spectacles); fitness (e.g. existing heart diseases, respiratory diseases); compatibility with other PPE needed (eye, hearing).
- Those to do with the equipment itself: robustness/durability; ease of maintenance; complexity (training needs); use life (battery life, cartridge life); cost; conformity to standards.

Example of How the Question Could be Answered

When selecting RPE for welders to use in an open-plan workshop there is a number of factors that need to be considered.

The nature of the tasks to be undertaken is important since the type of welding taking place will affect the ability to filter the contaminant. The duration, frequency and physical effort involved will also be relevant to the choice of RPE. The working environment should also be considered because high levels of heat and humidity may make the use of some types of RPE uncomfortable and may necessitate using others, such as airstream helmets.

The location where the welding actually takes place will determine the standard of existing ventilation and the fume control already available to use. If there is fume control equipment such as local exhaust ventilation already in place then this will affect the selection of RPE.

Welding produces toxic and irritant fumes, and the amount and type of particulate produced will determine the protection factor required and the filter type necessary to protect against the identified hazard. Legislation and international standards can be used for assistance in determining this.

Selection of RPE should involve the workforce, who will need to be made aware of the hazards and why controls and RPE are required. They should also be trained in how to fit the RPE correctly, how to choose the most appropriate type of RPE for the task (e.g. filtered half mask, filtered full mask or breathing apparatus), and also the significance of compatibility issues with other PPE such as welding masks or shields and eye protection.

Other factors to consider include the need for verbal communication whilst wearing RPE, the requirements for RPE with heat-resisting properties and any relevant standards such as BSEN standards for the equipment.

Finally, there are also individual issues to consider such as fitness to wear RPE, the need for regular face-fit testing and the training required on wearing, cleaning, checking and maintenance of the RPE chosen. You should also consider the compatibility of RPE with individuals with facial hair and glasses.

Reasons For Poor Marks Achieved By Candidate in Exam

- Is not structured around factors involving the individual, the task and the substance to be used.
- Describes how the equipment should be used, maintained and stored rather than referring to 'selection' as required by the question.
- Shows a lack knowledge of welding/fabrication work.

Element IB4

Monitoring and Measuring of Hazardous Substances

Learning Outcomes

Once you've read this element, you'll understand how to:

1. Explain how workplace exposure limits are used in the workplace.
2. Outline the methods for the sampling of airborne contaminants.
3. Outline the principles of biological monitoring.

Contents

Occupational Exposure Limits (OELs)

IN THIS SECTION...

- Occupational Exposure Limits (OELs) are standards for exposure to particular health hazards above which workers should not be exposed.
- Two OELs can be set for a chemical - a Long-Term Exposure Limit (LTEL) based on an 8-hour Time-Weighted Average (TWA) exposure and a Short-Term Exposure Limit (STEL) based on a 15-minute TWA exposure.
- LTELs are used to control long-term exposure and the chronic ill-health effects that might result, whereas STELs are used to control short-term exposure that might create acute effects.
- There are no internationally recognised standard exposure limits at present. Exposure limits are implemented differently in various countries; examples include Workplace Exposure Limits (WELs) in the UK and Permissible Exposure Limits (PELs) in the USA.
- In the UK, lead and asbestos have their own OELs set under their respective regulations, which apply a higher degree of control over these two health hazards.

The Meaning of Occupational Exposure Limits (OELs)

The use of **Occupational Exposure Limits (OELs)** is important for the protection of people at work from a wide variety of health hazards. For example, OELs are used to control personal exposure to hazardous substances, noise, vibration and radiation. This section focuses on OELs for hazardous chemicals. Those applicable to other health hazards will be dealt with later in the unit.

Protection from airborne hazardous substances

The ILO defines "exposure limit to airborne harmful substances at the workplace" as follows:

"*...concentration in the air of a harmful substance which does not, it is believed in the light of present scientific knowledge, cause adverse health effects – including long-term effects and effects on future generations – in workers exposed for eight to ten hours per day and 40 hours per week; such exposure is considered acceptable by the competent authority which establishes the values, although concentrations below the exposure limit may not completely guarantee protection of the health of all workers; the exposure limit therefore does not constitute an absolute dividing line between harmless and harmful concentrations but merely serves as a guide for the prevention of hazards*".

Source: ILO Code of Practice – Occupational Exposure to Airborne Substances Harmful to Health, Copyright © International Labour Organisation 1980

It is worth noting some of the subtleties in this definition:

- The substance must be airborne.
- It is established on the basis of current scientific knowledge, which is naturally subject to change.
- The limit might not completely guarantee the safety of all workers and is a guide.

Likewise the **ILO Code of Practice – Ambient Factors in the Workplace** has the following definition of an exposure limit:

"a level of exposure which is specified by a competent authority, or some other authoritative organization such as a professional body, as an indicator of the level to which workers can be exposed without serious injury."

Source: ILO Code of Practice – Ambient Factors in the Workplace, Copyright © International Labour Organisation 2001

Worker being exposed to airborne contaminant

OELs can be defined specifically for airborne contaminants, giving maximum concentrations (normally measured across a particular reference period of time) to which employees may be exposed. The intention of OELs is to put a ceiling in place so that employees will not be exposed to high concentrations of airborne substances (either for short durations of time or for long periods of the working day) where scientific evidence suggests that there is risk to health.

We will use the term "occupational exposure limits" throughout this element. However, different countries have applied different names and limits through national legislation. Examples will be given later in this section.

How OELs are Established

ILO Code of Practice – Occupational Exposure to Airborne Substances Harmful to Health (Section 3) establishes principles to be followed when setting exposure limits. It recognises that limits may be established through national legislation or through collective agreement with employers or workers, such as worker representative groups, and that such limits should be able to be modified in light of scientific knowledge.

The CoP also states that exposure limits should be established based on a study of the dose-effect and dose/response relationship in the context of the:

- Physical and chemical properties of the substances (including nature and quantity of contaminants).
- Way in which the substance will be used and hence the way in which workers will be exposed to it.
- Results of laboratory tests (including animal testing) which will establish the acute and chronic health effects.
- Results of health surveillance of workers, including epidemiological studies.

Data should be submitted to a competent authority so that suitable exposure limits can be established. These limits will apply to airborne exposure, but where there is potential for substances to be absorbed also through the skin this should be emphasised.

Once the data on the properties of the substances and the tests, epidemiological data, etc. have been gathered, the results can be extrapolated in order to establish an exposure limit. The ILO recognises that this should, however, incorporate a safety factor established by experts to take into account the following factors:

- Although animals are used in toxicological testing, there are metabolic and functional differences between man and animals.
- There may be differences between experimental conditions and occupational exposure conditions.
- There may also be an effect due to the selection of workers (as the working population may differ between regions/countries).

Long-Term and Short-Term Exposure Limits

Both long-term and short-term exposure limits are expressed as **Time-Weighted Average (TWA)** concentrations. This means that measurements are taken and the airborne concentrations are averaged out over a given period of time.

Long-Term Exposure Limits (LTELs)

Long-term exposure limits are designed to control the **chronic** ill-health effects of long-term exposure to harmful substances; the sort of exposures that might occur routinely on a daily basis over a period of weeks, months or years in a workplace.

The long-term exposure limit is based upon an **8-hour** TWA. If an 8-hour TWA exposure can be calculated then it can be compared to the LTEL.

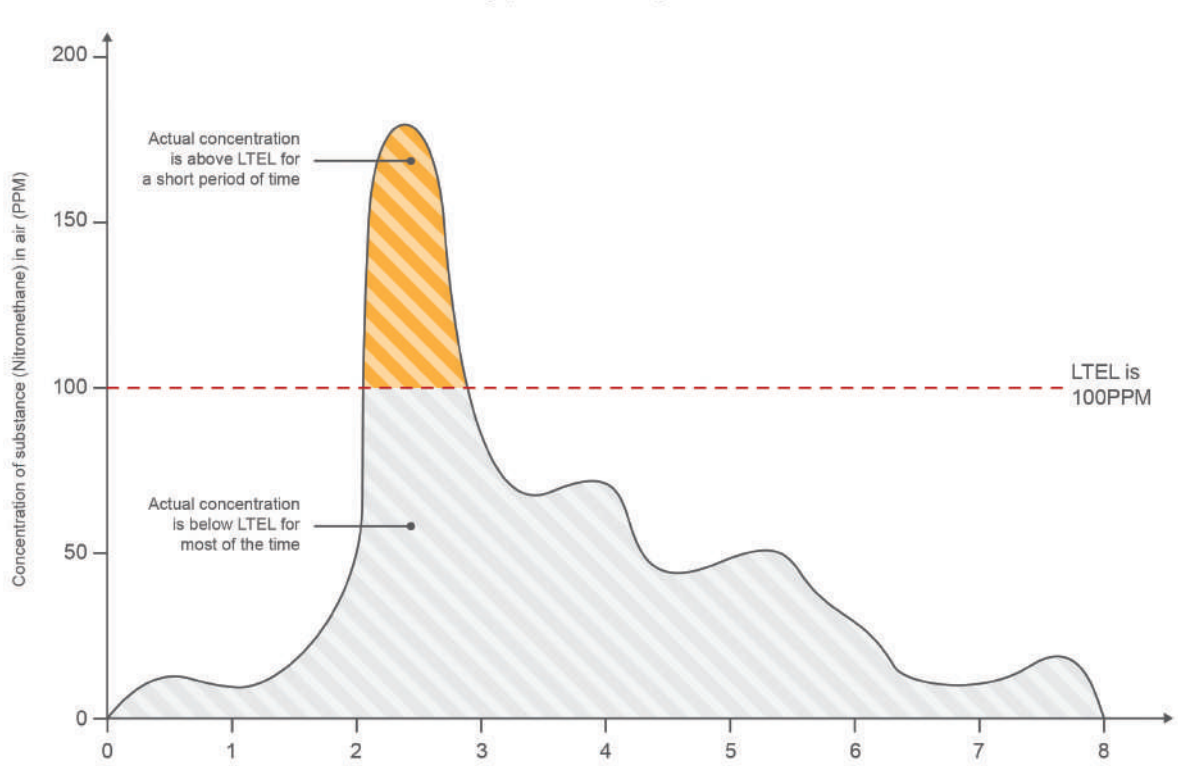
The general formula for calculating an 8-hour TWA exposure is:

$$\text{8-hour TWA exposure} = \frac{C_1T_1 + C_2T_2 + \ldots C_nT_n}{8}$$

Where C_1 is the concentration for time T_1, C_2 is the concentration for T_2 and so on. The concentrations (C_1, C_2 etc.) are measured in units of parts per million (ppm) or milligrammes per cubic metre ($mg.m^{-3}$). The times (T_1, T_2, etc.) are in hours.

The concept of a TWA allows excursion **above** the LTEL, provided there are equivalent excursions **below** the limit to compensate for the excess exposure.

The following figure illustrates a variable exposure over an eight-hour period.



Graph showing actual concentration of a substance (nitromethane) in air over an eight-hour working period along with the LTEL for the substance

From the graph, we can see that the actual concentration of the substance fluctuates over the eight-hour work period; from zero at the start, then rising above the LTEL (100ppm) for about an hour reaching a peak of 180ppm, then falling rapidly below the LTEL and gradually reducing to zero by the end of the sampling period.

From the graph, the TWA exposure can be estimated (by imagining the area under the line spread out evenly over the entire eight hours) at approximately 60ppm. This is below the LTEL of 100ppm. So even though there has been an excursion above the LTEL this **excursion** was not significant enough to take the TWA concentration above the LTEL. The LTEL has not been exceeded.

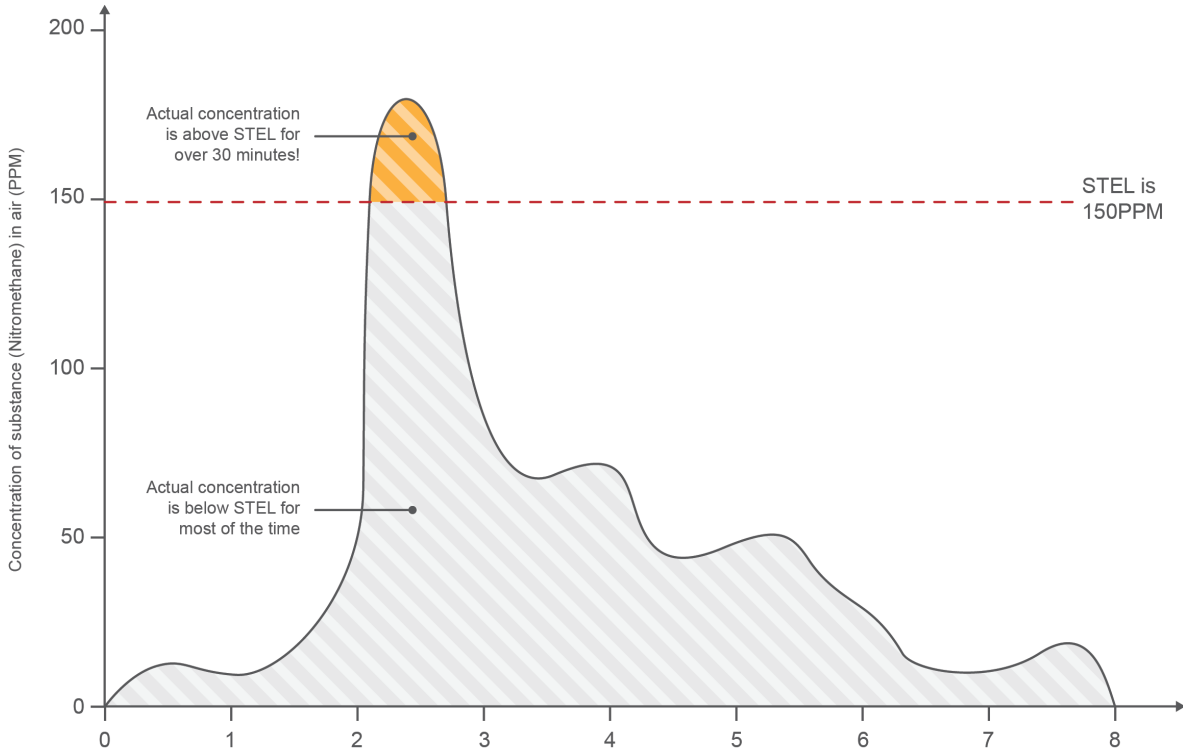
Short-Term Exposure Limits (STELs)

Short-Term Exposure limits are designed to control the **acute** ill-health effects that might result from exposure to a high concentration of a contaminant over short period of time. The short-term exposure limit is based on a 15-minute TWA. If the 15-minute TWA exposure can be calculated then it can be compared to the STEL.

15-minute TWA exposures have to be calculated by measuring airborne concentrations across the 15-minute reference period.

The practical effect of an STEL is that it imposes a ceiling on the peaks in airborne concentration (the excursions) that are permissible in the workplace.

The following graph shows the same variable exposure over an eight-hour period as before, only this time the STEL of 150ppm has been added.



Graph showing actual concentration of a substance (nitromethane) in air over an eight-hour working period along with the LTEL for the substance

From the graph, we can see that the actual concentration of the substance rises above the STEL (150ppm) for about an hour reaching a peak of 180ppm, then falling rapidly below the STEL and gradually reducing to zero by the end of the sampling period.

From the graph, it can be seen that this excursion above the STEL has lasted for well over 15 minutes. Therefore, the TWA concentration during the excursion must be above the STEL. The STEL **has** been exceeded.

So, even though the LTEL was not exceeded during the working period (see first graph), the STEL was exceeded. This means that the peak in concentration of the substance is too pronounced and must be reduced to below 150ppm so that the STEL is not exceeded.

Not all substances listed in EH40 are assigned STELs. Where an STEL has not been assigned, the guidance suggests that a value of **three times** the LTEL, averaged over 15 minutes, should be used to control short-term excursions.

International Examples of Occupational Exposure Limits

There are no internationally recognised standard exposure limits at present – different countries have implemented their own limits based on the interpretation of the dose-response data obtained. The names, definitions, methods for calculating exposures and the legal status of the limits vary between these countries. It is therefore important to select the correct OEL for the country in question and use the correct codes of practice in interpretation.

Some of the different occupational exposure limits are outlined below as examples:

- In the UK, the Health and Safety Executive (HSE) has established a series of **Workplace Exposure Limits (WELs)** which have legal status. Limits have been established for many substances including lead and asbestos.
- In the USA, OSHA have established **Permissible Exposure Limits (PELs)**, which are also enforceable limits. Additional controls, known as **Threshold Limit Values (TLVs)**, have been established by the American Conference of Governmental Industrial Hygienists (ACGIH); these are not enforceable, but in many cases establish a more stringent limit than the PEL established in law.
- There are numerous other national limits – in France these are known as the VME (Valeur Moyenne d'Exposition), whilst in Germany they are called MAK values (Maximale Arbeitsplatz-Konzentration). In the EU, **Indicative Limit Values** (published by the EU Commission) are used as the basis for many countries' limits.

As an example, the following table lists UK WELs for a range of substances.

Substance	CAS Number	Workplace exposure limit				Comments
		Long-term exposure limit (8-hr TWA reference period		Short-term exposure limit (15 minute reference period)		The Carc, Sen and Sk notations are not exhaustive. Notations have been applied to substances identified in IOELV Directives
		ppm	mg.m^{-3}	ppm	mg.m^{-3}	
Acetaldehyde	75-07-0	20	37	50	92	
Acetic anhydride	108-24-7	0.5	2.5	2	10	
Acetone	67-64-1	500	1210	1500	3620	
Acetonitrile	75-05-8	40	68	60	102	
o-Acetylsalicylic acid	50-78-2	-	5	-	-	
Acrylaldehyde (Acrolein)	107-02-8	0.1	0.23	0.3	0.7	
Acrylamide	79-06-1	-	0.3	-	-	Carc, Sk

Extract from Table 1 of EH40/2005 Workplace exposure limits (2nd ed.), HSE, 2011 (www.hse.gov.uk/pubns/priced/eh40.pdf)

Notes relating to the table:

- **CAS number** = Chemical Abstracts Service number, which provides a way of uniquely identifying a chemical compound. This is useful because the same compound may be known under different names.
- **LTELs** are listed for all substances, but **STELs** are only assigned for three.
- **ppm** = parts per million.
- **mg.m^{-3}** = milligrams per cubic metre of air.
- **Sk** in the comments column denotes skin absorption.
- **Sen** indicates a respiratory sensitiser.
- **Carc** indicates a carcinogen or mutagen.

We will now look at how exposure limits for two specific hazardous substances – lead and asbestos – have been implemented in different countries.

Lead

In the UK, the occupational exposure limits for lead are set out not in the WELs but in the **Control of Lead at Work Regulations 2002 (CLAW)**.

The limits are 8-hour TWA concentrations as follows:

- For **lead** other than lead-alkyls, a concentration of lead in the atmosphere to which any employee is exposed of **0.15mg.m^{-3}**.
- For **lead-alkyls**, a concentration of lead in the atmosphere to which any employee is exposed of **0.10mg.m^{-3}**.

These OELs are ceiling limits which must not be exceeded when calculated as time-weighted averages over 8 hours.

Actual exposures must be measured and calculated in accordance with the methods referenced in **CLAW**, but the general principles for use are the same as for WELs.

As far as exposure by inhalation is concerned, control is considered adequate when exposure does not exceed the relevant OEL. This is not sufficient to ensure absence of health risk however, because other routes of exposure to lead are also important, such as ingestion and contact with the skin (for lead-alkyls).

Because these other routes of exposure can contribute to the amount of lead that a worker might absorb, workers must be subjected to **biological monitoring**. This involves taking blood and urine samples and then analysing those samples to estimate the amount of lead in the worker's body. The results of this monitoring are then compared to the **biological limit values** contained in **CLAW.** Biological monitoring will be discussed in more detail later in this element.

MORE...

The UK Guidance Note EH40 *Workplace exposure limits*, which contains details of the UK limits and the means by which they are established, is available from:

www.hse.gov.uk/pubns/books/eh40.htm

The list of PELs in the USA is available from the OSHA website at:

www.osha.gov/dsg/annotated-pels/index.html

L132 - *ACoP and Guidance on the Control of Lead at Work Regulations 2002* is available from the HSE at:

www.hse.gov.uk/pubns

In the USA, there are PEL limits established for lead. These are lower than the UK limits and are set as an action limit of **30µg/m^3** as an 8-hour TWA, with no person to be exposed to a concentration greater than **50µg/m^3** as an 8-hour TWA.

Asbestos

In the UK, the occupational exposure limit for asbestos is set out in the **Control of Asbestos Regulations 2012**, where it is referred to as the control limit.

The control limit is **0.1 fibres per cubic centimetre** of air averaged over a continuous period of **four hours**.

Note that the general principles applied here are the same as those for WELs – the limit is a time-weighted average.

There are some differences though:

- The units of measurement for asbestos in air are fibres per cubic centimetre (**f/cm³**) or fibres per millilitre (**f/ml**).
- The reference period is four hours (not eight as for WELs).

In the USA, there is also a PEL for asbestos, which again illustrates the differences between the two countries. The PEL is established as 0.1 fibres per cubic centimetre of air averaged over a continuous period of 8 hours, with an excursion limit of 1 fibre per cubic centimetre of air averaged over 30 minutes.

The method by which the number of fibres is calculated involves light microscopy and will be outlined later in this element.

STUDY QUESTIONS

1. What specific form of hazardous substance are OELs intended to control?
2. Outline the difference between long-term and short-term exposure limits.

(Suggested Answers are at the end.)

Strategies, Methods and Equipment for the Sampling and Measurement of Airborne Contaminants

IN THIS SECTION...

- The identification, measurement and evaluation of health hazards, and the subsequent design and testing of control measures is often the work of the occupational hygienist.
- Safety practitioners may be involved in the management of occupational hygienists, so evaluating their competence and interpreting their reports can be important.
- The UK HSE's guidance HSG173 indicates that an effective strategy for monitoring hazardous substances calls for a three-stage approach: an initial appraisal, perhaps a basic survey and a detailed survey if needed.
- If quantitative monitoring is to be carried out, then an approved method (such as one from the UK HSE's MDHS guidance series) must be used to ensure the validity of results obtained.
- Direct reading instruments can be used to measure airborne concentrations of contaminants.
- Stain tube detectors provide a way of spot-sampling concentrations of gases and vapours in air. They are simple to use, but do have limitations.
- Dust concentrations in air can be monitored using an air pump and sampler containing a filter. Different types of sampler allow for inhalable or respirable dust to be collected. The amount of dust collected is quantified by weighing.
- Asbestos concentrations in air can be measured using similar equipment with a cowled sampler head. The amount of asbestos collected is quantified by counting fibres by Phase Contrast Microscopy (PCM).
- Gas and vapour concentration can be measured using various passive and active devices.
- Actual exposures can be calculated on an 8-hour TWA basis and these results can then be compared to the OEL for evaluation.

Role of the Occupational Hygienist

The work of the occupational hygienist generally involves:

- Identification of health hazards (such as toxic chemicals, heat or noise).
- Measurement of the hazard by data collection (e.g. personal dosimetry).
- Evaluation of the risk by comparing estimated exposures to legal standards (e.g. use of OELs).
- Identification of control measures and their implementation, use, testing and maintenance.

Occupational hygienists often specialise in one topic area, such as noise or asbestos. A wide range of monitoring techniques is available, making use of special equipment and instruments. The occupational hygienist must be trained and competent in their selection, use and, importantly, the interpretation and evaluation of the results.

Occupational hygienists must be trained and competent

Another of their areas of involvement is the monitoring of control measures to ensure they are working effectively. Consequently, they may be skilled in carrying out measurements on ventilation systems and other environmental control devices to ensure they operate at optimum performance.

Competence

It is important that before an employer retains the services of an occupational hygienist, their competence is checked. The level of competence needed will depend on the service required. The employer must make an informed choice based on:

- Training and qualification.
- Experience in the field in question.
- Background knowledge and education.
- Certification or accreditation to relevant standards.
- Membership of professional organisations. For example:
  - In the UK, the British Occupational Hygiene Society (BOHS) is the leading professional organisation for hygienists, operating a membership system (similar to IOSH) and examination/qualification schemes in various hazard areas. Care must be taken, since some membership grades can be achieved without qualifications, although higher membership grades do require qualifications.
  - Likewise, in the USA, the American Board of Industrial Hygiene (ABIH) is the certifying body for Certified Industrial Hygienists (CIHs). Earning the CIH certification requires candidates to meet rigorous education and experience requirements.

MORE...

For more information about the British Occupational Hygiene Society, visit:

www.bohs.org

For more information about the American Board of Industrial Hygiene, visit:

www.abih.org

In many instances there is no one standard of qualification or certification required and the employer must make a judgment. Depending on national circumstances, there may be a clear certification scheme that can be checked in some instances, such as when sampling asbestos.

Interpretation of Reports

Safety practitioners may be involved in the management of occupational hygienists. A safety practitioner should, therefore, be able to read and understand a report produced by an occupational hygienist to verify that it is appropriate and valid. Not only does this ensure that the appropriate recommendations are acted on, it also provides a way of checking the hygienist's competence.

There is a number of general issues that should be checked:

- An appropriate strategy and method of sampling has been used. Standard strategies and methods are published at national level by the regulatory bodies and other authorities (such as the World Health Organisation (WHO)). Where these exist they must be adhered to in order to ensure the scientific and legal validity of any result obtained.
- The equipment used was appropriately maintained, certificated and calibrated.
- The sampling was carried out at a place and time that would give results representative of real workplace conditions (this requires an understanding of the types and patterns of work that the hygienist may not have a full appreciation of).
- The results have been correctly evaluated against the correct legal Standards/OELs.

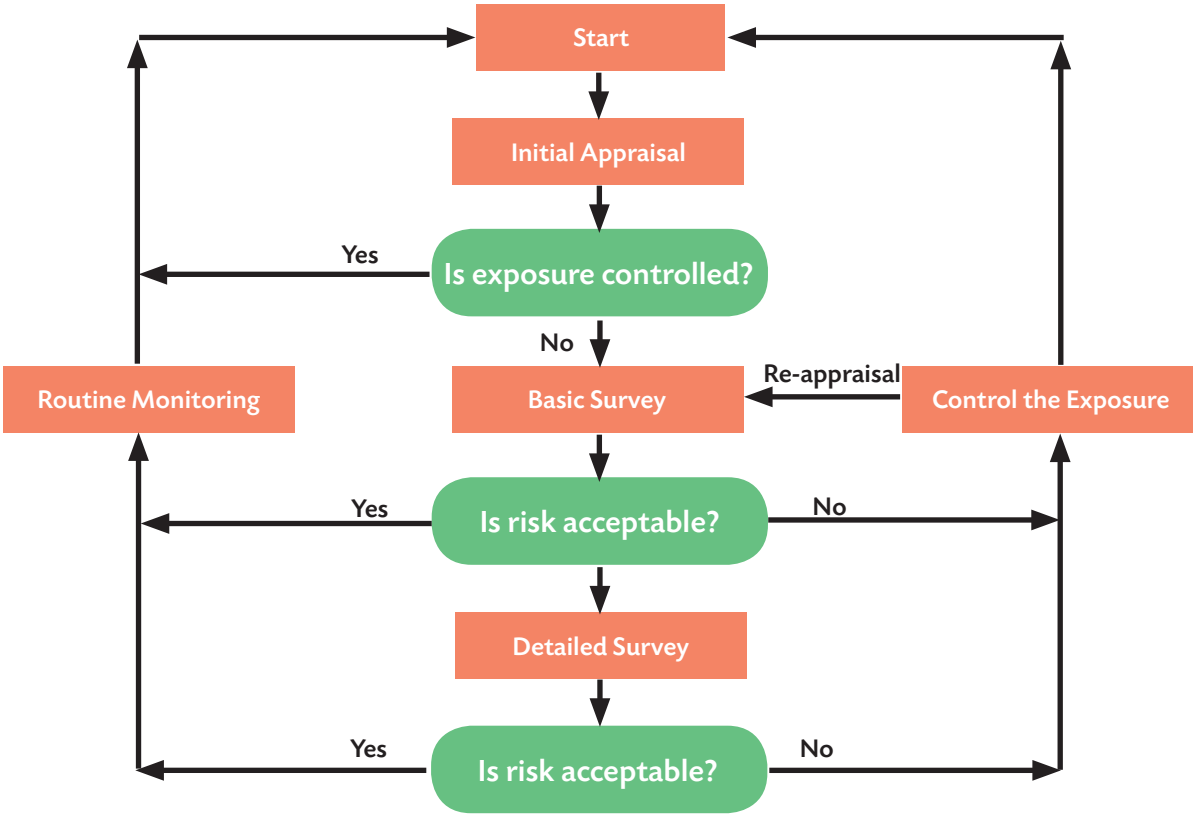
TOPIC FOCUS

Issues to consider when assessing a report on a Local Exhaust Ventilation (LEV) examination conducted by an occupational hygienist:

- Identification of the relevant legal standards (**COSHH**, **CLAW**, etc.).
- Identification of the LEV plant, process and substance(s) being controlled.
- Date of last examination and test (reference to at least every 14 months).
- LEV intended (design) performance.
- Current LEV performance (ascertained by a range of techniques, with results, e.g. static pressure, face velocity, dust lamps, visual inspections, etc.).
- Identification of the equipment used and its calibration and test certification.
- Assessment of whether any improvements/repairs are needed (which will depend on an analysis of current performance relative to design and legal standards).
- Date of examination/test.
- Name of person (and employer) doing the test.
- Credentials (qualifications, accreditation).
- Reference to record keeping (five years for LEV examination).

Monitoring Strategy

In Britain, the HSE has published the guidance booklet **HSG173**: *Monitoring Strategies for Toxic Substances* giving advice on the principles of monitoring of hazardous substances. The basic philosophy is "do not measure unless you know what you are measuring and what you will do with the results". The basic strategy is shown in the following flow diagram.



Monitoring of hazardous substances

Initial Appraisal

This helps establish the need for, and extent of, exposure monitoring. It helps you decide if you need more information - like actual monitoring data.

Stage 1: Gather information about:

- The substances to which employees are exposed:
  - Identity, hazardous and physical properties, airborne forms, e.g. dust, mist, fume, aerosol, vapour, and any applicable OELs or in-house limits.
- The possibility of exposure by inhalation, ingestion or skin absorption.
- Processes or operations where exposure is likely to occur.
- The number, type and position of emission sources.
- The groups or individuals most likely to be exposed.
- The likely pattern and duration of exposure.
- Any existing control measures in place – LEV, RPE (and effectiveness), etc.

Stage 2: Conduct some simple qualitative tests:

This helps establish if there is a risk to health, for example:

- Smoke tubes - show air movements.
- Dust lamp - makes fine dust visible and helps identify emission sources.
- Smell - can be unreliable.

Now conclude (based on gathered information and qualitative tests): is the level of exposure by inhalation acceptable?

- If **YES** - you may not need to carry out exposure monitoring at all (remember, exposure patterns can change, so keep it under review).
- If **NO** (or uncertain) - complete a basic survey.

Basic Survey

This estimates employees' personal exposure and the effectiveness of controls.

It is best to look at worst-case situations first. If exposure is found to present insignificant health risks when compared with current standards, then less exposed staff need not be assessed in detail. So, first identify those groups of staff most likely to be significantly exposed to a hazardous substance and also the conditions and factors giving rise to exposure. You can then use **semi-quantitative** methods to **estimate** personal exposure (to give a rough numerical estimate). These range from stain tubes ('Drager tubes') to more complex methods such as photoionisation detectors, which can be worn by individuals to analyse exposure to organic vapours (these methods will be discussed later). Alternatively, fully **quantitative**, validated, laboratory-based sampling and analysis can be used (as discussed later), or a mixture of methods. Anemometers and other such devices can be used to measure the performance of LEV systems.

Personal sampling can be used at peak periods and static sampling can be used to verify the existence, sources and spread of contaminant release.

Finally, conclude whether the risk is acceptable. If not, or uncertain, either take direct control action or conduct a detailed survey.

Detailed Survey

This is used, for example, when:

- Dealing with carcinogens, mutagens and respiratory sensitisers.
- Exposure is highly variable between employees doing similar tasks.
- The initial appraisal and basic survey indicate:
  - TWA concentrations are very close to the OEL; and
  - the cost of additional controls needs to be justified with more detailed evidence of the exposure profile.

Therefore, these surveys would tend to be used for complex processes. They involve techniques similar to those already used for the initial appraisal and basic survey, **but** more detailed monitoring and analysis would be used to identify exposure patterns and the degree of control.

Detailed surveys may be used for complex processes

Re-Appraisal

The monitoring conducted during basic and detailed surveys may indicate some problems with controls. Once remedial action has been taken, you need to see if the changes have had the desired effect. So, a brief reappraisal of the situation is usually all that is needed. Additional exposure monitoring may also be necessary (for high-risk cases like carcinogens or very variable exposure patterns).

Routine Monitoring

Once you have implemented effective controls, you may decide to use routine monitoring to ensure that controls stay effective. The frequency and type of routine monitoring required will vary depending on:

- **Legal standards** – some substances must be routinely monitored, e.g. in the UK continuous monitoring for vinyl chloride monomer is specified in the regulations.
- The **degree of confidence** that the controls are adequately controlling risks. For example, if the measured exposure is close to the OEL (rather than well below it), then monitoring may be needed to ensure compliance.

It may be more cost-effective in the long term to invest in better controls that always ensure that control is below the OEL – thus reducing the need for routine monitoring. Routine monitoring can be complicated and expensive in the long term, but it doesn't always have to be, e.g. smoke tubes, dust lamps and pressure sensors on LEV.

Personal and Static Monitoring

Workplace exposure limits relate to personal exposure to the hazardous substance. So, in many instances, it is necessary to carry out personal monitoring (or personal dosimetry) to determine what an individual worker's exposure to the airborne contaminant might be. It is not the concentration of the substance at one fixed point that has to be compared to the OEL, but the concentration of the substance that the worker might inhale. This is estimated by fixing them with personal monitoring equipment.

However, there are circumstances where fixed place or static monitoring are appropriate. This involves collecting a sample of the atmosphere (and the contaminant that it contains) at a fixed location, rather than securing the sampling equipment to a worker.

Standard Methods

If the monitoring strategy calls for the use of quantitative analysis of the concentration of airborne substances then it is essential to use the relevant standard method. This ensures scientific validity.

The Methods for the Determination of Hazardous Substances (MDHS) Series

In Britain, the HSE publication series *Methods for the Determination of Hazardous Substances (MDHS) Guidance* on Analysis is a set of detailed descriptions of approved sampling and analytical methods. MDHS methods exist for most chemical agents likely to be encountered in the workplace. They provide reliable and consistent methods to ensure that accurate measurement can be made. The use of these approved methods allows the results obtained to be meaningfully compared to the relevant standards (such as WELs). If sampling or analysis is not carried out in accordance with the relevant **MDHS** method, then the quality and validity of the results obtained are questionable and would not be legally admissible as evidence of compliance.

MORE...

MDHS14/4 General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols is available as a free download from the HSE website at:

www.hse.gov.uk/pubns/mdhs/pdfs/mdhs14-4.pdf

A good example of a widely used and important MDHS Guidance Note is the approved method for carrying out dust sampling as given in the MDHS Guidance Note 14, *General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols*. Note that this guidance note uses the broad term "aerosol" which applies to any solid or liquid suspended in air, rather than 'dust'.

The methods contained in this MDHS Guidance Note are described next.

The NIOSH Manual of Analytical Methods Series

In the USA, the National Institute for Occupational Safety and Health (NIOSH) have also published standard analytical methods for the analysis of airborne contaminants. This is a collection of analytical methods for the sampling of air, but also biological sampling of blood and urine of exposed workers (biological monitoring will be discussed later).

MORE...

The NIOSH Manual of Analytical Methods can be found at:

www.cdc.gov/niosh/docs/2003-154/method-I.html

The ISO catalogue of standards is available at:

www.iso.org/iso/iso_catalogue.htm

ISO Standards

The International Organisation for Standardisation (ISO) have also published analytical methods which can be employed when determining the content of samples taken in the workplace.

Direct Reading Instruments

Direct reading instruments can be used to measure the concentration of various chemicals in air. These instruments rely on a variety of techniques such as:

- **Chemical** reactions designed to produce a colour change, which enables a qualitative analysis to be made (often referred to as 'colourimetric').
- **Electrical** detection, in conjunction with chemical or electro-chemical processes.
- **Physical** methods based on the absorption of ultraviolet or infrared radiation, in proportion to the concentration of the contaminant.

They can be used in a variety of different ways, for example, to give:

- Simple quantification of concentration of a contaminant at one moment in time.
- Continuous monitoring of concentration of a contaminant with data-logging so that concentration profiles can be plotted over time.
- Continuous monitoring of concentrations such that alarms can be activated if levels rise or fall above or below pre-set values.

A typical example of a direct reading instrument is the **photoionisation detector** (PID) where the contaminant is drawn into a cell and is ionised by ultraviolet (UV) radiation, which generates a current proportional to the concentration of contaminant present. They are useful in measuring concentrations of airborne contaminants and can be used for continuous monitoring or general screening in a workplace.

Advantages of Direct Reading Instruments

Direct reading instruments have many advantages, such as:

- Some may be used to continuously monitor the air for the given substance.
- Some are specific to a given substance.
- They give an immediate (or nearly immediate) reading of a contaminant concentration.
- They are very useful for identifying periods of peak concentrations during a working shift.
- Many instruments can be connected to a chart recorder, data logger or a warning device so do not need constant attention.

Disadvantages of Direct Reading Instruments

They can also be disadvantageous in that they:

- Can be expensive.
- Need a competent technician.
- Need to be calibrated to ensure accurate measurement.
- Can be influenced by mixtures.

Stain Tube Detectors

Stain tube detectors are a type of colour metric direct reading instrument. They provide a convenient method of analysing gas and vapour contamination in air.

The principle of operation is very simple: a known volume of air is drawn over a chemical reagent in a glass tube. The contaminant reacts with the reagent and a coloured product, a **stain**, is produced.

Stain tube detectors are now made to allow grab sampling (a crude point-in-time measurement at one location) or long-term sampling, operated by hand bellows, hand pistons or motorised pumps.

The Drager stain tube detector is a typical example of the instrument. It consists of two main parts, the **bellows hand pump** and the **stain tube** (shown in the following figure), selected to suit the particular measurement to be carried out.

The bellows pump is designed to draw in 100cm^3 of air with one stroke. To achieve this, the bellows must be fully compressed before it opens to its maximum volume. The time taken for the bellows to open fully from the closed position gives one pump stroke. The stroke time will depend upon the type of Drager tube being used and can vary from three seconds to 40 seconds.

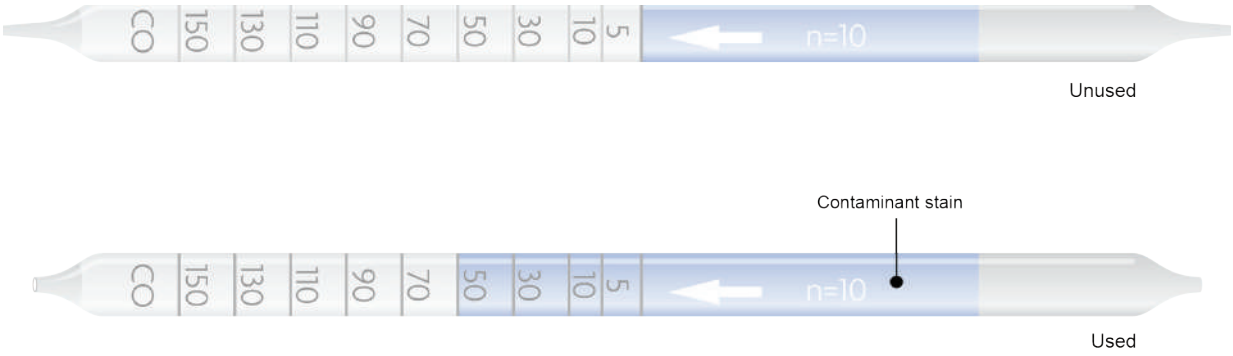
Owing to the time involved and the number of strokes required for a particular measurement, it is important to have a stroke counter fitted to the unit.

The detector tubes contain a reagent which reacts with the contaminant in the airflow passing through it to cause a coloured reaction.

The method of controlling the colour developed is either by drawing a fixed volume of air through the tube using a specified number of strokes, or by counting the strokes required to produce a colour change.

In the first method, the tubes are marked with a graduated scale; the longer the stain produced, the higher the concentration of contaminant. This is the most commonly used system. Unused and used tubes are illustrated below.

In the second method, used less frequently, the greater the number of strokes taken, i.e. the greater the volume of air sampled, the smaller the concentration of the contaminant.



Stain tube before and after use
Note the closed and open ends of the tube. Arrows show direction of air flow. n=10 indicates that 10 strokes on the hand-bellows are required. These tubes are sensitive to carbon monoxide (CO). Final concentration is given as 50 parts-per-million (ppm)

TOPIC FOCUS

General Method of Operation of Stain Tube Detectors

The general method of operation of stain tube detectors is as follows:

- Select the appropriate tube for the measurement being made, taking note of any possible cross-sensitivity.
- Break the end off of the tube to be inserted into the pump. (Use the tube end-breaker provided.)
- Insert the tube into the pump and exhaust the bellows by fully depressing the front plate.
- Allow the system to remain in this state for a few seconds and check for possible leaks.
- If there are no leaks, break off the remaining tip in an uncontaminated atmosphere. Cover the end with the rubber cap provided.
- Select the sampling position, remove the rubber cap and proceed to carry out the sampling procedure, e.g. the given number of strokes for a scale tube and the time allowed for the colour to develop fully.
- Note the reading and record the result and sample position.
- Remove the stain tube, cover both ends with a rubber cap and dispose of it according to the manufacturer's instructions.

Limitations of Stain Tube Detectors

Whilst there are various advantages to stain tube detectors (they are relatively cheap, easy to use, give quick results, etc.), there are also limitations that have to be recognised:

- The rate of flow of air is important, so stain tubes with incorrectly broken ends may not give the correct flow rate.
- The accuracy of the sampled volume is critical, therefore the bellows action must be fully operated for every stroke. The number of strokes must be recorded accurately, hence the need for an effective counter. Leaks must be eliminated.
- There may be the possibility of cross-sensitivity of tube reagents to other substances than the one being analysed. This will be indicated on the data sheet accompanying the particular stain tube.
- There may be problems caused by variations in temperature and pressure. Stain tubes are designed to operate at about 20°C and one atmosphere pressure. Variation in atmospheric pressure will probably be within the limits of accuracy of the system, although changes in altitude could cause problems. Normal variations in temperature will

be problematic; remember, a change of 10°C can cause a reaction rate to be doubled or halved. With ambient temperature ranging between 0°C and 30°C, the potential for error is considerable.

- Because of the complexity of the indicating reagent, tubes have a shelf life, so care must be taken to turn over stock and only use tubes that are currently operative.
- Reagent complexity also causes a variation between each tube; hence, judgments cannot be made on one grab sample.
- Hand-operated stain tube systems are capable of only a **point-in-time** (or 'grab') sample.

Personal Sampling for Solid Particulates

The sampling equipment (sometimes referred to as a 'sampling train') consists of an air pump, connecting hose and sampler (sampling head containing a filter):

- **Air pump** - must meet certain minimum standards and is usually a unit that can be worn by a worker on a beltor in a pocket and is capable of drawing air at a steady fixed rate for 4-8 hours.
- **Hose** - simply a clear plastic tube for connecting the air pump to the sampler.
- **Sampler** - a small filter holder that can be attached to the worker close to their breathing zone; usually clippedto clothing at the collar bone.
- **Flow meter** - used to check the flow rate of the sampler train before and after use.

There is a number of different types of sampler used for gravimetric analysis of dust. They fall into two maincategories: inhalable samplers and respirable cyclones.

General Method for Sampling and Gravimetric Analysis of Dusts

The UK HSE's MDHS Guidance Note 14 explains the general methods to be used when sampling and analysing both respirable and inhalable dust. You may remember that:

- **Inhalable** (or 'total inhalable') dust is dust where the particles are >0.1 microns in diameter that are suspended in air and so can be inhaled through the nose or mouth into the respiratory tract.
- **Respirable** dust is that fraction of inhalable dust that is small enough to pass through the upper respiratory tract, down into the lungs, to the region of gas exchange.

The most recent version of Guidance Note 14 (MDHS14/4) also gives guidance on collecting the thoracic aerosol fraction in air for the purpose of monitoring workplace exposure. This is the fraction of inhaled airborne material that penetrates beyond the larynx.

The general principle is simple:

- Contaminated air is drawn through a **filter** held inside a **sampler** (sampling head) for a period of time.
- The filter is **weighed** both before and after sampling to give the weight of dust that has collected (hence gravimetric analysis).
- The weight of dust collected is used to calculate the dust concentration in air ($mg.m^{-3}$).

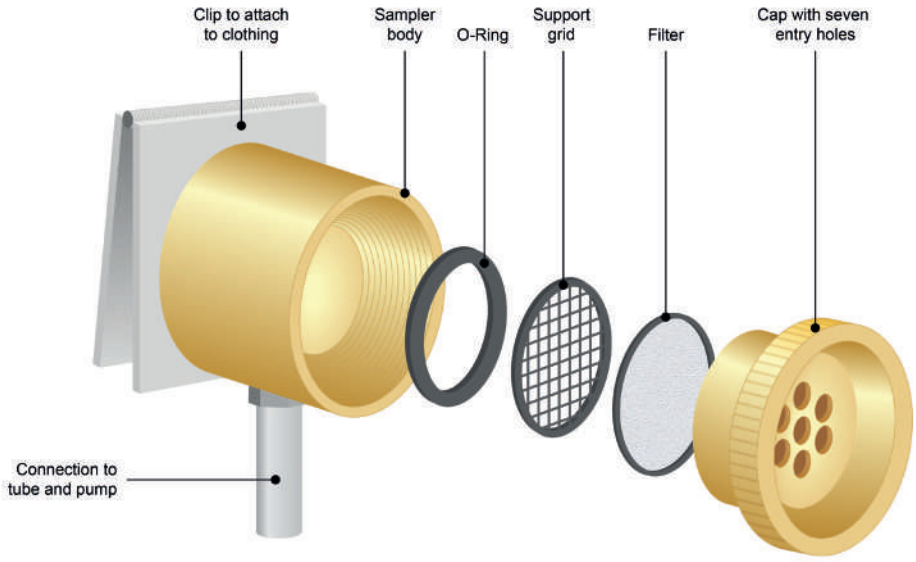
(The dust collected might also be analysed by other methods to reveal its chemical composition).

The type of sampling head used depends on the nature of the particulates being measured (e.g. inhalable vs. respirable dusts). A similar method is used for the analysis of asbestos fibres, but makes use of slightly different sampling equipment and a very different analysis method.

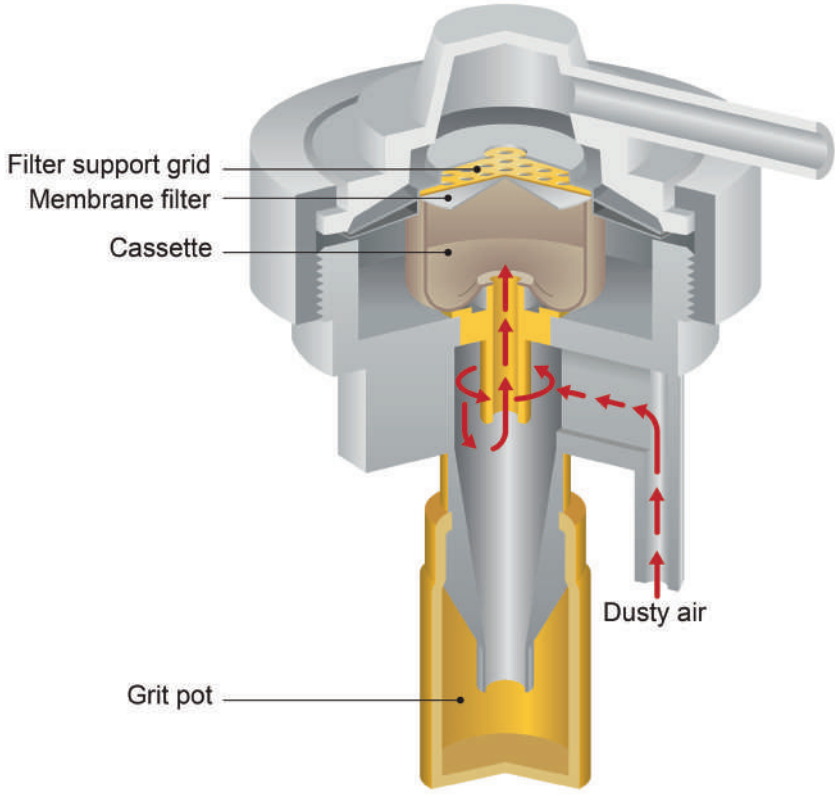
The MDHS Guidance Note 14 method of sampling can be used for both **background** (fixed point or static) sampling in the workplace environment (where the sampler is fixed at a set location in the workplace) and for **personal sampling** (where the sampler is attached to a worker). Personal sampling is always more indicative of real worker exposure levels.

The multi-orifice sampling head shown has to be fitted to an air pump unit capable of maintaining a smooth flow rate of 2.0 litres per minute (l/min). Different types of sampling head can be used. The multi-orifice type shown has

to be loaded with a pre-weighed filter before use. Other types, such as the Institute of Occupational Medicine (IOM) sampling head, are loaded with a cassette that contains the filter. This eliminates the need for the end user to directly handle the filter and reduces the potential for handling errors.



Multi-orifice inhalable sampling head - just one of the many types available
(Based on MDHS14/4 General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols, HSE, 2014 (www.hse.gov.uk/pubns/mdhs/pdfs/mdhs14-4.pdf))



Cyclone respirable sampler (Based on MDHS14/4 General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols, HSE, 2014 (www.hse.gov.uk/pubns/mdhs/pdfs/mdhs14-4.pdf))

The cyclone sampler works on a similar principle to the inhalable sampler, except that larger particles of dust are excluded from the sample by using a small cyclone (which works on the same principle as a Dyson vacuum cleaner).

Only smaller, respirable particles are permitted to enter the cassette in the middle of the sampler where they are then collected on a membrane filter. The cyclone sampler shown above requires a pump air-flow rate of 2.2 l/min.

Method of Use

MDHS Guidance Note 14 describes the sampling procedure in practical detail. Key points to observe are:

- Clean and load the sampler with a pre-weighed filter or cassette.
- Fit the sampler to the pump. Run the pump to stabilise airflow and then check and adjust flow rate using the flow meter.
- Attach the sampling train to the operator, not more than 30cm away from the nose-mouth region.
- Record the time at the start of the sampling period and check, record and readjust the flow rate as necessary at the end of each hour.
- At the end of the sampling period, note the time and remove the filter for re-weighing.
- Re-check the flow-rate using the flow meter.

Filters have to be weighed accurately using laboratory scales. The accuracy of the scales and weighing method usually means this should be carried out at an accredited laboratory.

Sampling and Analysis for Asbestos

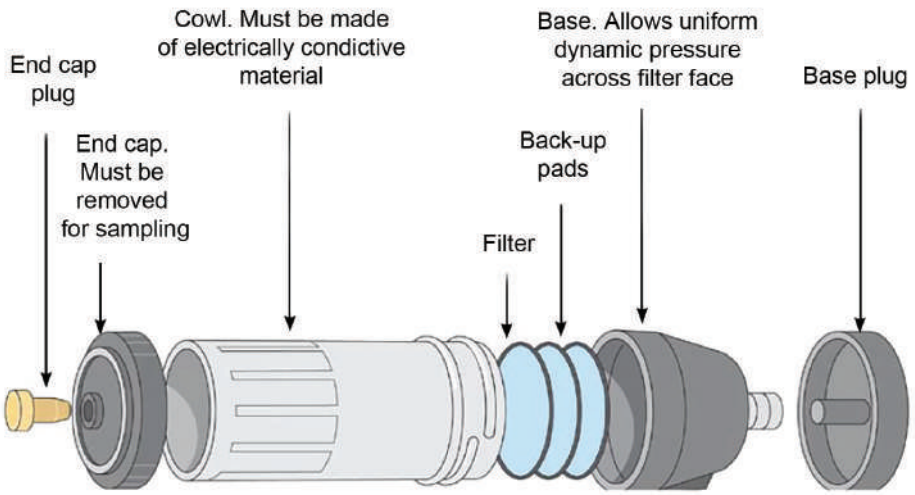
Sampling and analysis of asbestos fibres in the air should be carried out using the approved method (Appendix 1 of the HSE guidance note HSG248).

The method of sampling is similar to that for dust. A sample is collected by drawing a measured volume of air through a membrane filter held in a cowled sampler by means of an air pump.

The method of analysis is rather different. The filter is mounted on a microscope slide and rendered transparent ('cleared'). Fibres of appropriate dimensions ('countable fibres') on a measured area of filter are counted visually using Phase Contrast Microscopy (PCM) and the number of fibres in the air calculated.

Cowled Sampler

A cowl is a hood that is attached to the sampling head. Cowls can be bought in a variety of shapes and sizes, e.g. conical. The size of the cowl will affect the size of the surface area over which air is drawn. For the collection of asbestos fibres, an open-faced filter holder and a cylindrical cowl are used, as illustrated.



Sampling head with cowl, for collection of asbestos fibres Source: Figure A1.1 Exploded view of a personal sampling head from HSG248: Asbestos: The analysts' guide for sampling, analysis and clearance procedures, HSE, 2006 (www.hse.gov.uk/pubns/priced/hsg248.pdf)

The cowl is made of an electrically conductive material to ensure that static build-up does not affect the collection of fibres. The membrane filters used are of cellulose or nitrocellulose.

Fibres are collected using a very similar technique as for dusts. Fixed point and personal sampling can be conducted using a calibrated air pump, flexible tube and sampler. Different air pump flow rates and sampling durations are used depending on the purpose of the measurement.

Analysis - Phase Contrast Microscopy (PCM)

Phase Contrast Microscopy (PCM) is used to count the number of asbestos fibres collected on the filter. Before the fibres can be visualised by microscope, the filter has to be made transparent (**cleared**). This is done by mounting the filter on a microscope slide and then spraying it with **acetone vapour**. The filter is then dried and covered with a cover slip.

The filter is then examined on a phase contrast light microscope. This type of microscope allows asbestos fibres to be distinguished from the background of the filter.

A known proportion of the filter is visually scanned and the number of fibres counted. Only those fibres with a length in excess of 5µm, a width less than 3µm and a length to width ratio of more than 3:1 are defined as **countable fibres**. Measuring the length of a fibre requires a microscope eyepiece with a calibrated scale. By calculating the number of fibres in a known proportion of the sample collected, the number in the whole sample and the airborne concentration can be calculated.

The above is a simplification of the analysis method, which is necessarily complex. Counting has to be done to strict rules to avoid subjective errors in what constitutes a countable fibre.

Personal Sampling for Vapours

There are two main ways in which these airborne contaminants can be sampled: diffusion sampling and mechanical sampling. In **diffusion sampling** (or **passive sampling**), the contaminant passes over the sampling system in natural air currents and diffuses into a chamber containing an sorbent material for later analysis. The **mechanical sampling** (or **active sampling**) system uses a pump to provide airflow through the sampling device or analysin instrument. These techniques are described in the following section.

Passive Devices

Passive devices employ sorbent material to sample concentrations of airborne contaminants without using a pump to draw air through the collector. The sorbent material is contained in a holder designed to allow the gases to diffuse and/or permeate to the sorbent surface. These holders are small enough to be worn like a lapel badge and are free of any pump or tubing. At the end of the sampling period, the holder is returned to the laboratory, where the sorbent material is removed and the amount of gas or vapour collected can be analysed.

In practice, there are two main types of design. The badge-type sampler has a flat, permeable membrane supported over a shallow layer of sorbent (see below). The tube-type sampler has a smaller, permeable membrane supported over a deep metal tube filled with sorbent (see the following).

DEFINITIONS

ABSORB

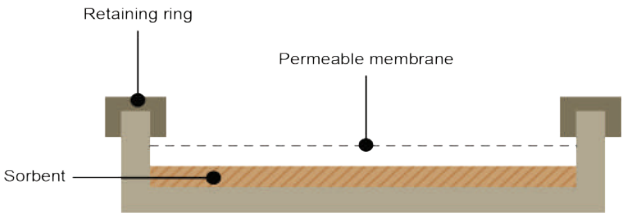
Any material is drawn into another material and held throughout its bulk, e.g. water into cotton wool. Note: no chemical binding takes place.

ADSORB

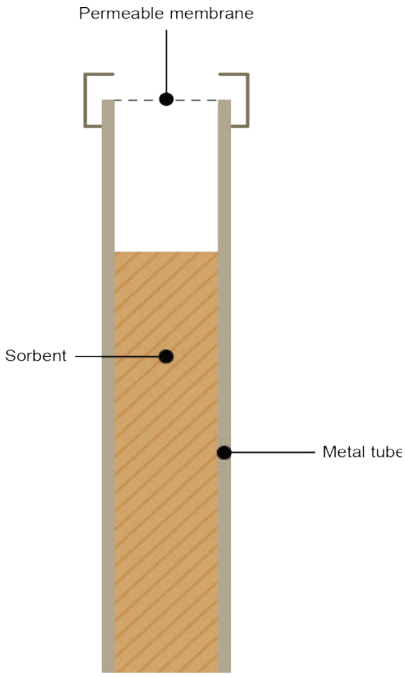
A process in which any material is attracted by and adhered to the surface of the 'sorbent'.

SORBENT

A solid or liquid material that is capable of absorbing or adsorbing a gas or vapour sample (e.g. activated charcoal).



Badge sampler



Diffusing sampler

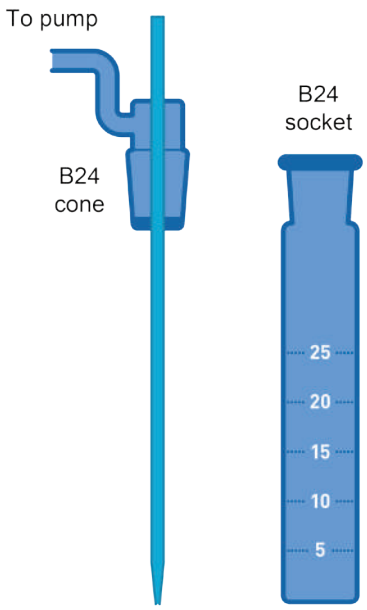
Active Devices

These largely involve contaminated air being drawn through some sorbent material (solid or liquid).

- ### Liquid Sorbents - The Midget Impinger

  A common example is a midget impinger (but, for reasons that will become clear, is commonly called a 'bubbler').

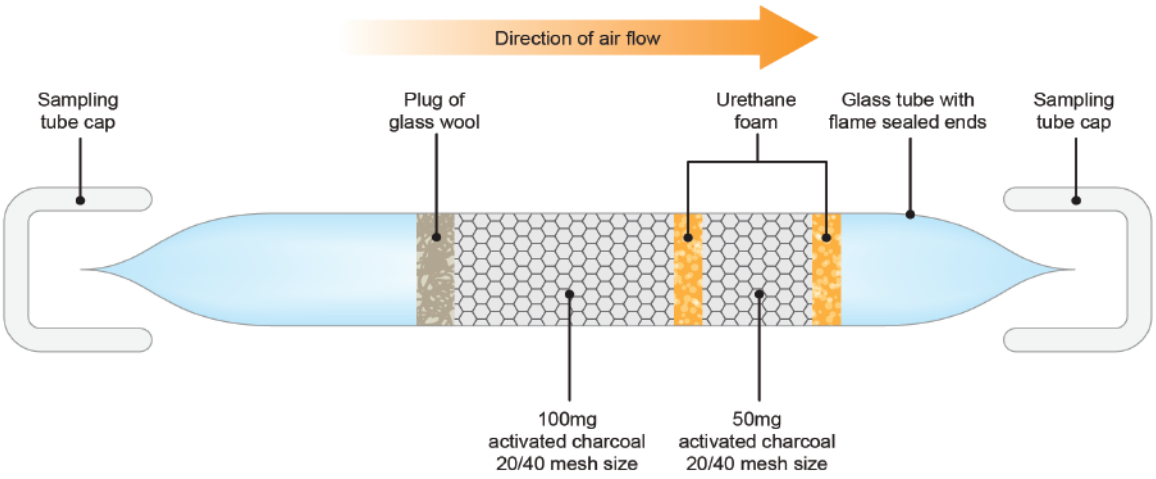
  Here, the bottle is partially filled with 10-20ml of a liquid sorbent (which could be something as simple as water), in which the vapour gas will readily dissolve (or react). The cone is inserted into the socket (see diagram), the outlet tube then being connected to the pump. This then 'bubbles' contaminated air through the sorbent. The impinger is attached to the worker's clothing.



Midget impinger for vapours

- ### Solid Sorbents - Sorbent Tubes and Pumps

  Certain gases and vapours are readily sorbed by solid materials such as silica gel, activated charcoal and various types of porous resin. When a continuous stream of air is pumped through a tube containing activated charcoal, any gases or vapours will be sorbed. The amount of contaminant collected can then be determined back in the laboratory. The pumps used in this technique are small and can be attached to the worker in the same way as a passive device. An activated charcoal sample tube is shown in the following figure.



Activated charcoal sampling tube

Analysis of Vapours

Vapours collected on sorbents within samplers can be desorbed in a laboratory and chemically analysed using a variety of techniques, e.g. Gas Chromatography (GC), or infrared spectroscopy. In this way, it is possible to identify the actual chemical collected and calculate its concentration (by calibration of the instrument for a given chemical and knowledge of the collection parameters - flow rate and collection time).

Calculating Exposures

General Method for Calculating 8-Hour TWA Exposures

The 8-hour TWA exposure for a work activity where the exposures have been measured can be calculated using the following formula:

$$\text{8-hour TWA exposure} = \frac{C_1T_1 + C_2T_2 + \ldots C_nT_n}{8}$$

The simplest way of using the formula is:

1. For each partial exposure period, multiply the concentration by the duration of exposure (in hours).
2. Add all of these partial exposures together.
3. Divide the sum by 8 (to give an 8-hour average).
4. Express the answer in the same units as the concentrations were first measured in.

Example:

Steps 1 and 2

Concentration of Contaminant in PPM	Exposure Time in Hours	Product
60	0.5	60 × 0.5 = 30
40	1.5	40 × 1.5 = 60
50	2.0	50 × 2 = 100
60	3.0	60 × 3 = 180
80	1.0	80 × 1 = 80
		sum 450

Table showing measured exposures (concentration and duration of exposure) along with the partial exposures (concentration × time in hours) and the sum of the partial exposures (Steps 1 and 2)

Steps 3 and 4

$$\text{8-hour TWA} = \frac{450}{8} = \mathbf{56.25\ ppm}$$

If the WEL listed in EH40 for the substance in question was:

- 30ppm, then the WEL would have been exceeded.
- 60ppm, then the limit would not have been exceeded, but the 8-hour TWA would be unacceptably close to the WEL.
- 200ppm, then the exposure would be acceptable in relation to the WEL.

Note that even if the total duration of the working period is less than, or more than, eight hours, the total exposure is **always** divided by 8 to give the 8-hour TWA.

Example Calculation Using Sampling and Gravimetric Analysis of Dust Method

When a dust sampling train is used to collect a dust sample from the atmosphere, then calculating the dust concentration in $mg.m^{-3}$ is relatively simple:

A. First calculate the volume of air (in m^3) drawn through the sampler:
   i Multiply the pump flow rate (l/min) by the sampling time (in minutes)
   ii Convert this from litres to cubic metres by dividing by 1000.
B. Second calculate the weight of dust (in mg) on the filter by:
   i Weight of the filter after use - weight of the filter before use
C. Third calculate the weight of dust per cubic metre of air ($mg.m^{-3}$) by dividing B with A.

So, for example, if the following sampling data is obtained:

- pump flow rate = 2.0 l/min
- sample duration = 6 hours
- pre-use filter weight = 2,123mg
- post-use filter weight = 2,136mg

then using steps above would give:

A. Total volume of air drawn through sampler = 2.0 × (6 × 60) = 2.0 × 360 = 720 litres 720 / 1000 = **0.72m^{-3}**

B. Weight of dust on filter = 2136mg - 2123 mg = **13mg**

C. 13 / 0.72 = **18.1 mg.m^{-3}**

Note that this exposure is for a 6-hour period of time.

Evaluation of the acceptability of this measurement would require that the result is first used to calculate the **8-hour TWA exposure**. Once this is done, the evaluation would then have to take account of the nature of the dust in question and the relevant standards that applied.

Calculation of the 8-hour TWA exposure is done using the method described above.

For the example given above, if we assume that no further dust exposure occurs during the working shift:

Concentration of Contaminant in mg.m^{-3}	Exposure Time in Hours	Product
18.1	6	18.1 × 6 = 108.6
Assumed 0	3	0 × 3 = 0
		sum 108.6

$$\text{8-hour TWA} = \frac{108.6}{8} = \textbf{13.6 mg.m}^{-3}$$

When evaluating whether this 8-hour TWA exposure is acceptable or not, reference would have to be made to the standards set out in EH40 (or elsewhere). However, it is worth noting that, generally, WELs for dust are set at 10 mg.m^{-3} or less and that for nuisance dust (dust of a general nature for which no specific WEL exists) a notional WEL of 10 mg.m^{-3} should be used. Therefore, we can see that an 8-hour TWA dust exposure of 13.6 mg.m^{-3} is unlikely to be acceptable under any circumstances.

If multiple samples are taken during a work shift, then each partial exposure will have to be accounted for when calculating the 8-hour TWA exposure as already described.

MORE...

Further information on this topic is available in the following guidance documents, available as free downloads from the HSE website at:

www.hse.gov.uk/pubns

HSG173 *Monitoring Strategies for Toxic Substances*

Appendix 1 of HSG248 Asbestos: *the Analysts' Guide for Sampling, Analysis and Clearance Procedures*

STUDY QUESTIONS

3. State the four stages in the practice of occupational hygiene.
4. Outline the monitoring strategy described in HSG173.
5. Describe the gravimetric method for the analysis of inhalable dust.
6. State the limitations of stain tubes as a method of quantifying airborne contaminant.

(Suggested Answers are at the end.)

Health Surveillance: Health Monitoring and Biological Monitoring

IN THIS SECTION...

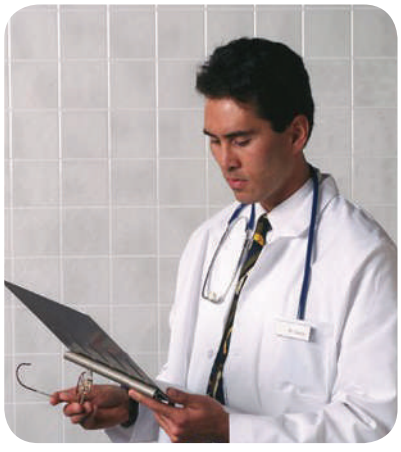
- General health assessment is an assessment of an individual's fitness to carry out the general duties or specific tasks associated with work.
- Health surveillance is the monitoring of an individual's health to ensure that they are suitable for work involving exposure to a specific type of health hazard and to track their health over time as they work with that hazard.
- Health records must be kept following health surveillance; these records contain personal details of the individual and their work and may contain the conclusions of a clinician following any test or assessment. These records must be kept for a defined period, often 40 years.
- Health records are subject to data protection legislation and must be kept secure and confidential.
- Since they do not contain clinical information, they may be viewed by the employer. Medical records containing clinical information are confidential between the clinician and individual. The content can only be shared with the employer with the individual's authority.
- Biological monitoring involves taking a blood, urine or breath sample and then measuring the concentration of a substance or its metabolic breakdown products in that sample.
- Biological monitoring is useful where inhalation is not the only significant route of entry for a substance, and it has advantages and disadvantages.
- For most substances where biological monitoring is carried out, the results are evaluated by comparison with biological limit values, such as the UK Biological Monitoring Guidance Values (BMGVs).

Health Assessment and Health Surveillance

It is important to distinguish between general health assessment and health surveillance.

General health assessment is any form of medical assessment that determines the general state of health or fitness of an individual. This assessment will normally be carried out by an occupational health doctor or nurse. However, it is quite possible that it is carried out by the individual themselves through some form of self-assessment. It may also be carried out by a specialist focusing on one specific aspect of health, e.g. an eye test carried out by an optician.

General health assessments are often carried out by organisations as a form of pre-placement assessment. These may take the form of self-assessment health questionnaires with follow up by an occupational health doctor or nurse where specific issues are raised by the answers given. These health assessments may then be repeated periodically.



Health assessments will determine the health of an individual

In some instances, there is no specific health and safety aspect to this assessment and it is provided as a benefit of employment.

Alternatively, specific health assessments are carried out by an organisation to ensure that a worker is fit for a specific role or task. For example, the DSE user's eye and eyesight test, a forklift truck driver's medical and a crane operator's medical are all forms of health assessment that ensure that an individual is medically fit for work. These health assessments may be provided:

- to comply with a clear statutory duty (e.g. a lorry driver's health assessment); or
- as a matter of good practice (e.g. a health assessment for a company car driver; though the driver has to be medically fit to drive, there is no statutory duty on their employer to carry out an assessment of fitness to drive).

Health surveillance is a more specific assessment of a worker's medical fitness that focuses on one specific aspect of health in relation to a particular hazard or hazard group. The intention of health surveillance is to determine a worker's state of health with regards to the hazard and then to track that aspect of their health forward in time through repeat assessments.

MORE...

Further information and guidance on **health surveillance** is available from the HSE online at:

www.hse.gov.uk/health-surveillance/index.htm

Health surveillance is legally required where the following criteria are met:

- there is an identifiable disease or adverse health condition related to the work concerned; and
- valid techniques are available to detect indications of the disease or condition; and
- there is a reasonable likelihood that the disease or condition may occur under the particular conditions of work; and
- surveillance is likely to further the protection of the health and safety of the employees to be covered.

Health surveillance is normally provided where there is a clear statutory duty under specific health and safety legislation.

The way that health surveillance is carried out will vary depending on the form of health surveillance and the relevant standards. Health surveillance might be carried out by:

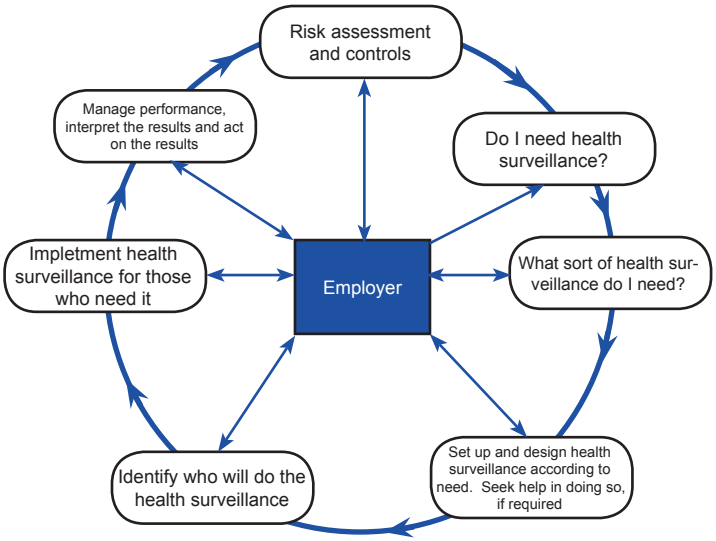
- Examination and assessment by a specialist or an occupational health doctor or nurse with a specific qualification in that particular form of health surveillance.
- Examination and assessment by an occupational health doctor or nurse using appropriate guidance to determine the method and standards.
- Examination and assessment by a responsible person under the supervision of an occupational health doctor or nurse.
- Self examination and/or self assessment by the worker under the supervision of a responsible person.

Most forms of health surveillance should be carried out by the first group.

A notable exception to this is the skin check that is often carried out when workers are potentially exposed to primary cutaneous irritants or skin sensitisers. These substances are capable of causing primary contact dermatitis or secondary allergic dermatitis, respectively. Since skin checks usually involve visual examination of exposed skin (on the hands and forearms), self assessment or assessment by a responsible person are normally adequate to ensure freedom from symptoms.

The Health Surveillance Cycle

The diagram below provides an overview of the health surveillance cycle. It shows how the employer is responsible for identifying the need for health surveillance through the risk assessment process and how the specific type of health surveillance must be sourced and implemented. Results from health surveillance then inform and feed back into the risk assessment process.



The health surveillance cycle

The diagram also clearly shows how the employer has a central role in every aspect (with involvement from employees) to ensure effective implementation.

Requirement for Health Records and Medical Records

Health surveillance programmes, such as those required by **statute law**, should include keeping a **health record** for each individual. These are important because they provide:

- A record of jobs involving potentially hazardous exposures.
- A record of the outcome of health surveillance (in terms of fitness for work, restrictions required, etc.).
- Information for inspectors to show that health surveillance has been carried out.

A health record can be paper-based or held on computer and, as a minimum, should contain:

- Surname.
- Forenames.
- Sex.
- Date of birth.
- Permanent address.
- Identification number.
- Date started present job.
- An historical record of jobs involving exposure to hazards for which health surveillance is required during the current spell of employment.

In some circumstances, the only health surveillance required is the setting up and maintenance of individual health records containing the information above. For example, workers working with known or suspected carcinogens should have this type of health record but do not necessarily undergo any form of medical examination, test or assessment. In these cases, the health record simply provides a record of potential and actual exposure.

If specific tests, examinations or assessment are conducted as a part of health surveillance (such as lung function testing), then the health record must also contain the conclusions of that health surveillance procedure and the date on which and by whom they were carried out.

The conclusions should indicate whether the individual is fit to continue to work, including, where appropriate, the decisions of the doctor or nurse where medical assessments have taken place (but not clinical information), or the conclusions of other suitably qualified or responsible people.

Health records are different from clinical medical records in that they do not contain confidential clinical details and can therefore be kept securely by the employer with other confidential personnel records. Medical records that include medical information arising from clinical examination are held in confidence by the doctor, nurse or other occupational health professional and can only be released to an employer or anyone else with the written consent of the individual.

Length of Retention of Health Records

As a general rule, health records have to be retained for as long as the employee that they relate to is under health surveillance.

Statute law or best practice may state that records should be retained for 40 years because ill-health effects might not emerge until a long time after exposure. For example, in the UK, the guidance on the Control of Asbestos Regulations 2012 recommends that records are retained for 40 years or until the employee reaches age 80, whichever is the longest.

Employers about to cease to trade may be obliged under statute law to notify the relevant authorities and to offer to provide paper copies of employees' health records for safe keeping. In this way, health records are maintained even though the employer organisation has ceased to exist.

Confidentiality

Health records created by the employer contain personal data about individuals. As such, they are likely to be subject to the data protection legislation and must be kept secure and confidential. They must not be accessed by anyone who does not have a legitimate right of access.

Local statute law may allow employees a right to see and comment on their health records. This includes any health record kept by their employer. Employees also usually have a right of access to their health records granted under the specific health and safety legislation that required the health surveillance in the first place. It is good practice to offer individual employees a copy of their health records when they leave employment.

Local labour law enforcement inspectors normally have a right of access to health records granted by specific legislation.

Trade Union safety representatives may also have a legitimate interest in health records. Legal guidance may indicate that they should be given access where the employee to whom the record relates has given authorisation.

Medical records contain clinical information that is legally and ethically confidential between the individual concerns and their clinician (medical practitioner, occupational health doctor, nurse, etc.). As such, this information can only be disclosed to the employer or any other party with the authorisation of the individual concerned. The storage and security of medical records is the responsibility of the clinician.

Data Protection Legislation

As an example of data protection legislation, we will look at the UK Data Protection Act 1998, which seeks to control the way that personal data (data that relates to an identifiable person) is stored and used. Key principles of the act are:

- Data can only be used for the purposes for which it was collected.
- Data must not be disclosed to others without the consent of the individual, unless there is a legitimate reason.
- Individuals have a right of access to data held about them.
- Data must not be kept for longer than is necessary.
- Data must be kept secure.
- The individual has the right to have factually incorrect information corrected.

In the context of health records, the Act places requirements on employers to tell employees on whom records are held:

- that a record is being kept;
- the purpose for which it is being held; and
- that they have the right of access to the information and the right to correct it.

The data protection legislation seeks to control the way personal data is stored

Principle of Biological Monitoring

Biological monitoring is a technique that complements air monitoring as a method of measuring and evaluating the risk to health of exposure to chemical agents. Its purpose is to assess the extent of exposure, uptake and metabolism of chemicals in the workplace. It involves the analysis of biological samples (blood, urine or breath) to provide an index of exposure, thereby giving an indication of the possible risks to health.

For example, the detection of significant levels of lead in blood indicates the presence of potentially harmful levels of absorbed lead. The concentration of bromide in blood is an indicator of methyl bromide exposure and the concentration of mandelic acid in urine is an indicator of styrene exposure.

Biological monitoring is used to indicate how much of a chemical has entered a worker's system (rather than simply how much was in the air that the worker might have inhaled).

The ILO Code of Practice – Occupational Exposure to Airborne Substances Harmful to Health (Section 4) states that biological monitoring "should be used to complement monitoring of the working environment in order to increase protection of workers' health." The CoP also states that, where necessary and practicable, biological monitoring should be based on several parameters for each hazardous substance.

Biological monitoring is especially useful when:

- Absorption is likely to be through skin and ingestion rather than inhalation, therefore air monitoring is not a complete indicator of uptake.
- There are valid laboratory methods available for the detection of the chemical or its metabolites in the body.
- There are reference values available for the interpretation of the results obtained.
- PPE is used as a significant control; failure to wear PPE correctly would not be shown up by air monitoring, but it would be indicated by biological monitoring.

DEFINITION

BIOLOGICAL MONITORING

Is defined by the COSHH Approved Code of Practice as, *"the measurement of a substance or its metabolite (substance formed when the body converts the chemical) in a biological fluid (breath, urine or blood), e.g. monitoring for isocyanates in urine".*

Advantages and Disadvantages

The **advantages** of biological monitoring include the following:

- It can help to demonstrate whether personal protective equipment (e.g. gloves and masks) and engineering controls (e.g. extraction systems) are effective in controlling exposure.
- It measures individual exposure to a chemical by all routes of entry.
- It identifies what has been absorbed by the body (unlike airborne monitoring).
- It shows how effective improvements in control measures have been in reducing exposure.
- It gives reassurance to workers that their individual exposure is being monitored.

The **disadvantages** of biological monitoring include the following:

- Sampling may require blood to be taken which would require a physician or nurse.
- Measurements relate to individuals, so confidentiality and data protection issues need to be addressed.
- As with all standards, biological monitoring standards aim to protect the majority of the exposed population.

An individual may suffer adverse changes at concentrations below the published standard.

The Role of Biological Limits

The ILO CoP states that:

- Evaluation of the overall hazard presented by the working environment should be based on the results from a group of workers exposed to a given level of the harmful substance, in order to offset the effect of individual biological variability.
- Any worker for whom the findings exceed the biological limits should undergo further and repeated biological and medical investigations.

Thus, the **Biological Limit** is the standard against which measurements taken from workers can be compared to see whether the workers have been over-exposed to the hazardous agent.

In the UK, the HSE has derived Biological Monitoring Guidance Values (BMGVs) for interpreting biological monitoring measurements. These are published in EH40 workplace exposure limits.

Substance	Biological monitoring guidance values	Sampling time
Butan-2-one	70 µmol butan-2-one/L in urine	Post shift
2-Butoxyethanol	240 mmol butoxyacetic acid/mol creatinine in urine	Post shift
Carbon monoxide	30 ppm carbon monoxide in end-tidal breath	Post shift
Chromium VI	10 µmol chromium/mol creatinine in urine	Post shift
Cyclohexanone	2 mmol cyclohexanol/mol creatinine in urine	Post shift
Dichloromethane	30 ppm carbon monoxide in end-tidal breath	Post shift
N,N-Dimethylacetamide	100 mmol N-methylacetamide/mol creatinine in urine	Post shift
Glycerol trinitrate (Nitroglycerin)	15 µmol total nitroglycols/mol creatinine in urine	At the end of the period of exposure
Lindane (γBHC(ISO))	35 nmol/L (10 µg/L) of lindane in whole blood (equivalent to 70 nmol/L of lindane in plasma)	Random
MbOCA (2,2' dichloro-4,4' methylene dianiline)	15 µmol total MbOCA/mol creatinine in urine	Post shift
Mercury	20 µmol mercury/mol creatinine in urine	Random
4-methylpentan-2-one	20 µmol 4-methylpentan-2-one/L in urine	Post shift

Extract from Table 2 of EH40 showing BMGVs
Source: EH40/2005 Workplace exposure limits (2nd ed.), HSE, 2011 (www.hse.gov.uk/pubns/priced/eh40.pdf)

BMGVs in EH40 do not have the same status as OELs. They are not approved and consequently are not legally enforceable.

Given that BMGVs are non-statutory, any biological monitoring undertaken must be conducted on a voluntary basis (i.e. with fully informed consent of workers). BMGVs are intended to be used as tools in meeting the employer's primary duty to ensure adequate control under relevant legislation. Where a BMGV is exceeded it does not necessarily mean that any corresponding airborne standard has been exceeded nor that ill health will occur. The intention is that where they are exceeded this will indicate that investigation into current controls and work practices is needed. Similarly, it must not be assumed that because biological monitoring results are below a particular guidance value no further action is needed to reduce exposure. BMGVs are not an alternative to or a replacement for OELs and airborne monitoring; instead they are a useful addition.

MORE...

BMGVs are explained in EH40 *Workplace exposure limits*, available from:

www.hse.gov.uk/pubns/books/eh40.htm

STUDY QUESTIONS

7. What is the minimum requirement for health surveillance and the keeping of a health record?
8. What is the difference between a health record and a medical record?
9. What does the term 'biological monitoring' mean?

(Suggested Answers are at the end.)

Summary

Occupational Exposure Limits (OELs)

We have examined how:

- Occupational Exposure Limits (OELs) are standards for exposure to particular health hazards above which workers should not be exposed.
- Two OELs can be set for a chemical, a Long-Term Exposure Limit (LTEL) based on an 8-hour Time-Weighted Average (TWA) exposure and a Short-Term Exposure Limit (STEL) based on a 15-minute TWA exposure.
- LTELs are used to control long-term exposure and the chronic ill-health effects that might result, whereas STELs are used to control short-term exposure that might create acute effects.
- There are no internationally recognised standard exposure limits at present. Exposure limits are implemented differently in various countries; examples include Workplace Exposure Limits (WELs) in the UK and Permissible Exposure Limits (PELs) in the USA.
- In the UK, lead and asbestos have their own OELs set under their respective regulations, which apply a higher degree of control over these two health hazards.

Strategies, Methods and Equipment for the Sampling and Measurement of Airborne Contaminants

We have examined how:

- The identification, measurement and evaluation of health hazards, and the subsequent design and testing of control measures is often the work of the occupational hygienist.
- Safety practitioners may be involved in the management of occupational hygienists, so evaluating their competence and interpreting their reports can be important.
- The UK HSE's guidance HSG173 indicates that an effective strategy for monitoring hazardous substances calls for a three-stage approach: an initial appraisal, perhaps a basic survey and a detailed survey if needed.
- If quantitative monitoring is to be carried out, then an approved method (such as one from the UK
- HSE's MDHS guidance series) must be used to ensure the validity of results obtained.
- Direct reading instruments can be used to measure airborne concentrations of contaminants.
- Stain tube detectors provide a way of spot-sampling concentrations of gases and vapours in air. They are simple to use, but do have limitations.
- Dust concentrations in air can be monitored using an air pump and sampler containing a filter. Different types of sampler allow for inhalable or respirable dust to be collected. The amount of dust collected is quantified by weighing.
- Asbestos concentrations in the air can be measured using similar equipment with a cowled sampler head. The amount of asbestos collected is quantified by counting fibres by Phase Contrast Microscopy (PCM).
- Gas and vapour concentration can be measured using various passive and active devices.
- Actual exposures can be calculated on an 8-hour TWA basis and these results can then be compared to the OEL for evaluation.

Health Surveillance: Health Monitoring and Biological Monitoring

We have described how:

- General health assessment is an assessment of an individual's fitness to carry out the general duties or specific tasks associated with work.
- Health surveillance is the monitoring of an individual's health to ensure that they are suitable for work involving exposure to a specific type of health hazard and to track their health over time as they work with that hazard.
- Health records must be kept following health surveillance; these records contain personal details of the individual and their work and may contain the conclusions of a clinician following any test or assessment. These records must be kept for a defined period, often 40 years.
- Health records are subject to data protection legislation and must be kept secure and confidential.
- Since they do not contain clinical information, they may be viewed by the employer. Medical records containing clinical information are confidential between the clinician and individual. The content can only be shared with the employer with the individual's authority.
- Biological monitoring involves taking a blood, urine or breath sample and then measuring the concentration of a substance or its metabolic breakdown products in that sample.
- Biological monitoring is useful where inhalation is not the only significant route of entry for a substance, and it has advantages and disadvantages.
- For most substances where biological monitoring is carried out, the results are evaluated by comparison with biological limit values, such as the UK Biological Monitoring Guidance Values (BMGVs).

Exam Skills

QUESTION

(a) Use the data below to **calculate** the 8 hour Time-Weighted Average (TWA) exposure to flour dust for a bakery operative. Your answer should include detailed working to show your understanding of how the exposure is determined.

Working Period (total shift time = 8 hours)	Tasks undertaken by bakery operative	Exposure to Flour dust (mg/m^3)
08:00 - 10:30	Weighing ingredients	14
10:30 - 10:45	Break	
10:45 - 12:45	Charging the mixers	10
12:45 - 13:45	Lunch	
13:45 - 15:45	Cleaning the equipment	2.5
15:45 - 16:00	Assisting maintenance staff	0 (assumed)

Assuming that exposure is zero during break times and lunch time.

Also assume that a legally enforceable Exposure Limit (8 hours TWA) of $10mg/m^3$ is applicable to flour dust. **(7)**

(b) The bakery changes the working patterns to the extent that the operative now only charges the mixer. In addition, shift times have been altered to a 10 hour shift, which includes a 1-hour lunch break where the exposure is assumed to be zero. Using the relevant data above, **re-calculate** the equivalent 8-hour TWA exposure in their new role **AND comment** on the legal implications of this change. **(3)**

Approaching the Question

This question has been selected because, at first glance, it can seem quite daunting. It is not uncommon to see calculation questions in Unit IB, but they are usually quite simple if you understand the basis of the calculations, so you can pick up marks very quickly.

1. For this 10-mark question you are asked to calculate and comment on the data. There are no command words (such as "outline") to assist further, but it is clear that NEBOSH want to see that you can carry out the calculations and then understand what the data is telling you.
2. Now highlight the key words. In this case, we will be highlighting nearly everything, as everything in the data table is essential information:

(a) Use the data below to **calculate** the 8 hour Time-Weighted Average (TWA) exposure to flour dust for a bakery operative. Your answer should include detailed working to show your understanding of how the exposure is determined.

Working Period (total shift time = 8 hours)	Tasks undertaken by bakery operative	Exposure to flour dust (mg/m^3)
08:00 - 10:30	Weighing ingredients	14
10:30 - 10:45	Break	
10:45 - 12:45	Charging the mixers	10
12:45 - 13:45	Lunch	
13:45 - 15:45	Cleaning the equipment	2.5
15:45 - 16:00	Assisting maintenance staff	0 (assumed)

Assuming that exposure is zero during break times and lunch time.
Also assume that a legally enforceable Exposure Limit (8 hours TWA) of $10mg/m^3$ is applicable to flour dust. **(7)**

(b) The bakery changes the working patterns to the extent that the operative now only charges the mixer. In addition, shift times have been altered to a 10 hour shift, which includes a 1-hour lunch break where the exposure is assumed to be zero. Using the relevant data above, **re-calculate** the equivalent 8-hour TWA exposure in their new role **AND comment** on the legal implications of this change. **(3)**

3. You can see that the majority of the marks (7) are available for part (a) and the remaining marks (3) are available for part (b), which should assist you in your time allocation.
4. You may find it useful to make notes on the data table, or to make a rough copy of the data table in your answer book as part of your answer plan. Remember if you make notes on the question paper the examiner won't be able to mark it. If you do decide to copy the data table, don't worry about making it neat – there won't be any marks in the marking scheme for use of a ruler here!
5. Now have a go at the calculations and answer the question.

Example of How the Question Could be Answered

Working Period (total shift time = 8 hours)	*Tasks undertaken by bakery operative*	*Exposure to flour dust (mg/m^3)*
08:00 - 10:30 (2.5 hr)	*Weighing ingredients*	*14*
10:30 - 10:45 (0.25hr)	*Break*	*(Assume 0)*
10:45 - 12:45 (2 hours)	*Charging the mixers*	*10*
12:45 - 13:45 (1 hour)	*Lunch*	*(Assume 0)*
13:45 - 15:45 (2 hours)	*Cleaning the equipment*	*2.5*
15:45 - 16:00 (0.25 hr)	*Assisting maintenance staff*	*0 (assumed)*

(a) Exposure calculations:

Period 1 (weighing) = 2.5 × 14 = 35 mg.m^{-3}

Period 2 (break) = 0.25 × 0 = 0 mg.m^{-3}

Period 3 (charging) = 2 × 10 = 20 mg.m^{-3}

Period 4 (lunch) = 1 × 0 = 0 mg.m^{-3}

Period 5 (cleaning) = 2 × 2.5 = 5 mg.m^{-3}

Period 5 (maintenance) = 0.25 × 0 = 0 mg.m^{-3}

Total exposure during shift = 35 + 0 + 20 + 0 + 5 + 0 = 60 mg.m^{-3}

Total shift time = 8 hours, hence exposure as an 8 hour TWA = 60/8hr =7.5 mg.m^{-3} (which is below the legal exposure limit).

(b) The operator now only charges the mixer and the shift is 10 hours long with 1 hour lunch.

Exposure calculations:

Activity 1 (charging the mixer) = 9 × 10 = 90 mg.m^{-3}

Activity 2 (lunch) = 1 × 0 = 0 mg.m^{-3}

Total exposure over 10 hour shift = 90 mg.m^{-3}

Exposure calculated as an 8 hr TWA = 90/8 = 11.25 mg.m^{-3}

When this new exposure is compared to the legal limit of 10 mg.m^{-3}, it is clear that the operator is now exposed to more than the legal limit and as such the employer is failing to adequately control exposure to flour dust.

Reasons For Poor Marks Achieved By Candidate in Exam

An exam candidate would achieve poor marks for an answer which:

- Showed a lack of understanding of the method of calculation of TWA.
- Did not demonstrate understanding of the relevance of legally enforceable exposure limits.
- Calculated the TWA in part (b) incorrectly by dividing the total exposure by the numbers of hours worked rather than by eight.
- Failed to compare the calculated exposure with the legal exposure limit and comment on the legal implications of the change in working patterns.

Element IB5

Biological Agents

Learning Outcomes

Once you've read this element, you'll understand how to:

1. Explain the types and properties of biological agents found at work.
2. Explain the assessment and control of risk from deliberate and non-deliberate exposure to biological agents at work.

Contents

Types and Properties of Biological Agents

IN THIS SECTION...

- Biological agents are micro-organisms, cell cultures, or human endoparasites which may cause infection, allergy, toxicity or a similar health hazard.
- The four types of biological agent of concern are fungi, bacteria, viruses and protozoa. These are all microscopically small entities passed to humans from other humans, animals or environmental sources.
- Many biological agents have special properties that complicate the risk that they present, namely a rapid mutation rate, an incubation period, infectiousness and the ability to multiply rapidly.
- Zoonoses are diseases that are passed to humans from vertebrate animals. Examples include animal influenza, cryptosporosis and psittacosis. Malaria can be a significant risk to workers in or travelling to tropical countries where the disease is present.
- Occupational diseases of note caused by biological agents include those caused by blood-borne viruses - hepatitis and AIDS, legionella, leptospirosis, malaria and norovirus.

Introduction

In this first section of the element a short introduction to biological agents is presented. The element then focuses on the specific requirements for assessing and controlling the risks inherent in work with potential for exposure to these agents.

Definitions

The ILO defines a biological agent as:

> *"any micro-organism, cell culture, or human endoparasite, which may cause any infection, allergy, toxicity or otherwise create a hazard to human health. These include viruses and bacteria which can cause infection and disease, dangerous plants and animals (for example parasites or insects), biologically contaminated dusts, or wastes from humans and animals."*

Source: **Health, Safety and Environment: A series of trade union education manuals for agricultural workers (Manual 4, Fact Sheet 3), Copyright © International Labour Organisation 2004**

Bacteria, fungi and viruses are micro-organisms

And a **micro-organism** is defined as:

> *"A microbiological entity, cellular or non-cellular, which is capable of replication or of transferring genetic material."*

This definition of micro-organism includes **bacteria**, **fungi** and **viruses** as well as other microscopically small biological entities, such as protozoa and algae.

Human endoparasites are parasites that are capable of infecting and then living within the human body. For example, malaria (caused by a singled celled organism that infects the blood) and tape worms (large multicellular organisms that live in the gut).

The biological agents dealt with in this section of the course are all fungi, bacteria, viruses or protozoa. It is worth noting that the above definitions include a wider range of biological entities, such as algae and endoparasites, and that, therefore, relevant legislation could be applied to these organisms if they presented an occupational health risk. The definitions do not include large multicellular organisms (other than endoparasites). So a dog is not a biological agent, but the rabies virus that the dog might be carrying is.

Types of Biological Agent

Though the definition of the term 'biological agent' is very broad and encompasses many different forms of entity, this element will focus on four principal types of biological agent: fungi, bacteria, viruses and protozoa.

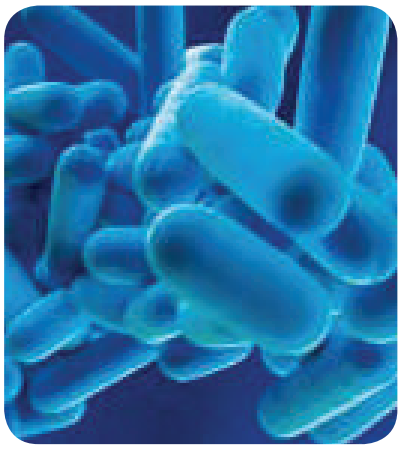
- **Fungi**

  Fungi include moulds and yeasts. Some fungi are able to cause infection on or inside the human body (e.g. athlete's foot). Some fungi produce toxins (mycotoxins) that are harmful to humans. Fungi reproduce by forming spores that are released, dispersed and find a suitable environment to grow in. Inhalation of large numbers of these tiny spores can cause lung disease, such as Farmer's Lung. Generally, most fungi are harmless in an occupational context.

- **Bacteria**

  Bacteria are simple single-celled organisms. They vary widely in shape and many have a tail (flagella) that allows them to move through liquid. Some form hardy spores that can survive adverse conditions such as heat, cold and lack of water (e.g. bacillus anthracis, the bacteria responsible for anthrax).

  Bacteria grow in virtually every environment on the planet, from water and soil to deep ocean and subterranean rock. There are approximately ten times as many bacteria growing in or on the typical human body as there are human cells. Most of these do not cause disease because of the immune system. Some (e.g. certain gut bacteria) are actually beneficial. Some bacteria can cause disease (e.g. **Legionnaires' disease** is caused by the *Legionella* bacterium). Antibiotics such as penicillin can be used to treat most bacterial infections.



Legionella bacteria
Source: IACL 27 Legionnaires' disease – A guide for employers, HSE, 2001 (www.hse.gov.uk/pubns/iacl27.pdf)

- **Viruses**

  Viruses are micro-organisms but are not strictly alive. They are self-replicating molecules (genetic material contained in a protein shell) that invade host cells, take control of the cell to produce more viruses, and then release these viruses to repeat the cycle. Virus particles are much smaller than fungal and bacterial cells. Hepatitis and Acquired Immune Deficiency Syndrome (AIDS) are two diseases of occupational significance that are caused by viruses present in human body fluids. Viral infections are usually prevented or halted by the body's immune system. This immune response takes time to come into effect, however, so there is often a period of illness before the body's defences become effective (an effect seen every time you catch a cold). Some viral infections are so severe that the immune system cannot respond effectively and serious disease or death results (e.g. smallpox). Some viral infections are not dealt with effectively by the body and so can persist (e.g. Human Immunodeficiency Virus (HIV), the causative agent of AIDS).

- **Protozoa**

  Protozoa are a very large and diverse group of single-celled organisms that all have a cell nucleus. They are therefore different to bacteria where no nucleus is present in the cell. Protozoa are often motile (able to move) and do not photosynthesise.

Many diseases are caused by protozoans, perhaps the most notable being malaria. Sleeping sickness, giardia, amoebic dysentery and toxoplasmosis are all caused by different protozoans. Treatment often requires drugs (not antibiotics - which are only effective against bacteria). Diseases caused by protozoa do not usually self-resolve, i.e. the human immune system is incapable of dealing with the infection independently.

Sources of Biological Agent

Pathogenic (disease causing) biological agents come from three main sources; humans, animals and the environment.

- **Human sources** – many fungal, bacterial and viral infections are passed from person-to-person. This can happen by transfer of body fluids (e.g. **viral hepatitis** can be transferred by a needle-stick injury), by droplet infection (e.g. **tuberculosis** (TB) can be spread by coughing and sneezing) or by physical cross-contamination (e.g. 'flu virus spread by touching the nose and then touching a surface that others then come into contact with).
- **Animal sources** – some serious fungal, bacterial and viral infections are passed from animals to humans. This can happen by the same general mechanisms as for person-to-person infection. For example, rabies is a viral disease that can be passed from infected animals to people, usually from a bite; Leptospirosis is a bacterial disease spread by coming into contact with water or surfaces contaminated with an infected animal's urine (e.g. rat urine). A disease that can pass from animals to humans is referred to as a zoonosis (or zoonose or zoonotic disease).
- **Environmental sources** – some serious occupational diseases originate in the general environment rather than coming from a human or animal source. A classic example of this is Legionnaires' disease (or 'legionella') caused by the *Legionella* bacteria. This bacterium is naturally occurring in damp soil and water courses through the UK.

Properties of Biological Agents

It is possible to think of biological agents as being simply another form of chemical agent. Indeed, national **legislation often** defines biological agents as a type of '**hazardous substance' (for example, the Control of Substances Hazardous to Health Regulations** in Great Britain), **in effect, putting biological agents in the same category as hazardous chemicals**.

This simple approach can be a little misleading however, because biological agents can have the following **special properties**:

MORE...

WWW.

Some useful information relating to biological agents:

www.hse.gov.uk

Dozens of websites also have background information on micro-organisms.

- **Rapid mutation** – like all living organisms, biological agents are subject to mutation; their genetic code changes over time, so changing the characteristics of the organism. However, unlike many organisms, some biological agents have a very high mutation rate. This means that their genetic code and their characteristics change quickly, making it very difficult for the human body to effectively recognise and attack them. HIV, for example, is very difficult for the body to combat because the virus is constantly changing.
- **Incubation period** – there is usually a time delay between infection (when a person catches a disease) and when the first signs and symptoms of the disease become apparent. This incubation period can range from 1-3 days (for 'flu) to many years (perhaps 30-50 years for Creutzfeldt-Jakob Disease (CJD)). This means that the presence of a biological agent may not be readily detectable and that a link between the source of an infection and the symptoms of the disease may not be made.
- **Infectious** – it is often the case that a person (or animal) suffering from a disease is infectious, i.e. capable of spreading the agent to others. Many diseases spread by making the carrier infectious. When this is the case, an infected person poses a risk to their colleagues; others that they might come into direct contact with; and in some cases the community at large. Tuberculosis is an example of a highly infectious disease that can spread within the community. Some diseases are not infectious, e.g. Legionnaires' disease is not passed from one person to another. In some cases a person may be infected with a disease and become infectious without showing any signs or symptoms of the disease (they are asymptomatic); they become a carrier, capable of spreading the disease, but will be unaware of their infectious state. Hepatitis C is an example of this type of disease.

- **Rapid multiplication** – micro-organisms can multiply very rapidly when environmental conditions are right. For example, the *E. coli* bacterium (a gut bacteria) is capable of multiplying at a rate greater than one cell division every 30 minutes. Though this may not sound impressive, it becomes more so when you consider that in a 24 hour period one bacterium can multiply to become over 200,000,000,000,000. It does not take long for a small number of agents (that might not present a risk of infection) to multiply to become large numbers that are capable of overcoming the body's defences to cause infection.

In general, with biological agents, there will not be a simple dose/response relationship of the kind that exists for chemical substances, and risk may be high even at small exposures.

Zoonotic/Vector-Borne Disease

Zoonoses (singular, 'zoonosis'), or zoonotic diseases, are those that can be transferred to humans from vertebrate animals.

MORE...

www.hse.gov.uk/agriculture/topics/zoonoses.htm

www.who.int/zoonoses/en

Vector-borne diseases can be transferred to humans by the bite of an infected arthropod, such as a mosquito.

Occupations at risk from zoonoses will vary depending on the disease in question, but, clearly, people whose work brings them intentionally or incidentally into close proximity with animals will be at risk from one or several zoonotic diseases, such as:

- Farm workers.
- Vets.
- Zoo workers.
- Pet shop workers.
- Sewage workers.
- Construction workers.

Though control measures will vary depending on circumstances, the general preventive measures described later for leptospirosis and *E.coli* are relevant to all zoonoses.

Examples of occupational zoonoses include:

- **Animal influenza** – a viral disease of various animals, such as birds, pigs, horses and dogs. In some cases, it is possible for the animal influenza ('flu) virus to change to a form that can infect humans and can be passed from person to person. This can potentially give rise to a 'flu pandemic. The most significant potential for this animal-to-human transmission is from birds and/or pigs. Exposure may occur in those who are in close contact with infected birds or pigs or who work with materials or products from infected birds or pigs. The H1N1 'flu pandemic of 2009 originated in pigs. Such 'flu pandemics are often called by the source animal name, such as bird 'flu or swine 'flu.

  It is important to recognise that 'flu is also a disease naturally present in human populations and 'flu pandemics can have a human origin. Every year, hundreds of 'flu outbreaks occur, predominantly in the winter months, hence the title 'seasonal 'flu'.

  MORE...

  www.nhs.uk/conditions/pandemic-flu/Pages/Introduction.aspx

  Typical symptoms of 'flu include high temperature, headache, tiredness, aching muscles and cough. Since the disease is caused by a virus, antibiotics will not prevent or treat it. A vaccine is available against seasonal 'flu and is usually offered to vulnerable people (such as the elderly or asthma sufferers). This vaccine is not effective against all types of 'flu and especially not against newly emergent variants. Most people do not require any treatment for 'flu as their own immune system deals with the infection within a week or so. However, vulnerable individuals, such as the elderly and immune-compromised, may needed treatment with anti-virals to support them for long enough for their own immune system to fight off infection.

- **Cryptosporidiosis** – an infectious diarrhoeal disease. It is caused by a protozoan parasite and can be transmitted via contact with infected animals (mainly cattle and sheep). It can be caught by contact with faecal contaminated water or food (such as salad) and can also be spread from person to person where there is poor hygiene. Principal groups of workers at risk include farm workers, construction workers where there is stagnant contaminated water and healthcare workers dealing with infected people. There is no vaccine available and no treatment either (other than staying hydrated). Infected individuals usually recover within one month. The disease is best prevented through good personal hygiene measures, such as avoiding contact with potentially infected animals and contaminated water, use of gloves and hand washing.
- **Psittacosis** – also known as 'ornithosis' or 'parrot fever', is primarily an infection of birds. It can be transmitted to humans by breathing in infected material or occasionally by oral infection. The disease is caused by bacteria. Principal occupations at risk are poultry farmers, bird-keepers, cleaners and construction demolition workers working in bird-infested areas. The disease has a 1-4 week incubation period leading to 'flu-like symptoms, such as headache, fever, aching muscles with the possibility of pneumonia. The disease responds to antibiotic treatment.

  Again, the disease is best prevented by isolating known infected birds, removing faecal material (before it has time to dry out and become airborne), preventing of creation of aerosols of faecal material during cleaning operations, use of protective clothing, particularly respiratory protective equipment and good personal hygiene.

  Even diseases that are not endemic in the UK can be of interest in the context of occupational health where an organisation is sending workers overseas into parts of the globe where the disease is present. A good example of such a disease is malaria which is a vector-borne disease.
- **Malaria** – is caused by a protozoan parasite of the plasmodium classification of which there are five species that cause malaria in humans. The WHO estimates there were 198 million cases of malaria worldwide and 584,000 deaths in 2013. In the UK, for example, 1,586 travellers were diagnosed with the disease in 2014 (after returning home) and three people died.

  The parasite is spread by 'night-biting' mosquitoes (specifically the female anopheles mosquito). As a consequence of a bite, the parasite passes into the bloodstream, where it breeds and multiplies. Symptoms usually appear between 7 and 18 days after becoming infected, but in some cases the symptoms can appear up to a year or more after. Symptoms include fever, sweats and chills, headache, vomiting, muscle pain and diarrhoea. It can prove fatal if not detected early and treated.

  Malaria is found in more than 100 countries, mainly in tropical regions of the world, such as large areas of Africa and Asia, Central and South America, parts of the Middle East and some tropical island groups.

  Control measures include:

  – Obtaining travel advice before travelling to tropical areas to see if the area of travel is a malaria infested area.
  – Taking prophylactic anti-malarial drugs before during and after visits.
  – Preventing mosquito bites by using mosquito repellents, clothing and sleeping under mosquito nets at night.
  – Early recognition of symptoms of the disease (which may occur weeks or months after infection) and referral to GP for proper diagnosis and treatment.
  – Antimalarial drugs are also used for treatment of the disease which, if it is caught early, will usually be fully effective.

Diseases Caused by Biological Agents

This section considers a range of diseases caused by biological agents, together with the occupational contexts of exposure and the preventive measures commonly applied.

Blood-Borne Viruses

Hepatitis

There are at least five types of viral hepatitis, all caused by different viruses – types A, B, C, D and E. Hepatitis A is usually contracted by the faecal-oral route. The other types are blood-borne viruses transmitted by contact with contaminated body fluids. In recent years, infectious hepatitis has become the most common occupational disease amongst medical staff; those at risk include doctors, surgeons, nurses and ancillary staff, such as hospital porters. Refuse disposal operatives form another group increasingly at risk from this severe form of jaundice. Infection amongst health workers is a result of contact with blood or excreta of patients suffering from viral hepatitis or in whom the disease is still in its incubation stage. Hospital porters and refuse disposal operatives appear to be at risk from carelessly discarded syringes and other 'sharps' in disposable plastic sacks. The problem is becoming more severe with the increase in drug addiction and the use of shared needles (a practice that is also thought to be responsible for the spread of HIV-AIDS among drug users).

MORE... www.

The UK's HSE guidance INDG342 - *Blood-Borne Viruses in the Workplace* is available from:

www.hse.gov.uk/pubns

General information and advice regarding hepatitis is also available from the UK's National Health Service (NHS) and the World Health Organisation (WHO):

www.nhs.uk/conditions

www.who.int/topics

The course of the disease is very much like that of leptospirosis (see later), but is usually much less severe and normally self-limiting with recovery in about six weeks. In about 5% of cases, chronic infectious hepatitis follows, leading to cirrhosis, liver cancer and possibly death. Some individuals infected with hepatitis (in particular, type C) do not show symptoms but still carry and transmit the disease.

Vaccinations are available for hepatitis types A and B (but not for C). Some antiviral drugs, such as interferon, are available for chronic cases.

Preventive measures include:

- Prohibition of eating, drinking, smoking and the application of cosmetics in working areas where there is a risk of contamination.
- Prevention of puncture wounds, cuts and abrasions, especially in the presence of blood and body fluids.
- Avoiding the use of, or exposure to, sharps, such as needles, glass, metal, etc. or, if unavoidable, take care in handling and disposal.
- Using devices incorporating safety features, such as safer needle devices and blunt-ended scissors.
- Covering all breaks in exposed skin by using waterproof dressings and suitable gloves.
- Protecting the eyes and mouth by using a visor/goggles/safety spectacles and a mask, where splashing is possible.
- Avoiding contamination by using water-resistant protective clothing.
- Wearing rubber boots or plastic disposable overshoes when the floor or ground is likely to be contaminated.
- Using good basic hygiene practices, such as hand washing.
- Using appropriate decontamination and waste disposal procedures.

Human Immunodeficiency Virus (HIV)

Human Immunodeficiency Virus (HIV) is the virus responsible for **Acquired Immune Deficiency Syndrome (AIDS)**. HIV attacks the immune system by which the human body can resist infection. An infected individual may not show any signs of illness for several years. Once the HIV virus has weakened the immune system sufficiently, the person will then become prone to

MORE... www.

General information and advice regarding HIV and AIDS is available from the UK's National Health Service (NHS) and the World Health Organisation (WHO) from:

www.nhs.uk/conditions

www.who.int/topics

infection and disease (such as pneumonia and cancer). There is no vaccine or cure, though anti-viral drugs are effective in combating the effects of the disease in many cases. The virus is found in most body fluids but is relatively delicate and can be killed by heat and chemicals. It has a low infectivity and transmission is thought to be more likely with repeated exposure to infection rather than to a single contact.

Occupational risk comes from accidental inoculation or contamination of a cut or abrasion with the blood or body fluids of an infected person. Various studies of groups around the world who have been occupationally exposed to HIV-positive people, usually by accidental inoculation, have revealed only a handful of occupationally acquired infections. Doctors, nurses, dentists, laboratory and hospital support staff are identified as workers who can be at some risk, since they may come into close contact with body fluids and hence face the possibility of infection through an exposed cut or by accidental injection. Other workers possibly at risk might include community, welfare, custodial and emergency service workers. Thousands of health care workers have come into direct contact with HIV infected blood and body fluids through needle-stick injuries and other accidents, but only a very small number of occupationally acquired infections have been reported.

Since HIV is a blood-borne pathogen, the **preventive measures** are similar to those for hepatitis listed previously.

Legionella

The bacterium, *Legionella pneumophila*, is responsible for two important occupational diseases: Legionnaires' disease and pontiac fever. Legionella is the generic term used to cover **Legionnaires' disease** and pontiac fever.

The first identified outbreak of Legionnaires' disease occurred among people who had attended a Pennsylvanian State Convention of the American Legion in 1976. Delegates subsequently suffered respiratory illness and the bacterium *Legionella pneumophila* was isolated from lung specimens.

Legionnaires' disease is a type of pneumonia. As well as affecting the lungs, it may also have serious effects on other organs of the body. Infection is caused by inhaling airborne droplets or particles containing viable *Legionella*, which are small enough to pass deep into the lungs and be deposited in the alveoli.

The disease usually has an incubation period of three to six days. Males are more likely to be affected than females by a ratio of 3 to 1. Most reported cases occur in the 40-70 year age group. Although healthy individuals may develop Legionnaires' disease, people at greatest risk include smokers, alcoholics and patients with cancer, chronic respiratory disease or kidney disease. The case-fatality rate is approximately 12%.

Initial symptoms include high fever, chills, headache and muscle pain. A dry cough soon develops and most patients suffer difficulty with breathing. About a third of patients also develop diarrhoea or vomiting and about half become confused or delirious.

MORE...

The HSE website has a wealth of information and resources on this topic, including:

- L8 *Legionnaires' disease - The control of legionella bacteria in water systems - Approved Code of Practice and guidance on regulations* (4th edition), available at:

  www.hse.gov.uk/pubns/priced/l8.pdf

- HSG274, which gives practical advice on the legal requirements concerning the risk from exposure to *Legionella* and is in three parts:

  Part 1: *The control of legionella bacteria in evaporative cooling systems*

  www.hse.gov.uk/pubns/priced/hsg274part1.pdf

  Part 2: *The control of legionella bacteria in hot and cold water systems*

  www.hse.gov.uk/pubns/priced/hsg274part2.pdf

  Part 3: *The control of legionella bacteria in other risk systems*

  www.hse.gov.uk/pubns/priced/hsg274part3.pdf

- INDG458 *Legionnaires' disease - A brief guide for dutyholders*, available at:

  www.hse.gov.uk/pubns/indg458.pdf

Pontiac fever is a milder, non-fatal condition with an incubation period between five hours and three days. The illness usually lasts between two and three days. The symptoms of pontiac fever are similar to those of moderate to severe influenza, with headache, tiredness, fever and in a small proportion of cases nausea, vomiting and coughing.

***Legionella* bacteria** are widespread in natural water sources and found in rivers, lakes, streams, mud and soil as well as man-made water systems. To date, at least 34 different species of *Legionella* are recognised. *Legionella pneumophila* is the most pathogenic and is the species most commonly associated with disease outbreaks.

The following conditions have been found to affect its rate of growth:

- Water temperatures in the range of 20-45°C favour growth. It is uncommon to find proliferation below 20°C and it does not survive above 60°C. Organisms may remain dormant in cool water, multiplying only when the temperature reaches a certain level.
- The presence of sediment, sludge, limescale and organic material can act as a source of nutrients.
- Commonly encountered organisms in water systems, such as algae, amoebae and other bacteria may serve as an additional nutrient source for *Legionella*. Algal slime may provide a stable habitat for multiplication and survival.
- Incorporation of *Legionella* in slime on surfaces in contact with water can protect it from concentrations of biocides which would otherwise kill it if it were freely suspended in water.
- *Legionella* can be identified in the laboratory from water samples but this can take at least seven days.

Man-made systems with a reasonably foreseeable risk of exposure to *Legionella* include:

- Water systems incorporating a cooling tower.
- Water systems incorporating an evaporative condenser.
- Hot and cold water systems.
- Other plant/systems containing water which is likely to exceed 20°C and which may release a spray or aerosol during operation or when being maintained (e.g. humidifiers, air washers, spa baths and pools).

Preventive measures for the control of legionella include:

- The appointment of a competent person to take responsibility for managing the control scheme.
- Assessment of the risks inherent in the water system in the workplace (recorded if there are five or more employees).
- Preparation of a written scheme for the control of the *Legionella* risk, including information on the system, the responsible person, the operational parameters of the water system, the control methods and precautions and the checks to be carried out.
- The adoption of practical controls, such as:
  - Proper control of the release of water spray.
  - Management of water temperatures and conditions to avoid those that favour the growth of *Legionella* and other micro-organisms.
  - Preventing water from stagnating anywhere in the system by keeping pipe lengths as short as possible and by removing redundant pipework.
  - Avoiding materials that encourage the growth of *Legionella*.
  - Keeping the system and the water in it clean.
  - Treating water to kill or limit *Legionella* growth.
- Water treatment, such as:
  - Treatment of cooling towers/systems using biocides.
  - Ultraviolet (UV) irradiation, copper/silver ionisation and ozone.

  - Storing hot water above 60°C and distributing it at above 50°C – and keeping cold water below 20°C if possible.
  - Using chlorine dioxide (chlorination) for tap water.
- Water sampling to test for *Legionella*. Though a negative result does not prove that an entire system is *Legionella*-free and a positive result may not mean that there is unacceptable risk.

Leptospirosis

Leptospirosis (often called **Weil's disease**) is caused by bacteria of the genus *Leptospira*.

Symptoms of the disease can be divided into three stages:

The *Leptospira* bacteria are found in the kidneys of infected rats (and other mammals, such as cattle) and are urinated out of the host animal; it is from this source that humans are infected. Infection usually occurs following contact with fresh rat urine or water that has been urinated into. The bacteria enter the body through damaged skin and through the mucous membranes of the mouth.

Occupational at-risk groups include anyone who is exposed to rats, rat or cattle urine or to foetal fluids from cattle. Farmers are now the main group at risk for both Weil's disease and cattle leptospirosis - the cattle form is a special risk for dairy farmers. Other occupational groups who have contracted leptospirosis in recent years include vets, meat inspectors, butchers, abattoir and sewer workers. Workers in contact with canal and river water are also at risk.

Preventive measures include:

- Good pest control, such as getting rid of rats and avoiding rat infestations through good housekeeping.
- Washing cuts and grazes immediately with soap and running water.
- Covering cuts and broken skin with waterproof plasters before and during work.
- Wearing protective clothing (and laundering it).
- Good hand-washing after handling animals or contaminated material.
- Good hand-washing before eating, drinking or smoking.
- Early reporting of symptoms to a doctor.
- Carrying an alert card to provide additional information to the doctor about the risk.

Norovirus

Norovirus, sometimes known as the 'winter vomiting bug' or 'Norwalk virus', is the most common cause of gastroenteritis in the UK. Each year, it's estimated that between 600,000 and 1 million people in the UK catch norovirus.

The virus is highly contagious and easily spread. If an infected person doesn't wash their hands before handling food, they can pass the virus on to others. It is also possible to catch it by touching contaminated surfaces or objects. It can affect people of all ages and causes vomiting and diarrhoea. The incubation period is usually between 12 and 48 hours. Once sickness and diarrhoea start, the symptoms usually last for one to two days and then resolve naturally as the immune system rids the body of the virus. Sufferers are infectious to other people during this time. Although having norovirus can be unpleasant, it's not usually dangerous and most people make a full recovery within a couple of days.

The following control measures can help prevent the virus spreading:

- Frequent hand-washing.
- Avoiding the sharing of potentially contaminated articles, such as towels, clothing and PPE.
- Disinfecting potentially contaminated surfaces (that an infected person has touched).

Outbreaks of norovirus in public places, such as hospitals, nursing homes and schools, are common because the virus can survive for several days on surfaces or objects touched by an infected person.

STUDY QUESTIONS

1. How does ILO define a biological agent?
2. What are the four main categories of micro-organisms?
3. What are the symptoms of Weil's Disease (*Leptospirosis*)?
4. Explain the term 'zoonoses' and describe an occupational example.
5. Identify two occupational groups at risk from exposure to biological hazards, and for one of these groups summarise the ill-health conditions that could arise.

(Suggested Answers are at the end.)

Assessment and Control of Risk

IN THIS SECTION...

- Statute law or best practice principles apply if work creates potential for deliberate or incidental exposure to biological agents, but not if the exposure is not work-related.
- Various factors must be considered when undertaking a risk assessment of exposure to biological agents, such as the hazard group of the biological agent, the likelihood and nature of the resultant disease, the modes of transmission, the stability of the agent in the environment and the availability of prophylaxis and treatment.
- A general hierarchy of control can be applied to biological agents: eradication, reduced virulence, minimising generation of aerosols, isolation and segregation, containment including the use of microbiological safety cabinets, sharps control, vaccination, decontamination and disinfection, effluent and waste disposal, personal hygiene, PPE, biohazard signs, and baseline testing and health surveillance
- Special control measures are applied to biological agents used in laboratories, animal rooms and industrial processes that are based on the principle of containment, including the use of microbiological safety cabinets.
- According to the WHO Laboratory Biosafety Manual, the specification of workrooms to a containment level and the class of microbiological safety cabinet used in rooms are often determined by reference to the hazard group classification of the agent being worked with.

Intentional Work and Incidental Exposure

Generally, there are three categories of exposure to biological agents:

- Exposure resulting from a **deliberate intention** to work with a biological agent, i.e. work with biological agents that involves research, development, teaching or diagnosis.
- Exposure that arises out of the work activity, but is **incidental** to it, i.e. the activity does not involve direct work with the agent itself, e.g. health care, food production, agriculture, refuse disposal and work in sewage purification.
- Exposure that **does not arise out of the work activity** itself, e.g. where one employee catches a respiratory infection from another. This might be thought of as an exposure resulting from normal life in that it could and would occur simply as a result of living in the community.

COSHH applies only to work-related exposure

The health and safety regulatory framework usually only applies to the first two categories of exposure described above. This is because health and safety statute law usually covers only those circumstances where risks of exposure are work-related and not those where they have no direct connection with the work being done.

If work creates a deliberate or incidental exposure to biological agents then legislation or good practice will require:

- Assessment of the risk to health created by the work.
- Prevention or control of exposure.
- Use of the control measures.
- Maintenance, examination and testing of control measures.
- Monitoring of exposure at the workplace.

- Health surveillance.
- Information, instruction and training for those exposed.
- Arrangements to deal with accidents, incidents and emergencies.

Risk Assessment Factors

When undertaking the risk assessment of potential exposure to biological agents, several factors should be considered:

MORE...

See the WHO Biosafety manual at:

www.who.int/csr/resources/publications/biosafety/en/Biosafety7.pdf

- **The Risk Group/Category of the Agent**

  The WHO classifies biological agents into risk groups on the basis of the risk they pose to health. This classification is achieved by considering four characteristics of the biological agent:

  - Its ability to cause human disease.
  - Whether it may be a hazard to workers.
  - The likelihood that the disease might spread to the community.
  - The availability of effective prophylaxis (preventive measures such as immunisation) and treatment.

The following table shows how each hazard classification category relates to the parameters listed above.

Risk Group	Ability to Cause Human Disease	Hazard to Workers	Spread in the Community	Prophylaxis and Treatment
Group 1	Unlikely	-	-	-
Group 2	Possible	Possible	Unlikely	Available
Group 3	Serious	Serious	Possible	Available
Group 4	Severe	Serious	Likely	Unavailable

Risk Group 4 organisms are all highly infectious viruses (such as Ebola) that present a significant health hazard to workers, could spread rapidly in the community at large and for which there is no known vaccine or cure.

If intentional work is taking place for research, development, teaching, diagnosis or industrial purposes, then the risk group classification will, to a large degree, determine the biosafety containment level used. If the work creates an incidental exposure, then the classification can still be useful in giving an indication of the risk level.

- **Pathogenicity and Infectious Dose**

  The likelihood of disease is influenced by many factors, one of which is the virulence of the biological agent (i.e. how readily it can cause infection). For example, many people will contract gastroenteritis when exposed to norovirus (Norwalk virus) as it is highly infectious. An important factor in determining the likelihood of disease is personal susceptibility. Individual workers and non-workers (such as hospital patients) may be particularly susceptible, for example because they are immuno-compromised (e.g. elderly, infirm or receiving a treatment that has suppressed their immune system).

- **Likelihood and Nature of the Resultant Disease**

  Many pathogenic biological agents cause diseases that are relatively minor in the vast majority of cases. Others cause serious, chronic or fatal disease. For example, whilst orf (a zoonotic disease often contracted from sheep) is not a pleasant disease to have (it causes lesions to appear on the skin), it is usually self-limiting and resolves without complications in a few weeks. Hepatitis, however, is a far more severe disease that can have very significant long-term consequences for the sufferer.

- **Modes of Transmission**

  Some biological agents, such as Hepatitis B Virus (HBV) and HIV, are principally transmitted in blood and other body fluids. Others are transmitted orally (e.g. hepatitis A is principally transmitted by faecal-oral cross-contamination).

  Some are only transmitted by droplet inhalation (e.g. legionella is only transmitted by inhalation of contaminated water droplets).

Biological agents can be transmitted in blood and other fluids

- **Stability of the Agent in the Environment**

  It is important to have an appreciation of how stable or robust the agent is in the environment in order to appreciate the potential for it to be transmitted. For example, some bacteria, such as *B. anthracis* (anthrax) are able to form a hardy spore that will resist adverse treatment and can remain viable for very long periods of time.

  Other agents are relatively delicate and will not survive for long outside of the host. For example:

  – Some viruses, such as 'flu viruses, can retain their viability for periods of time when outside their host organism's body. They may be found up the host's nose, on the skin of their face and hands, on contact surfaces and in exhaled droplets.
  – Other viruses are far less stable and do not retain their viability once outside their host organism; the HIV virus, for example, is relatively delicate and will not survive in a viable form outside the host's body.

  So, the principal source of infection will be the host's blood and other fresh body fluids.

- **Concentration and Amounts**

  When carrying out a risk assessment on a laboratory environment, it is possible to determine the quantity of biological agent which is likely to be present. For example:

  – Cultures may be grown in a given quantity of media, which will limit the size of any potential spillage (remembering, of course, that many millions of bacteria will be present).
  – Biological samples (e.g. blood) will usually be small.

  Outside of the laboratory, such control is not possible, e.g. when working with animals.

- **Presence of a Suitable Host**

  Some biological agents can survive outside of the body, whilst others require a suitable host in order to survive. Hosts may be human or animal.

- **Available Data**

  In order to determine the pathogenicity of agents, toxicological tests (e.g. on animals) and epidemiological data will have been gathered. This data can be reviewed in order to assist in the risk assessment process.

- **Nature of Activity**

  There are many types of work where exposure to a biological agent is possible but not certain (e.g. a fire-fighter might be exposed to Leptospira bacteria, but it will not happen frequently). In other instances, work is almost certain to involve exposure to a particular agent (e.g. a sewage worker is certain to be exposed to pathogens capable of causing gastroenteritis).

  In certain circumstances, for example in medical facilities or livestock farming, the assessment should take account of uncertainties about the presence of infectious agents in patients, animals and associated samples, wastes, etc.

The risks associated with tissues and other waste material removed from patients and animals, or specimens sent for examination, should be assessed at each stage of handling.

- Local Availability of Prophylaxis/Treatment

  Consideration should finally be given to the availability of immunisation against infection and treatment in the event of accidental exposure. An example of this is the provision of immunisation against hepatitis B for first aiders – whilst exposure can be minimised through the use of gloves and other controls, there remains a risk of infection and therefore vaccination is a valid control which is used. When no vaccination is available and exposure is suspected, it may be possible to temporarily boost the immune system with injections (e.g. gamma globulin).

General Hierarchy of Control for Biological Agents

Biosafety Levels Control Approach

The levels of control required whilst working with biological agents is outlined in the WHO Laboratory Biosafety Manual, Chapters 1-5.

In particular, it outlines the special control measures needed for laboratories, which are based heavily on the principle of **containment**, i.e. the **containment** of the biological agent in a workroom that has specific design and operational characteristics to prevent the escape of the agent (there are also recommendations for personal protective equipment, administrative controls and procedures, which we will cover later in this element). This containment principle is often reinforced by the use of **Biological Safety Cabinets (BSCs)** (these are sometimes called **Microbiological Safety Cabinets (MSCs)**) to further contain the agent, when it is being handled within the workroom. The minimum Biosafety Level required for a biological agent is determined by its Risk Group classification.

The minimum **Biosafety Level** required for a biological agent is determined by its **Risk Group** classification:

- Biosafety Level 2 for activities which involve working with a Group 2 biological agent.
- Biosafety Level 3 for activities which involve working with a Group 3 biological agent.
- Biosafety Level 4 for activities which involve working with a Group 4 biological agent.

The Risk Group classification is done according to the criteria that were outlined earlier in this element (in the Risk Assessment Factors topic).

The following table, based on the WHO Laboratory Biosafety Manual, summarises the relationship between Risk Groups and Biosafety Levels and practices.

Risk Group	Biosafety Level	Laboratory Type	Laboratory Practices	Safety Equipment
1	Basic – Biosafety Level 1	Basic teaching, research	Good Microbiological Techniques (GMT)	None; open bench work
2	Basic – Biosafety Level 2	Primary health services, diagnostic services, research	GMT plus protective clothing, biohazard sign	Open bench plus Biological Safety Cabinet (BSC) for potential aerosols
3	Containment – Biosafety Level 3	Special diagnostic services, research	As Level 2 plus special clothing, controlled access, directional airflow	BSC and/or other primary devices for all activities
4	Maximum containment – Biosafety Level 4	Dangerous pathogen units	As Level 3 plus airlock entry, shower exit, special waste disposal	Class III BSC, or positive pressure suits in conjunction with Class II BSCs, double-ended autoclave (through the wall), filtered air

Based on extract from Laboratory Biosafety Manual (3rd ed.), WHO, 2004 (www.who.int/csr/resources/publications/biosafety/Biosafety7.pdf)

As the risk group increases, so the level of control required to prevent infection and release increases. The most hazardous agents will clearly require the most stringent of controls, which (for Groups 2 and above) will usually include the use of biological safety cabinets.

Below is a summary of the required controls for different Biosafety Levels. This is based on the WHO Laboratory Biosafety Manual, though greater detail is provided in the source publication.

	Biosafety Level			
	1	2	3	4
Isolation of laboratory	No	No	Yes	Yes
Room sealable for decontamination	No	No	Yes	Yes
Ventilation:				
• Inward airflow	No	Desirable	Yes	Yes
• Controlled ventilating system	No	Desirable	Yes	Yes
• HEPA-filtered air exhaust	No	No	Yes/No (dependent on location of exhaust)	Yes
Double-door entry	No	No	Yes	Yes
Airlock	No	No		Yes
Airlock with shower	No	No		Yes
Anteroom	No	No	Yes	-
Anteroom with shower	No	No	Yes/No (dependent on agent(s) used)	
Effluent treatment	No	No	Yes/No (dependent on agent(s) used	Yes
Autoclave:				
• On site	No	Desirable	Yes	Yes
• In laboratory room	No	No	Desirable	Yes
• Double-ended	No	No	Desirable	Yes
Biological safety cabinets	No	Desirable	Yes	Yes
Personnel safety monitoring capability (e.g. window, closed-circuit television, two-way communication)	No	No	Desirable	Yes

Based on extract from Laboratory Biosafety Manual (3rd ed.), WHO, 2004 (www.who.int/csr/resources/publications/biosafety/Biosafety7.pdf)

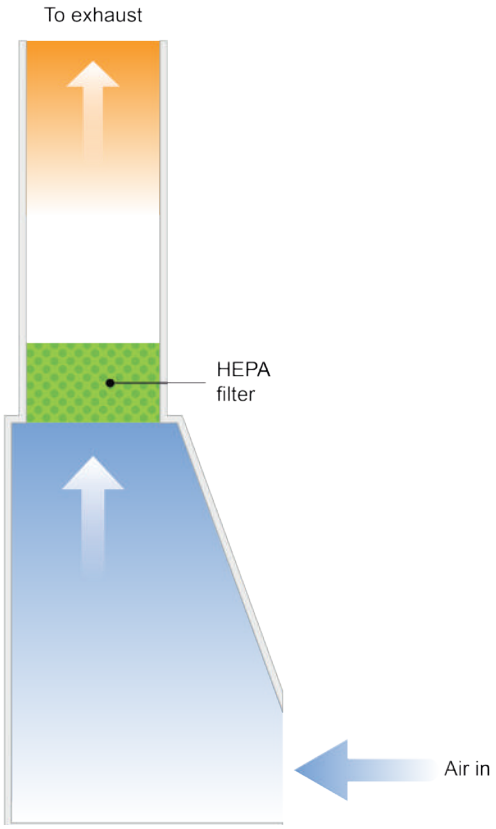
Biological Safety Cabinets (BSCs)

Biologcial Safety Cabinets (BSCs) provide a ventilated enclosure to contain any airborne contamination generated by handling a biological agent in a laboratory setting. The degree of enclosure depends partly on the risk group of the biological agent. Three **classes** of biological safety cabinet are used. Their method of operation is briefly described below (the design features and specification of each type of cabinet are the subject of a BS EN standard in the UK).

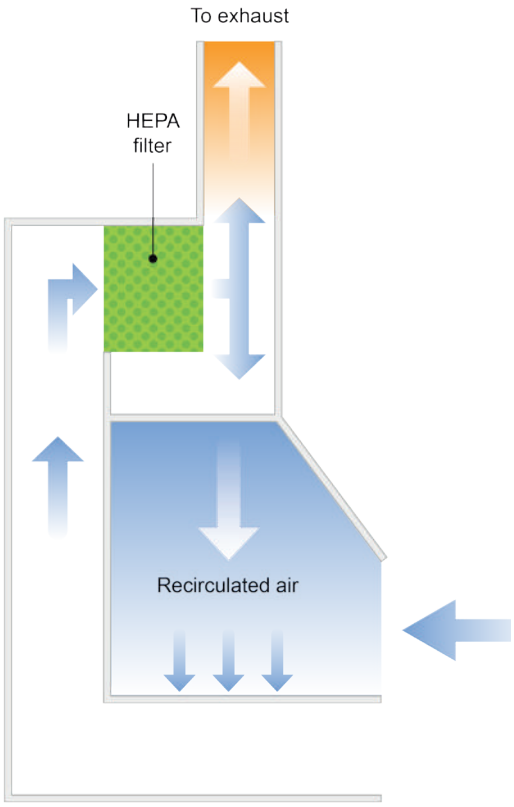
Class I – these are open-fronted cabinets where air is drawn in, filtered through a HEPA filter and discharged to the atmosphere. The cabinet protects the operator only from agents that might infect the operator by airborne routes (see following figure).

Class II – these are open-fronted cabinets where air is drawn in, exhausted through slits in the front base of the cabinet then filtered through a HEPA filter. The air drawn down over the open front forms a curtain to prevent the escape of aerosols back into the laboratory. A proportion of the air is discharged to atmosphere but the rest is recirculated through the cabinet.

These cabinets protect the operator and also the work from external contamination. They are suitable for work with Risk Group 2 organisms and possibly Risk Group 3 organisms, if indicated by the risk assessment.



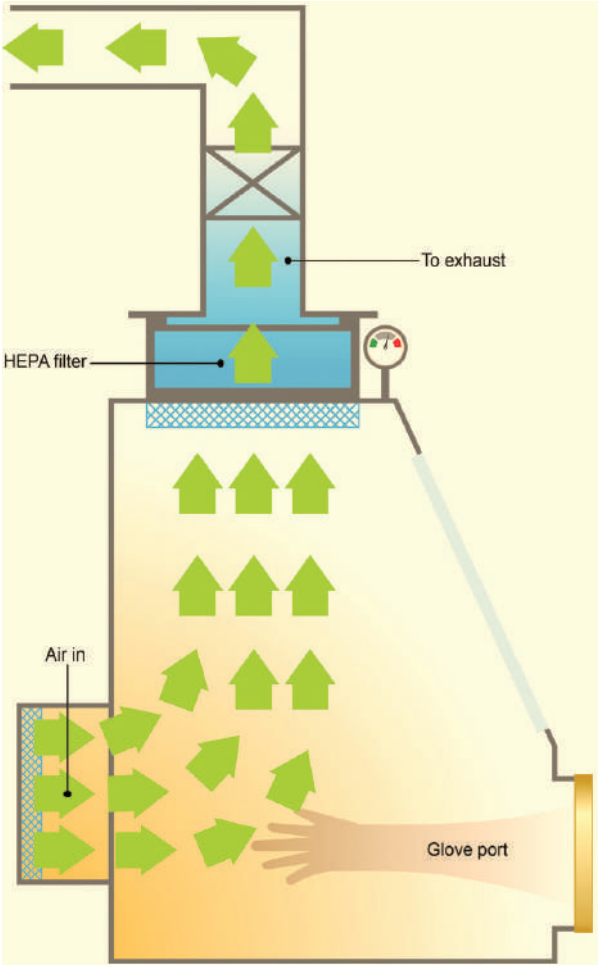
Class I biological safety cabinet



Class II biological safety cabinet

Class III – these are totally enclosed, leak-proof cabinets where the operator works through glove ports. Air is drawn in and extracted through HEPA filters and discharged to atmosphere.

These cabinets protect both the operator and the work from external contamination. They are suitable for work with Risk Group 3 and 4 organisms.



Class III biological safety cabinet

Sharps Control

Sharps include scalpels, needles, blood lances and any sharp instrument that is capable of puncturing the skin. Contaminated sharps should not be passed from hand to hand, handling should be kept to a minimum and they should be placed in a special container at the point-of-use (**ISO 23907** gives specifications for this type of container).

Immunisation/Vaccination

Vaccines consist of dead or live attenuated organisms that, when administered to individuals, are able to initiate immunity to the organism (and sometimes similar pathogens). Where appropriate vaccines exist, consideration should be given to the vaccination of staff at risk from exposure to harmful organisms.

In some cases, e.g. clinical work where there is a hepatitis B risk, vaccination may be a requirement before work in high-risk areas is allowed to commence. Vaccination can never be considered to be the principal defence against infection; it is only a risk reduction measure. Protection can never be guaranteed since certain individuals may not develop immunity after vaccination. A further problem is the possibility of adverse reaction to the vaccine. The possible side-effects must be considered before the decision to vaccinate is taken.

The following vaccinations are recommended for particular categories of staff:

- Healthcare workers: rubella, tuberculosis (TB) and hepatitis B.
- Sewage workers: tetanus and hepatitis A.
- Agricultural/horticultural workers: tetanus.

Decontamination and Disinfection

Disinfection is a process whereby biological agents are killed or rendered harmless by exposure to certain chemicals known as disinfectants or biocides.

The main categories of disinfectants commonly in use are:

- Hypochlorites (chlorine-based bleach) – effective on bacteria, spores, viruses and fungi.
- Alcohols – used for skin disinfection or surface decontamination.
- Phenolics – effective on bacteria, some viruses and fungi.
- Glutaraldehyde (a hazardous substance in its own right, so personal exposure must be controlled within exposure limits) – effective on bacteria, spores, viruses and fungi.

Sterilisation is the complete eradication of all biological agents. Principal methods are:

- Incineration for clinical waste at temperatures up to 1000°C.
- Dry heat for metal and glass equipment at 160-180°C for one to two hours.
- Steam in an autoclave at 121°C (pressurised) for 20 minutes.
- Ionising radiation to sterilise medical equipment.

Effluent and Waste Disposal

Microbiological materials will remain hazardous after use and should therefore be rendered safe before disposal. Heat treatment, by autoclaving or incineration, is commonly used to kill microbiological organisms, but it is also possible to use chemical disinfection.

Clinical waste is a controlled waste; it is normally double bagged in distinctively-labelled, heavy-duty, yellow plastic bags for storage prior to collection and disposal. Persons handling clinical waste for disposal must be adequately trained and equipped with protective clothing.

Personal Hygiene Measures

Good personal hygiene is essential to minimise infection. This includes appropriate washing facilities with a relevant biocide, keeping nails clean and not eating, drinking or smoking and suitable facilities for storage of outside clothing.

Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) occupies a position low in the hierarchy of control measures for biological agents. However, there are occasions when the use of PPE is necessary to supplement other control measures. The use of PPE can be related to the potential routes of entry of biological agents into the body:

- ### Absorption Through the Skin

  Gloves give protection to either intact or broken skin where biological agents may penetrate. In addition, all cuts, wounds and sores should be covered, even when gloves are worn.

- ### Absorption Through the Membranes of the Eye

  The eye is an area where biological agents can gain access to the body, so where there is a risk of splashing of infected materials into the eyes, goggles, safety spectacles or visors will be required. Eye protection also prevents accidental touching of the eyes by contaminated fingers.

- ### Inhalation Into the Lungs

  It may be necessary to use respiratory protection to supplement engineering controls (such as ventilation systems). A common example of this is the use of airstream helmets in animal houses to prevent inhalation of potentially allergenic dusts.

The use of PPE as a control measure against biological agents follows the general principles you have already encountered. The following example of its application in microbiological laboratories (particularly those operating under containment levels 2, 3 and 4) will illustrate these principles:

- **Laboratory coats or gowns** are worn to protect clothing from contamination. They are usually high-necked with back or side fastenings and closefitting cuffs. They need to be changed regularly and autoclaved before laundering to ensure that any biological contamination is sterilised.
- **Gloves** to protect the hands from contact with contamination are worn and if there is a high risk of the gloves being torn or punctured, two pairs are worn together.
- **Visors** may need to be worn to protect the face if there is a risk of splashing.
- **Positive pressure particulate respirators** may be required if there is a risk of inhaling harmful organisms. This may be a particular concern if there has been an accidental spill or release.

MORE...

The WHO Laboratory Biosafety Manual contains more information about the requirements of the Biosafety Levels Control Approach, including useful illustrations of laboratories at each level. It is available from:

www.who.int/csr/resources/publications/biosafety/Biosafety7.pdf

STUDY QUESTIONS

6. List the four criteria that are used to classify a biological agent into one of the four hazard groups.
7. Which type of biological safety cabinet would be appropriate for work with Risk Group 3 and Risk Group 4 organisms?

(Suggested Answers are at the end.)

Summary

Types and Properties of Biological Agents

We have described how:

- Biological agents are micro-organisms, cell cultures, or human endoparasites that may cause infection, allergy, toxicity or a similar health hazard.
- The three types of biological agent of concern are fungi, bacteria, viruses and protozoa. These are all microscopically small entities passed to humans from other humans, animals or environmental sources.
- Many biological agents have special properties that complicate the risk that they present, namely a rapid mutation rate, an incubation period, infectiousness and the ability to multiply rapidly.
- Zoonoses are disease that are passed to humans from vertebrate animals. Examples include animal influenza, cryptosporosis and psittacosis. Malaria can be a significant risk to workers in or travelling to tropical countries where the disease is present.
- Occupational diseases of note caused by biological agents include those caused by blood-borne viruses - hepatitis and AIDS, legionella, leptospirosis, malaria and norovirus.

Assessment and Control of Risk

We have examined how:

- Statute law or best practice principles apply if work creates potential for deliberate or incidental exposure to biological agents, but not if the exposure is not work-related.
- Various factors must be considered when undertaking a risk assessment of exposure to biological agents, such as the hazard group of the biological agent, the likelihood and nature of the resultant disease, the modes of transmission, the stability of the agent in the environment and the availability of prophylaxis and treatment.
- A general hierarchy of control can be applied to biological agents: eradication, reduced virulence, minimising generation of aerosols, isolation and segregation, containment including the use of biological safety cabinets, sharps control, vaccination, decontamination and disinfection, effluent and waste disposal, personal hygiene, PPE, biohazard signs, and baseline testing and health surveillance.
- According to the WHO Laboratory Biosafety Manual, the specification of workrooms to a containment level and the class of biological safety cabinet used in rooms are often determined by reference to the Hazard Group classification of the agent being worked with.

Exam Skills

QUESTION

A company that operates hotels and health spas is looking to minimise the risks associated with the *Legionella* bacteria.

(a) In this scenario, **identify** specific sources of potential exposure to *Legionella* for **BOTH** employees and guests. **(5)**

(b) **Describe** the control measures that this company should implement to minimise people being exposed to *Legionella* bacteria. **(15)**

Approaching the Question

Remember to look out for the key words in the question before you attempt to write your answer. Make sure you write out a full answer this time, it's an important skill you need to develop.

HINTS AND TIPS

Remember, you need to average at least 50% across all questions to give yourself a great chance of success in the exam. Most people will have topics that they are more confident at tackling than others – during your revision try to study areas that you know are weaker in order to broaden your knowledge. Though it is easier to revise topics you are happiest with, it doesn't give you the greatest improvement!

Suggested Answer Outline

(a) The examiner would be looking for five points from the following:

Any water storage and transfer system held at or passing through the optimum growth temperature (20°C-45°C) could harbour the bacteria. But, we need to look at the potential for these organisms to get airborne and be breathed in. So: showers, taps, Jacuzzis (spa baths), saunas, fountains and other water features (in the grounds), sprinklers (e.g. fire, garden), laundry rooms; air-conditioning/cooling systems (wet or condenser type - such as was the case in the Barrow-in-Furness outbreak). Maintenance workers could also conceivably be directly exposed to water within pipework deadlegs (where stagnation occurs).

(b) The examiner would be looking for 15 points from the following:

These are largely the usual measures to discourage *Legionella* growth and aerosol formation, (and are described in L8). Thus: water temperature control (hot water stored >60°C, cold water <20°C, use of thermostatic mixing valves on outlet taps), eliminate pipework deadlegs, cleaning of showerheads/taps (sludge/scale can harbour the bacteria), regular flushing of showerheads and taps if used infrequently, cleaning and disinfection of hot water systems with biocides, cleaning and disinfection of calorifiers (annually), inspection and cleaning of cold water storage tanks, regular cleaning and continuous dosing of Jacuzzis (spa pools) with chlorine disinfectant or biocides, the use of construction materials that do not encourage *Legionella* growth (so avoid rubber, wood), monitoring regime as appropriate (chlorine levels, temperature), training of staff (risk factors, controls, responsibilities), etc.

Example of How the Question Could be Answered

(a) Sources of potential exposure to legionella at the hotel and health spa would include:

- *The spa itself, i.e. the bubbling effect releasing* legionella *into breathing zone.*
- *Water storage calorifiers, where temperature is kept between 20°C to 45°C.*
- *Showers and spray taps releasing mists.*
- *Air-conditioning equipment.*
- *Foot bath sprays*
- *Dead legs in water supply lines which might lead to stagnation of water.*
- *Fire sprinkler systems.*

(b) Implementation of control measures to minimise the risks to people being exposed at the hotel and health spa should start with the appointment of a responsible person to manage legionella *control for the complex, and to develop the* legionella *risk assessment.*

Guidance specifies the requirement for routine disinfection of water systems with records kept of the cleaning and disinfection regime. Other controls include regular running of taps to remove stagnant water from dead legs and minimising mists by cleaning valves/leaks to avoid sprays. Water treatment on spa and pools is necessary to control bacteria, and there should be regular testing to monitor chemical dosage to ensure that it is effective. Hot water temperatures should be maintained above 60°C and cold water below 20°C.

Systems should be designed to minimise the likelihood of legionella *forming, with filters on air-conditioning systems regularly cleaned to avoid the build up of bacteria and air intakes sited away from any potential sources of bacteria.*

Finally, staff need to be trained in safe systems of work, including cleaning, and disinfection control.

Reasons For Poor Marks Achieved By Candidates in Exam

- Failing to identify examples that relate to the question.
- Failing to give controls that relate to the question and failing to mention relevant legislation, codes of practice or guidance.

Unit IB - Part 1

Suggested Answers

No Peeking!

Once you have worked your way through the study questions in this book, use the suggested answers on the following pages to find out where you went wrong (and what you got right), and as a resource to improve your knowledge and question-answering technique.

Element IB1: Managing Occupational Health

Question 1

Physical (e.g. noise), chemical (e.g. lead), biological (e.g. *Legionella*), psycho-social (e.g. stress) and ergonomic (e.g. repetitive handling).

Question 2

- **RIDDOR** – which requires the reporting of specific occupational diseases by the employer.
- Labour Force Survey (LFS) – is a national survey of private households in the UK each quarter. The survey is managed by the Office for National Statistics.
- The Health and Occupation Reporting (THOR) network – a voluntary surveillance scheme for work-related ill health under which specialist doctors systematically report all new cases that they see in their clinics.
- The Industrial Injuries Scheme – administered by the Department for Work and Pensions (DWP) to compensate workers who have been disabled by a prescribed occupational disease.
- Death certificates – as a source of deaths from asbestos-related and other occupational lung diseases.

Question 3

Occupations requiring specific fitness-to-work standards include:

- Vehicle driving, e.g. forklift trucks (FLT), Large Goods Vehicles (LGV), cranes, buses, trains, etc.
- Working in confined spaces.
- Emergency service workers.
- Night shift workers.
- Divers.
- Working at heights.

Question 4

Vocational rehabilitation is the process of returning a worker back to meaningful work as a way of aiding their recovery and return to health following a period of physical or mental ill health. It can also be a way of improving the health of an individual through getting them in to work and keeping them in work.

Question 5

The bio-psychosocial model is a way of considering ill health as being more than simply a case of a biological disease.

It takes a more holistic view that includes biological, psychological and social aspects of the condition:

- Biological refers to the physical or mental health condition.
- Psychological recognises that personal/psychological factors also influence functioning and the individual must take some measure of personal responsibility for his or her behaviour.
- Social recognises the importance of the social context, pressures and constraints on behaviour and functioning.

Question 6

- Pre-employment screening – general health assessment of both general fitness and specific job fitness.
- Health surveillance – routine checks or tests focusing on specific aspects of health as a result of exposure to a specific hazard.
- Return-to-work rehabilitation programmes – management of the rehabilitation of specific workers back into work.

- Sickness absence management – recording and analysis of absence data and involvement in sickness absence procedures.
- Counselling – formal or informal listening service with in-house or external referral as required.
- Risk assessments – involvement in some general workplace assessments and conducting specific assessments, such as those for pregnant women.
- Health education and promotion – running campaigns and providing support on various public health issues.
- Providing advice – to employers and workers on specific health issues and queries.
- Treatment services and first aid – such as management of main treatment facility and assessment and management of first-aid provision.

Question 7

Health surveillance is required where the following criteria are met:

- there is an identifiable disease or adverse health condition related to the work concerned; and
- valid techniques are available to detect indications of the disease or condition; and
- there is a reasonable likelihood that the disease or condition may occur under the particular conditions of work; and
- surveillance is likely to further the protection of the health and safety of the employees to be covered.

Question 8

A workplace Health Needs Assessment (HNA) is carried out to identify the occupational health priorities that are of concern to the workplace so that an appropriate occupational health service response can be planned and implemented.

Question 9

SEQOHS stands for Safe, Effective, Quality Occupational Health Service and is a set of standards and a voluntary accreditation scheme for occupational health services established by the Faculty of Occupational Medicine. It provides an assurance to service users that service providers achieve the minimum standards established under the scheme.

Element IB2: Identification, Assessment and Evaluation of Hazardous Substances

Question 1

Inhaled air passes through the nose or mouth, down the trachea, bronchi and bronchioles, into the alveoli. Here, the very thin lining of alveoli and blood vessels allows oxygen to diffuse into the bloodstream where it then diffuses into red blood cells and is bound to haemoglobin. Carbon dioxide is excreted by the same process.

Question 2

To deliver oxygen to all parts of the body and remove impurities and waste products.

Question 3

The heart (the pump); the blood vessels (pipes for carrying the fluid) and the valves within the heart (valves for regulating the fluid flow).

Question 4

When light strikes the retina, electrical impulses are generated and transmitted via the optic nerve to the brain.

Question 5

Local effects are confined to the specific area of the body where contact with chemical occurs. Systemic effects occur at target organs or target systems of the body distant from the site of contact.

Question 6

The respiratory system's main defences are nasal hair, mucous, sneeze reflex, ciliary escalator and, in the lungs themselves, phagocytosis. The inflammatory response is also a defence mechanism, as is acquired immunity.

Question 7

Solid, liquid and gas.

Question 8

- Solid – massive form, dust, fibre or fume.
- Liquid – massive form or mist.
- Gas – gas and vapour.

Question 9

- The inhalable (or total inhalable) dust fraction is the fraction of airborne dust that enters the nose and mouth during breathing, and is therefore available for deposition in the respiratory tract.
- The respirable dust fraction is the fraction of airborne dust that penetrates to the gas exchange region of the lung. Typically, this is dust particles of less than 7µm diameter.

Question 10

The Globally Harmonised System of Classification and Labelling of Chemicals (GHS) is a non-legally-binding international agreement on the labelling and classification of chemicals, with the aim that each chemical will have the same label worldwide.

Question 11

Produces serious, acute or chronic ill health or death at very small or small doses.

Question 12

Carbon monoxide (CO) is an asphyxiant gas, i.e. when inhaled it reduces the oxygen available to the body. The presence of CO in air causes asphyxiation when the CO combines with haemoglobin to form carboxy-haemoglobin, a compound which prevents oxygen transport by the blood. This causes headache, drowsiness, unconsciousness and death at relatively low concentrations.

Question 13

They are to ensure that the user is made fully aware of the potential risks or hazards associated with a chemical or mixture and the precautions to take. They can be found on product labels, safety data sheets and for many substances they originate from the harmonised classifications found in Table 3.1 of Part 3 of Annex VI of CLP.

Question 14

Supplier/manufacturer details, hazards, composition and/or ingredients, first-aid recommendations, fire-fighting procedures, accidental release procedures, handling and storage, exposure controls, personal protection, physical and chemical properties, stability and reactivity, and toxicological, ecological, disposal, transport, regulatory and other information.

Question 15

Several factors must be considered during this assessment, such as:

- Hazardous properties of the substances.
- Type and level of exposure.
- Duration and frequency of exposure.
- Number of people exposed.
- Effect of mixtures.
- Unusual activities and emergencies.
- Relevant Occupational Exposure Limits (OELs).
- Effectiveness of existing controls.
- Results of monitoring and health surveillance.
- Individual susceptibility.

Question 16

Whether the individual is atopic and therefore more prone to sensitisation; whether they are pregnant or a new mother or whether they are a woman of reproductive capacity; whether they are a young person; and whether they are already sensitised to a substance.

Question 17

In a case-control study, the risk factors of people with a disease are compared with those without a disease. It is a retrospective study. Members of the two cohorts are chosen on the basis that they either have the disease in question (case) or are disease-free (control).

A prospective cohort study follows two groups (cohorts) over a period of time (usually years). One cohort is known to be exposed to the agent in question; the other cohort (control) has no exposure to this agent. Both groups undergo medical surveillance to look for disease that might be linked to the agent in question.

Question 18

A good occupational example would be asbestos exposure and lung diseases.

Two populations are identified which differ only by the fact that one group has been historical exposed to asbestos and the other has not. Evidence of exposure is collected from health records. Medical surveillance is then carried out to gather data about the prevalence of lung disease in these two groups. This is reinforced with other health data. Statistical analysis is then carried out to see if a link between lung disease and historic asbestos exposure can be proven to exist.

Question 19

Acute toxicity (oral, dermal, inhalation, dermal irritancy/corrosion, eye irritancy/corrosion; skin sensitisation); repeated dose (28 days) toxicity; sub-chronic repeated dose (90 days) toxicity; chronic toxicity; mutagenicity; carcinogenicity and reproductive toxicity.

Question 20

Acute toxicity tests measure the effects which occur within a short period after dosing. The dose of the substance is successively increased and the effects are measured.

For the fixed dose acute toxicity test, the test substance is administered orally to test animals at one of four dose levels – 5, 50, 300 and 2000mg/kg. The animals are observed for 14 days and any deaths or serious ill health are observed.

The results are then compared with regulatory criteria in order to classify the chemical toxicity.

Question 21

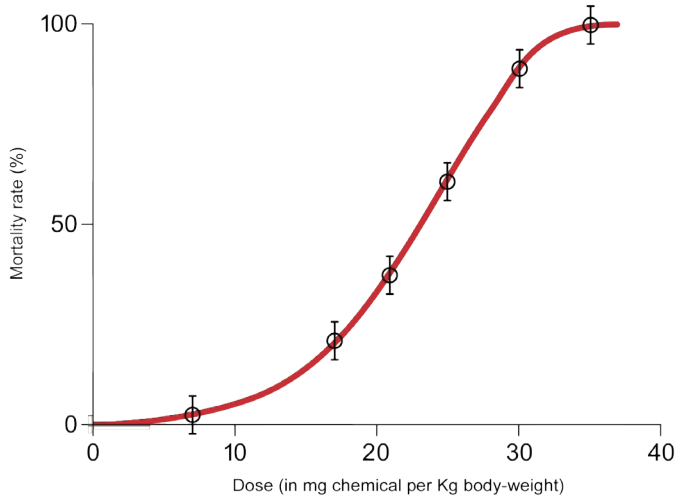
The most well known test is the Ames test. This involves exposing the mutagen to a specific strain of bacteria that will not normally grow in a histidine-deficient growth medium. Mutagens will cause a mutation in the bacteria allowing them to grow in a histidine-free medium.

Question 22

This measures the response (usually percentage killed) of a given animal species to logarithm of a known dose of a toxic substance.

Question 23

The curve should be S-shaped as shown in the dose/response curve figure below:



The LD_{50} and LD_{90} of a given substance is the dose that kills 50% and 90% respectively of the animal population tested.

Element IB3: Control of Hazardous Substances

Question 1

A simple hierarchy of controls is as follows:

- Eliminate exposure, following these steps:
  - Cease use of the hazardous chemical.
  - Substitute for a less hazardous alternative.
  - Implement an alternative process.
- Control exposure, through:
  - Good design and installation (through total enclosure of the process, segregation of the process from workers, modification of the process to reduce exposure potential, implementation of Local Exhaust Ventilation (LEV) – with or without partial enclosure – and the use of general ventilation).
  - Implementing work systems and practices to minimise the numbers of people exposed, restrict access to the processes, restrict the duration of exposure and provide for cleaning and decontamination, maintenance of controls, and safe storage/disposal of materials.
  - The use of PPE, good hygiene practices, welfare facilities, warning signs and emergency arrangements.

Question 2

Totally enclosing the process and handling systems, unless not reasonably practicable; prohibition of eating, drinking and smoking in possibly contaminated areas; cleaning floors, walls and other surfaces at regular intervals; designating areas and installations which may be contaminated and using warning signs; storing, handling and disposing of carcinogens and mutagens safely.

Question 3

- Asbestosis – asbestos fibres lodge deep in the lungs and cause scar-tissue formation. If enough of the lung is scarred then severe breathing difficulties occur. Can prove fatal. Increases risk of cancer.
- Lung cancer – asbestos fibres in the lung trigger the development of cancerous growths in the lung tissue. Usually fatal.
- Mesothelioma – asbestos fibres in the lung migrate through the lung tissue and into the cavities around the lung and trigger the development of cancerous growths in the lining tissue. Always fatal.
- Diffuse pleural thickening – thickening of the lining tissue of the lung (sometimes known as pleural plaques) that causes breathing difficulties. Not fatal.

(Only three were required.)

Question 4

Dilution ventilation is a method of diluting the concentration of a contaminant by changing the workplace air regularly. This might be done passively or with the use of fans to power the air movement. This method is only suitable where there is a relatively low concentration of high OEL contaminant which is given off slowly. It is not suitable where operators are in close contact with the source of contamination.

Question 5

To ensure that the system is working to its design specification. This should, in turn, ensure that the system is maintaining an acceptable work environment by keeping levels of airborne contaminants below set standards. In the absence of monitoring, the system may stop working effectively and this may go unnoticed.

Question 6

To give an indication of blockage or reduced efficiency of the filters. This may indicate that the filters need to be changed or cleaned.

Question 7

Section 11 of the ILO code recommends that the following information is kept as a record of each thorough examination and test:

- Name and address of the employer responsible for the plant.
- Identification and location of the LEV plant, process, and hazardous chemicals concerned.
- Date of the last thorough examination and test.
- Conditions at the time of testing; normal production or special/unusual conditions.
- Information about the LEV plant which shows:
  - Its intended operating performance for controlling the hazardous chemicals.
  - Whether the plant continues to achieve the same performance.
  - If not, the repairs required to achieve that performance.
- Methods used to make the above judgments, e.g. visual, pressure measurements, airflow measurements, dust lamp, air sampling and filter integrity tests.
- Date of examination and test.
- Name, designation and employer of the person carrying out the examination and test.
- Signature or authentication of the person carrying out the examination and test.
- Details of the repairs to be carried out (this section should be completed by the employer responsible for the LEV plant). The effectiveness of repairs should be assured by carrying out a re-test.

Question 8

It is appropriate for the risk and conditions; it takes account of ergonomic requirements; it will fit, it does not increase overall risk and it meets relevant standards.

Question 9

Compatibility means that where more than one piece of PPE is required, the wearing of one does not affect the effectiveness of another.

Question 10

Respirators are designed to purify respirable air by filtering air taken from the immediate surroundings of the wearer, whilst breathing apparatus supplies respirable air from an uncontaminated source.

Question 11

The pump attached to a powered respirator provides positive air pressure; this reduces fatigue, allows longer work periods and minimises the risk of ingress of contaminants.

Question 12

Factors to consider include: the hazard which the eye protection is intended to protect against, the conditions under which it would be used, the ergonomic requirements and compliance with standards. Compatibility with other items worn is also an issue.

Question 13

Loss of dexterity and feeling; overheating of the hands resulting in sweating leading to dermatitis or opening of the skin pores; possible removal of the gloves whilst carrying out a hazardous operation.

Element IB4: Monitoring and Measuring of Hazardous Substances

Question 1

OELs are intended to control the exposure of employees to a hazardous substance by inhalation (i.e. an airborne substance).

Question 2

Both long-term and short-term exposure limits are expressed as Time-Weighted Average (TWA) concentrations. This means that measurements are taken and the airborne concentrations are averaged out over a given period of time.

Long-term exposure limits are measured over 8 hours and are designed to control the chronic ill-health effects of long-term exposure to harmful substances; the sort of exposures that might occur routinely on a daily basis over a period of weeks, months or years in a workplace.

Short-term exposure limits are designed to control the acute ill-health effects that might result from exposure to a high concentration of a contaminant over a short period of time (usually measured over 15 minutes). This places a limit on the peaks in the exposure concentration that might occur in the workplace.

Question 3

- Recognition/identification of the hazard – identifying those factors that may cause harm.
- Measurement of the hazard/extent of exposure – determining who is affected and by how much.
- Evaluation against recognised standards – making a judgment on the risk posed.
- Control – putting measures in place to reduce or eliminate the risk.

Question 4

Initial appraisal helps establish the need for, and extent of, exposure monitoring. It is conducted in two stages – information gathering and simple qualitative tests. Depending on the conclusions drawn, a basic survey may then be needed. This estimates an employee's personal exposure using crude methods. The conclusions of this stage will enable you to decide if a detailed survey is required. The detailed survey is conducted in cases such as highly variable exposure and involves more detailed monitoring and analysis. In addition, there are the stages of re-appraisal (to see if changes have had the desired effect) and routine monitoring (to ensure controls remain effective) described in HSG173.

Question 5

The sampling equipment (sampling train) consists of an air pump, connecting hose and sampler (containing a pre-weighed filter):

- Clean and load the sampler with a pre-weighed filter or cassette.
- Fit the sampler to the pump. Run the pump to stabilise airflow and then check and adjust flow rate using the flow meter.
- Attach the sampling train to the operator, not more than 30cm away from the nose-mouth region.
- Record the time at the start of the sampling period and check, record and re-adjust the flow rate as necessary at the end of each hour.
- At the end of the sampling period, note the time and remove the filter for re-weighing.
- Re-check the flow-rate using the flow meter.
- Once the weight of dust collected on the filter is known, a simple calculation is carried out to give the weight of dust per cubic metre of air ($mg.m^{-3}$).

Question 6

- Tubes with incorrectly broken ends may not give the correct flow rate.
- Bellows action and the number of strokes are critical in ensuring that the correct volume of air is drawn through the tube.
- Tubes may be cross-sensitive to substances other than the one being analysed.
- Tubes give inaccurate readings at non-standard temperatures and pressures; these have to be corrected for.
- Tubes have a limited shelf-life.
- Measurements obtained are inherently inaccurate, so the margin of error of the tube type must be taken into account.
- Hand-operated stain tube systems are capable of only a point-in-time or grab sample.

Question 7

The minimum requirement for health surveillance is that a health record is created for each employee exposed or potentially exposed to the hazard in question. That health record is simply a record of the fact that exposure has, or is liable to have, occurred.

The minimum requirements for record keeping in a health record are:

- Surname.
- Forenames.
- Sex.
- Date of birth.
- Permanent address.
- Identification number.
- Date started present job.
- An historical record of jobs involving exposure to hazards for which health surveillance is required during the current spell of employment.

Question 8

- A health record is a record of the conclusions of a clinician (such as an OH doctor) on health surveillance results. It does not contain clinical information and so is not medically confidential. It can, therefore, be viewed by the employer.
- A medical record is created by a clinician, contains clinical information and is medially confidential. Therefore, it cannot be viewed by the employer without the authorisation of the individual concerned.

Question 9

Biological monitoring is the measurement of a substance or its metabolite (substance formed when the body converts the chemical) in a biological fluid (breath, urine or blood). An example of this is monitoring urine for the presence of isocyanates.

Element IB5: Biological Agents

Question 1

ILO defines a biological agent as "any micro-organism, cell culture, or human endoparasite, which may cause any infection, allergy, toxicity or otherwise create a hazard to human health. These include viruses and bacteria which can cause infection and disease, dangerous plants and animals (e.g. parasites or insects), biologically contaminated dusts, or wastes from humans and animals."

Question 2

Fungi, bacteria, viruses and protozoa.

Question 3

Stage I – fever with 'flu-like symptoms lasting for about a week.

Stage II – by the start of the second week, the fever has abated and jaundice becomes more obvious.

Stage III – in severe cases, jaundice may be present for three or four weeks, followed by a second fever lasting for up to two weeks. Recovery/convalescence can take many weeks or months.

Question 4

Zoonoses are animal infections that may be transmitted to people in the course of their work. For example, anthrax is an acute, infectious disease of farm animals caused by a bacterium.

Question 5

Agricultural workers, and sewage and construction workers; who are exposed to sewage and polluted water (polio, leptospirosis, hepatitis, etc.).

Question 6

- Ability to cause human disease.
- Possible hazard to workers.
- Likelihood of spread of disease in the community.
- Availability of prophylaxis and treatment.

Question 7

Class III microbiological safety cabinet – totally enclosed, leak-proof cabinets where the operator works through glove ports. Air is drawn in and extracted through HEPA filters and discharged to atmosphere.