STUDENT MANUAL

Basic Principles in Occupational Hygiene

July 2019

This course is offered by the Occupational Hygiene Training Association and available free of charge though the OHTA website ohtatraining.org.

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ACKNOWLEDGEMENTS

This manual was originally developed by Hirst Consulting Limited, UK and GlaxoSmithKline. The Occupational Hygiene Training Association Ltd (OHTA) would like to acknowledge the contribution of these organisations in funding and developing the material and is grateful for their permission to use and modify it.

OHTA would also like to express its appreciation to the following individuals for their support or contribution.

- Steve Bailey
- Roger Alesbury
- Phil Johns
- Brian Davies
- BP International Limited
- GlaxoSmithKline

This manual was updated in 2016/7 and the contribution of the following people is greatly appreciated.

- Kerrie Burton
- Brian Davies
- John Dobbie
- Jen Hines
- Terry McDonald

Minor formatting amendments were made in 2019. OHTA would like to thank John Henderson for his contribution.

Version	Release Date	Comments
I.0	October 2010	Initial version
2.0	May 2016 and February 2017	Update of technical information and minor editorial changes.
3.0	July 2019	Minor formatting amendments

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IOHA

1 INTRODUCTION

The International Occupational Hygiene Association (IOHA) defines Occupational Hygiene as:

'The discipline of **anticipating**, **recognizing**, **evaluating** and **controlling** health hazards in the working environment with the objective of protecting worker health and well-being and safeguarding the community at large'.

ANTICIPATION – this involves identifying potential hazards in the workplace before they are introduced.

RECOGNITION - this involves identifying the potential hazard that a chemical, physical or biological agent - or an adverse ergonomic situation - poses to health.

Chemical agents	Gases, vapours, solids, fibres, liquids, dusts, mists, fumes, etc.
Physical agents	Noise and vibration. Heat and cold. Electromagnetic fields, lighting etc.
Biological agents	Bacteria, fungi, etc.
Ergonomic factors	Lifting, stretching, and repetitive motion.
Psychosocial factors	Stress, workload and work organisation.

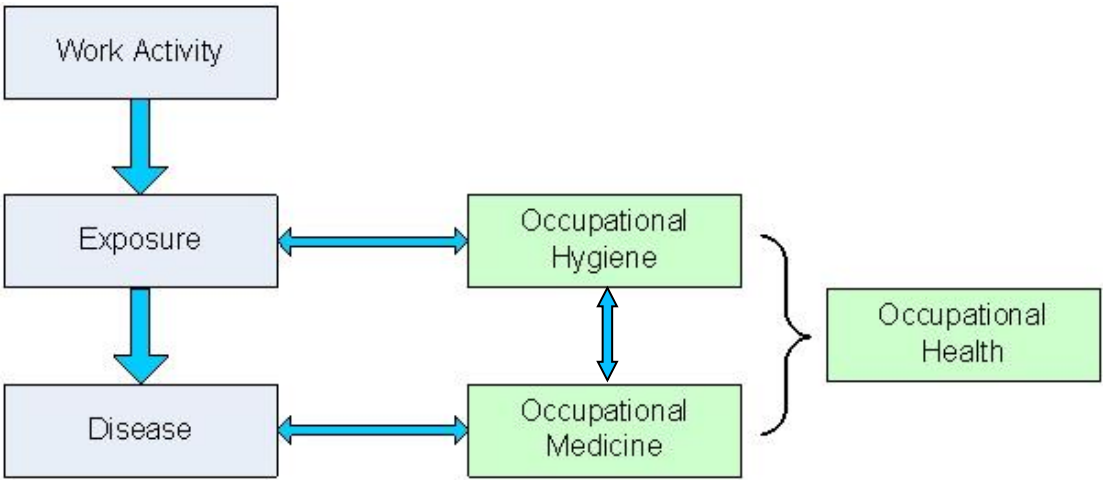
EVALUATION of the extent of exposure to the chemical hazards, physical or biological agents (or adverse ergonomic situation) in the workplace. This often involves measurement of the personal exposure of a worker to the hazard / agent in the workplace, particularly at the relevant interface between the environment and the body, e.g. breathing zone, hearing zone, and assessment of the data in terms of recommended occupational exposure limits (OELs), where such criteria exist.

CONTROL of the chemical, physical or biological agent - or adverse ergonomic situation, by procedural, engineering or other means where the evaluation indicates that this is necessary.

Occupational hygiene therefore focuses essentially on a preventative approach through the minimisation of exposure to chemical, physical and biological agents in the work environment and the adoption of good ergonomic practices.

In the occupational health field there are a number of specialist health protection disciplines, other than occupational hygiene, which play an important role in the endeavour to protect the health of employees, customers, contractors and the public who may be affected by the work activities.

Occupational Medicine – this covers both clinical practice (doctors) as well as nursing and is concerned with the effect of **work on health** and **health on work**. This involves the prevention of health problems, promotion of healthy living and working conditions as well as the diagnosis and treatment of work related ill health.



Epidemiology - concerned with the statistical study of disease patterns in groups of individuals.

Toxicology - concerned with the prediction and the evaluation of the effects of chemical substances on living organisms, especially man.

The main areas of activity of an occupational hygienist include:

- The anticipation of health hazards in new and proposed work situations.
- The recognition of health hazards in existing workplaces.
- The assessment of health risks in the workplace; through qualitative assessments as well as quantitative exposure measurement surveys.
- The selection of appropriate control measures for health risks; this requires a thorough working knowledge of measures such as elimination, substitution, local exhaust ventilation.
- The development of tailored control solutions for unique work activities; many workplaces require the modification and development of control measures since off the shelf measures will not work adequately.
- The investigation into the causes of work related ill health.
- Assistance with occupational health related activities such as health surveillance / biological monitoring.
- Training and education; such as informing workers of the hazards associated with their work and training them in the correct use of control measures.
- Research activities into improved methods for recognition, evaluation and control of exposure.

The occupational hygienist can regularly work closely with environmentalists, safety personnel, medical practitioners, project managers, engineers from all disciplines, food hygienists, local Government Officials, etc., to help reduce and control exposure to health hazards in the workplace.

1.1 History

Industrial diseases have been known about since Hippocrates (ancient Greece. ca 400 BC). There is even evidence to show that occupational diseases were recognised by the ancient Egyptians. Over time the recognition of links between occupation and ill health has increased and the associations strengthened. In parallel with this, techniques were developed to evaluate and control the risks. The table below represents a selection of some of the interesting and notable events in the development of occupational hygiene.

Ca 400 BC	Hippocrates in ancient Greece first noted illness in mercury sulphide workers.
Ca 100 AD	The Roman Plutarch notes that: "*It is not just to expose non-criminals to the poisons of the mines*". He also documents the use of bladder skins as a form of Respiratory Protective Equipment to control dust exposure in the mines.
Ca 1540	Paracelsus in Austria described lung diseases in mineworkers.
1556	Agricola (ca 1556) in Bohemia wrote "De Re Metallica" which describes the diseases associated with miners as well as the use of ventilation and respiratory protective equipment to control exposures to gases and dusts.
1700	Ramazzini, the father of industrial medicine, and Professor of Medicine in Padua, wrote "De Morbis Artificum Diatriba", the first formal study of industrial diseases. It was he who added an addition to Hippocrates list of questions to patients when taking a history, namely "what is your occupation".
1750 onwards	The Industrial revolution from the late 1700's through to the late 1800's led to increased urbanisation and industrialisation. This in turn led to more workers being exposed to increasing levels of health risk.
1815	Sir Humphrey Davy develops the Davy Lamp which was a safety lamp used in mines. The lamp was also used to detect the presence of combustible gases in mines. Interestingly the lamp was later blamed for an increase in the number of accidents as it allowed workers to continue working in more hazardous atmospheres.
1833	First (four) factory inspectors appointed in the UK.
1840's	Charles Dickens novels and campaigning politicians such as Lord Shaftesbury, increases people's awareness of poor working conditions.
1855	In the UK certifying surgeons (who previously certified age) were instructed "to certify that young persons were not incapacitated for work by disease or bodily infirmity, and to investigate industrial accidents". (Schilling).
1858	John Stenhouse introduces a charcoal impregnated mask to control exposure to gases and vapours.
1889	Exposure limits are set for humidity and carbon dioxide in cotton mills in the UK. This in turn led to the development of Local Exhaust Ventilation rather than general ventilation. It also led to the development of monitoring devices in the form of Indicator Tubes for carbon dioxide.
1898	Thomas Legge was appointed to be the first Medical Inspector of Factories. He did the first work in industry on lead poisoning, which was made a notifiable disease in 1899.
1890's	Haldane undertakes work on the toxicity of carbon monoxide by exposing rats, mice and even himself to varying concentrations within an "exposure chamber". He used these

	results to develop “dose v time” plots for severity and discomfort of health effects. He introduced the use of small animals and in particular canaries as the first way of monitoring to give an indication of the levels of toxic gas.
1910	Alice Hamilton worked in the US as the first Industrial Toxicologist pioneering the field of toxicology and occupational hygiene.
1917	During the first world war the urgency of the work in munitions factories led to poor working conditions. It is recognised that the poor working conditions had a significant effect on productivity as well as health. The work of the “Health of Munitions Workers Committee” laid the ground for many subsequent practices in ergonomics, psychology, welfare and shift-work regimes.
1920-30’s	Industrial hygiene developed and grew in the USA in both the Public Health Service (PHS) and large private companies. These developments lay the foundations for the creation of two professional organisations.
1938/9	The American Conference of Governmental Industrial Hygienists (ACGIH) and the American Industrial Hygiene Association (AIHA) were formed. The first independent professional organisations for industrial/occupational hygienists. IH numbers in USA grew rapidly during WWII to assist the war effort.
1953	British Occupational Hygiene Society (BOHS) founded. Society started publishing Annals of Occupational Hygiene in 1958.
1960	Sherwood and Greenhalgh documented the development of the first personal sampling pump and sampling head; the first comparison between personal sampling and static sampling and the first observation of the possible effect of personal sampling on the individual being sampled.
1970’s	Occupational Safety and Health Act in the USA and the Health and Safety at Work Act in the UK lay the path for Risk Assessment / performance based legislation.
1980	The Australian Institute of Occupational Hygienists (AIOH) founded.
1980/90’s	The practice of occupational hygiene grew widely in the USA, UK, the Netherlands and Australia with legislation in these countries being introduced specifically to focus on chemical and physical hazards.
2000’s	The societies of 25 different countries are members of the International Occupational Hygiene Association (IOHA). Industrialisation in countries such as China and India increase the need for occupational hygiene. The development of modelling techniques for assessing exposure.

1.2 The Importance of Occupational Hygiene

Whilst a brief examination of the history and trends in occupational hygiene shows a general improvement in both our understanding and control of health risks there are still many issues to be tackled. Increasing industrial activity in developing countries means that there are more people exposed worldwide. Technological advancements also mean that new hazards are being introduced into the workplace. It is estimated that there are:

- **2.3 million work-related deaths per year**, with disease responsible for 2.0 million and 0.3 million linked to occupational injuries (Takala, Hämäläinen, Saarela, Yun, Manickam, Jin, Heng, Tjong, Kheng & Lim 2014)
- **386,000 deaths each year from exposure to airborne particulates.** (asthma: 38,000; COPD*: 318,000; pneumoconiosis: 30,000). This amounts to nearly 6.6 million DALYs** (asthma: 1,621,000; COPD: 3,733,000; pneumoconiosis: 1,288,000) due to exposure to occupational airborne particulates (Prüss-Üstün & Corvalán 2006)
- 107 000 – 194 000 deaths each year are attributable to occupational exposure to asbestos (Forouzanfar, Alexander, Anderson, Bachman, Biryukov, Brauer, Burnett, Casey, Coates & Cohen 2015)
- **152,000 deaths per year from carcinogens in the workplace.** (lung cancer: 102,000; leukaemia: 7,000; malignant mesothelioma: 43,000) and nearly 1.6 million DALYs (lung cancer: 969,000; leukaemia: 101,000; malignant mesothelioma: 564,000) due to exposure to occupational carcinogens (Prüss-Üstün & Corvalán 2006)
- **37% of Lower Back Pain is attributed to occupation**, with two-fold variation across regions. Work-related Lower Back Pain was estimated to cause 818,000 DALYs lost annually (Punnett, Prüss-Ütün, Nelson, Fingerhut, Leigh, Tak & Phillips 2005)

*COPD = Chronic obstructive pulmonary disease which is chronic bronchitis and emphysema, a pair of two commonly co-existing diseases of the lungs in which the airways become narrowed.

**DALYs = Disability Adjusted Life Years - The sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability.

The relative importance of occupational hygiene can be illustrated by comparing statistics about incidence of accidents with that of ill health. In the UK the number of deaths due to work related activities is approximately 250. This may be compared to the number of deaths due to road traffic accidents which is approximately 2500. However, the number of deaths each year due to work related cancer and respiratory disease is estimated at 12,000. This gives a ratio of 1:10:48.

2 HUMAN PHYSIOLOGY AND INDUSTRIAL DISEASES

The human body is a complex organism which can be affected greatly by chemical and physical hazards; the body also has many ways of regulating itself when exposed to hazards. In order to control the risks to the body it is necessary to have an understanding of how it works, and the kinds of harm that can occur as a result of exposure.

2.1 Skin

The skin is the outer covering of the body, also known as the epidermis. It is the largest organ of the body and is made up of multiple layers of epithelial tissues, and guards the underlying muscles, bones and internal organs.

As the skin interfaces with the environment, it plays an important role in protecting the body against pathogens.

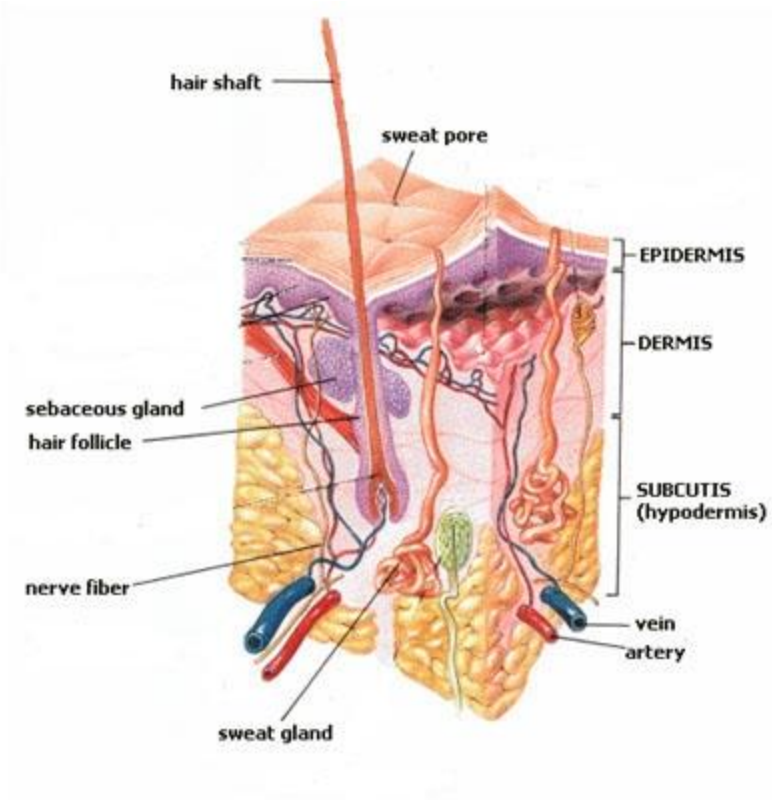


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Figure 2.1 - Diagram of Skin

The skin performs multiple functions including:

- Protection: an anatomical barrier from pathogens and damage between the internal and external environment. Some substances e.g. acetone, remove the oil from the skin and hence decrease protection (defat).
- Sensation: contains a variety of nerve endings that react to heat, cold, touch, pressure, vibration, and tissue injury.
- Heat regulation: the skin contains a blood supply far greater than its requirements which allows precise control of energy loss by radiation, convection and conduction. Dilated blood vessels increase perfusion and heat loss while constricted vessels greatly reduce cutaneous blood flow and conserve heat.
- Control of evaporation: the skin provides a relatively dry and impermeable barrier to fluid loss. Loss of this function contributes to the massive fluid loss in burns.
- Storage and synthesis: acts as a storage center for lipids and water, as well as a means of synthesis of vitamin D.
- Excretion: sweat contains urea, however its concentration is 1/130th that of urine, hence excretion by sweating is at most a secondary function to temperature regulation.
- Absorption: While skin acts as a barrier some chemicals are readily absorbed through it.
- Water resistance: The skin acts as a water resistant barrier so essential nutrients aren't washed out of the body.

The skin can be affected by chemical, physical and biological agents and skin disorders account for a substantial proportion of industrial diseases. The types of effect can be classified into; dermatitis, physical damage, cancer, biological and other effects.

2.1.1 Dermatitis

The most common disorder is contact dermatitis and 70% of cases are due to primary irritation i.e. direct action on the skin, most often of the hands and forearms. An irritant is an agent that directly damages cells if applied to the skin

in sufficient concentration and for sufficient time (i.e. all effects are dose-related), leading to irritant contact dermatitis. Alkalis dissolve keratin and some solvents remove the sebum. Any direct skin effects can make the surface more vulnerable to other agents and reduce the skin's entry defences.

The other form of contact dermatitis is allergic contact dermatitis. This results from sensitising the skin by initial contact with a substance and subsequent re-contact. A sensitizer (allergen) is a substance that can induce a specific immunological sensitivity to itself. The trigger dose may need to be quite high and leads to a delayed-type hypersensitivity response mediated by lymphocytes and involving antibody production. This dose may produce no visible effects but subsequent, often minute, exposures may lead to dermatitis.

Common irritants include detergents, soaps, organic solvents, acids and alkalis. Common sensitizers are plants (gardening), antibiotics (pharmaceutical industry), dyes (paint and cosmetic industry), metals (nickel (usually non-industrial), and chromates (cement industry), rubbers and resins.

People working with cutting oils can have both irritant and allergic contact dermatitis, being irritated by the oil itself and allergic to biocides within it.

2.1.2 Physical damage

Physical agents which can harm the skin include weather, friction and injury. Cold, wind and rain cause dry chapped skin, and sunlight can burn or cause skin tumours, so occupations exposed to the elements (fishing, farming) are at risk. Friction injuries are common in heavy manual labouring (construction and mining), and sharp equipment used in many occupations can lead to abrasions and lacerations.

2.1.3 Biological agents

The skin can be prone to the effects of biological agents such as viral infections from animals, yeast / fungal infections when prolonged contact with water occurs and anthrax infections where animal products are handled.

2.1.4 Cancer

Malignant skin tumours and cancers can result from contact with creosote, and mineral oils, ionising radiation (radioisotope work, radiographers). Exposure to ultraviolet radiation whilst working outdoors is also a common cause of skin cancer.

2.1.5 Other effects

Work involving mineral oils can lead to oil acne particularly on forearms and thighs. Plugged pores becoming infected produce blackheads and pustules. Chloracne, with blackheads and cysts on the face and neck results from the effects of some polychlorinated aromatic hydrocarbons on sebaceous glands.

Alterations in skin pigmentation can result from chemical contact.

Strong alkaline and acid solutions cause burns.

2.2 Musculoskeletal System

The musculoskeletal system provides form, stability, and movement to the human body. It is made up of the body's bones, the skeleton, muscles, cartilage, tendons, ligaments, and joints. The musculoskeletal system's primary functions include supporting the body, allowing motion, and protecting vital organs. The skeletal portion of the system serves as the main storage system for calcium and phosphorus and contains critical components involved in the production of blood.

There are, however, diseases and disorders that may adversely affect function and overall effectiveness. These diseases can be difficult to diagnose due to the close relation of the musculoskeletal system to other internal systems.

The skeletal system serves many important functions; it provides the shape and form for our bodies, in addition to supporting, protecting, allowing bodily movement, producing blood for the body, and storing minerals.

Another function of bones is the storage of certain minerals. Calcium and phosphorus are among the main minerals being stored. This storage "device", helps to regulate mineral balance in the bloodstream. This storage ability can

be important when it comes to exposure to hazardous substances. For instance; lead is stored in the blood for long periods after exposure, this can be released selectively at a later date and give rise to issues with lead poisoning in the body. e.g. during pregnancy.

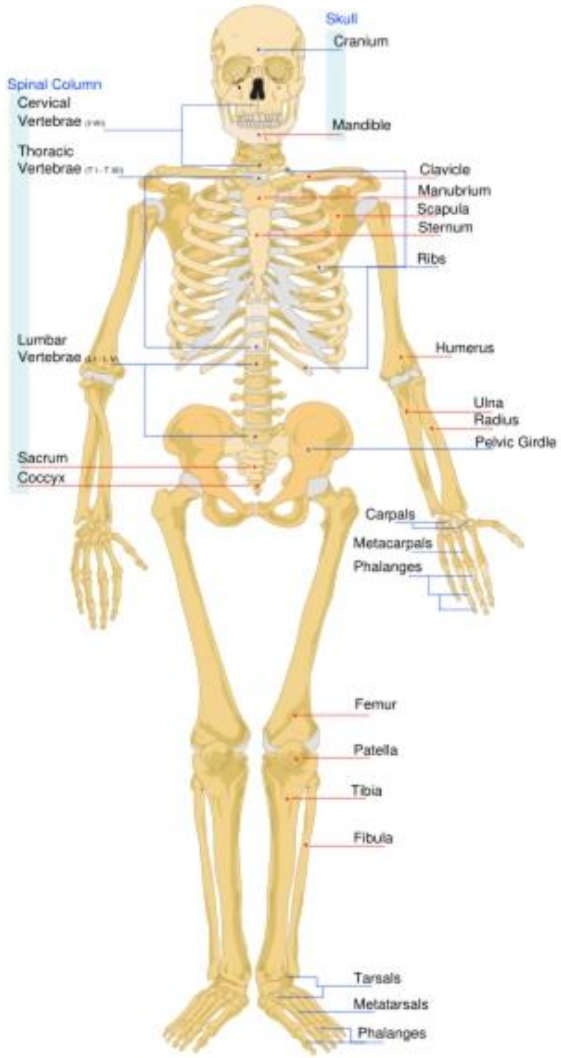

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Figure 2.2 - Skeletal System

2.3 Nervous System

The nervous system is a network of specialized cells that communicate information about our body's surroundings and ourselves. It processes this information and causes reactions in other parts of the body. The nervous

system is divided broadly into two categories: the central nervous system and the peripheral nervous system.

The **central nervous system** (CNS) is the largest part of the nervous system, and includes the brain and spinal cord.

The **peripheral nervous system** (PNS) is a term for the collective nervous structures that do not lie in the CNS.

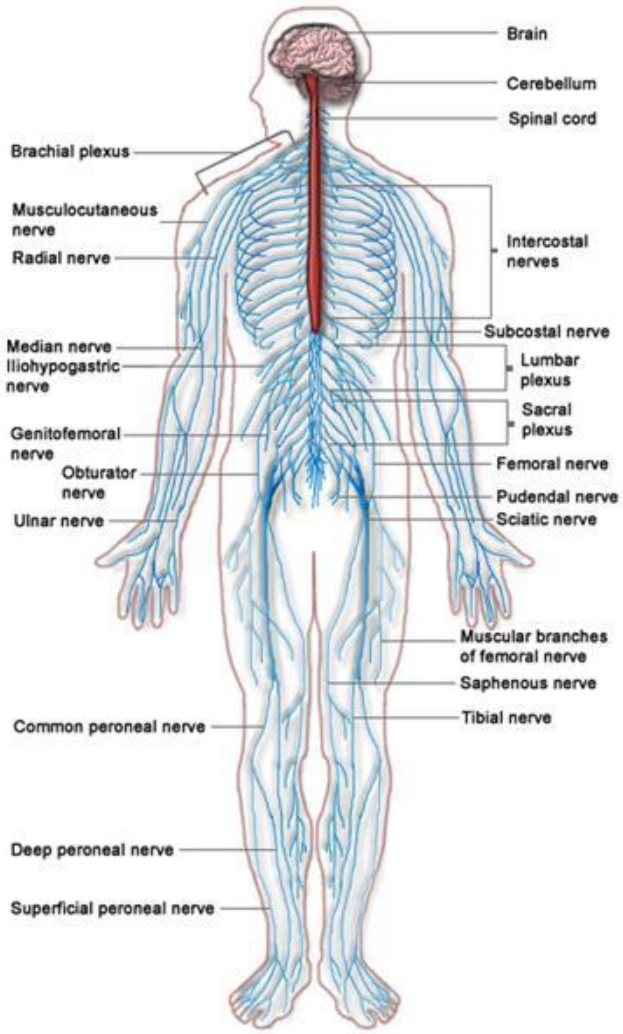

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Figure 2.3 – Nervous System

Industrial toxins can affect the central nervous system (brain and spinal cord) or peripheral nervous system (motor and sensory nerves) or both and the resulting conditions depend on the site of attack. The nervous system is similar

to the liver in that fat-soluble agents are much more likely to cause damage. They can also cross the blood-brain barrier.

Central nervous system damage can produce narcosis, toxic organic psychosis, epilepsy, Parkinsonism and behavioural changes.

Perhaps the easiest recognisable central nervous system effect is the acute loss of consciousness produced by narcotic agents such as chloroform, carbon tetrachloride, and trichloroethylene (all fat-soluble halogenated hydrocarbons) and solvents such as acetone, toluene and carbon disulphide.

Behavioural changes, demonstrable by intelligence, dexterity and vigilance tests, have been found to result at much lower levels than normally accepted as safe on exposure to trichloroethylene, white spirits, carbon monoxide and methylene chloride.

2.4 Endocrine System

The **endocrine system** is the collective name given to a system of small organs that release extracellular signalling molecules known as hormones. The endocrine system is instrumental in regulating metabolism, growth, development, puberty and tissue function. It also plays a part in determining our mood.

The endocrine system is an information signalling system much like the nervous system. However, the nervous system uses nerves to conduct information, whereas the endocrine system mainly uses blood vessels as information channels through which it passes the hormones.

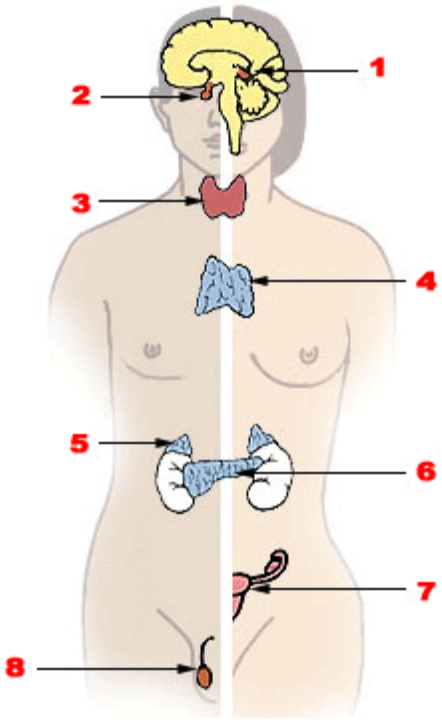

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Figure 2.4 - Major Endocrine Glands (Male on the left, Female on the right)

1. Pineal gland, 2. Pituitary gland, 3. Thyroid gland, 4. Thymus,
5. Adrenal gland, 6. Pancreas, 7. Ovary, 8. Testes.

Pharmaceutical workers handling endocrine drugs like oestrogen (in 'the pill') or thyroxin (used for thyroid treatment) are at risk of upsetting their own endocrine balance and diethylstilboestrol (DES) has led to tumours in the children of workers of both sexes.

Anaesthetic gases (female anaesthetists) and vinyl chloride exposure while pregnant have been linked to stillbirth or birth defects. Ionizing radiation can damage gonads reducing fertility or increasing risks of congenital malformations and cancer in the offspring.

2.5 The Circulatory System

The circulatory system moves nutrients, gases, and wastes to and from cells to help fight diseases and help stabilize body temperature and pH. This system may be seen strictly as a blood distribution network, but some consider the

circulatory system as composed of the **cardiovascular system**, which distributes blood, and the **lymphatic system**, which distributes lymph.

The main components of the human circulatory system are the heart, the blood and the blood vessels. The circulatory system includes:

- Pulmonary circulation: where blood is passed through the lungs and becomes oxygenated.
- Systemic circulation: where the oxygenated blood is passed through the rest of the body.

An average adult contains 4.7 to 5.7 litres of blood, which consists of plasma, red blood cells, white blood cells and platelets. Also, the digestive system works with the circulatory system to provide the nutrients the system needs to keep the heart pumping.

The lymphatic system is responsible for the removal of interstitial fluid from tissues as well as the absorption and transport of fats and fatty acids. The lymphatic system is also responsible for the transport of antigen presenting cells (APCs).

The cardiovascular system is exposed to any agent carried in the blood. Carbon monoxide and many metals (including chromium, manganese and lead) are thought to cause damage to heart muscle, but the only proven link is with cobalt. Chlorinated hydrocarbons like CFCs (chloro fluoro carbons), trichloroethylene and 1,1,1-trichloroethane can induce arrhythmias (abnormal heart rhythms due to defects in electrical conduction in the heart). Trichloroethylene has caused sudden death this way. Carbon disulphide (viscose rayon industry) speeds up atherosclerosis (hardening of the arteries).

High or low temperature work affects the peripheral circulation and can strain the heart.

2.5.1 The blood

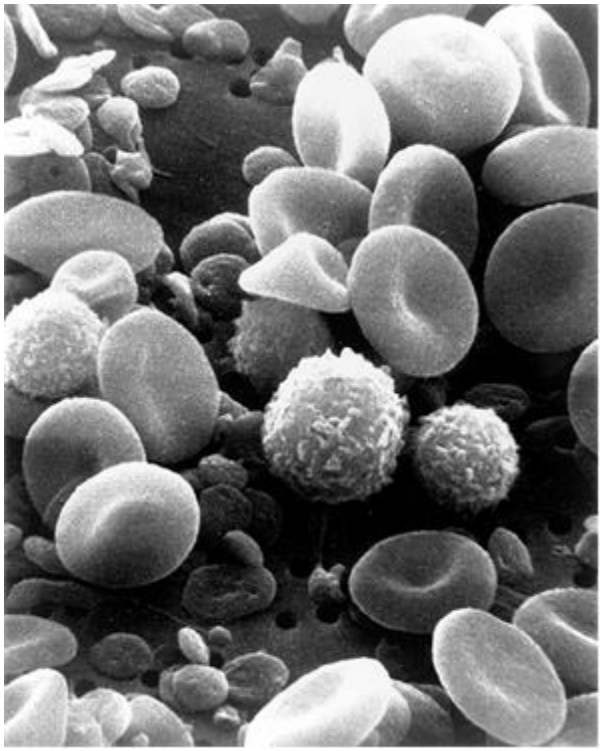

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Figure 2.5 - Electron Micrograph of Blood Cells Showing White Blood Cells, Red Blood Cells and Platelets

Production of haemoglobin, the oxygen-carrying red pigment in red cells, is inhibited by inorganic lead interfering with enzyme systems. The result is anaemia characterised by pale skin and mucous membranes, fatigue and sometimes breathlessness on exertion. Arsine and stibine cause red cell break-up (haemolysis) and the result is again anaemia. X-irradiation (nuclear accidents) and benzene can cause leukaemia (overgrowth of blood cells), probably by action on DNA synthesis.

Oxygen transport can be affected in two ways, both being forms of asphyxia. In atmospheres where normal air is displaced by inert gases like nitrogen, methane, helium and carbon dioxide, the oxygen content (normally 21%) is diluted and hypoxia (low oxygen tension in the blood) results. This initially will lead to a compensatory increased pulse and respiratory rate. If hypoxia continues, judgement will be impaired and the person will lapse into

unconsciousness and eventually die. Breathing 100% inert gas (sticking head into a gas-filled chamber) will cause instant unconsciousness.

The other industrial form of asphyxia is chemical asphyxia. Aniline and nitrobenzene, as liquids absorbed through intact skin, and inhaled carbon monoxide, interfere with the blood's ability to carry oxygen linked with haemoglobin, as oxyhaemoglobin. Aniline and nitrobenzene link with haemoglobin to form methaemoglobin leading to cyanosis (a blue tinge to the mucous membranes, especially the lips). Carbon monoxide combines with haemoglobin in competition with oxygen to form carboxyhaemoglobin, a bright crimson pigment, making the sufferer appear cherry red.

2.6 Respiratory System

The major function of the respiratory system is gas exchanged between the external environment and the circulatory system. This involves taking in oxygen from the air to the blood and releasing carbon dioxide (and other gaseous waste products) from the blood back into the air.

Upon inhalation, gas exchange occurs at the alveoli, the tiny sacs which are the basic functional component of the lungs. The alveolar walls are extremely thin (approx. 0.2 micrometres). These walls are composed of a single layer of epithelial cells in close proximity to the blood capillaries which in turn are composed of a single layer of endothelial cells. The close proximity of these two cell types allows permeability to gases and, hence, gas exchange. Oxygen is taken into the blood whilst excess carbon dioxide is released.

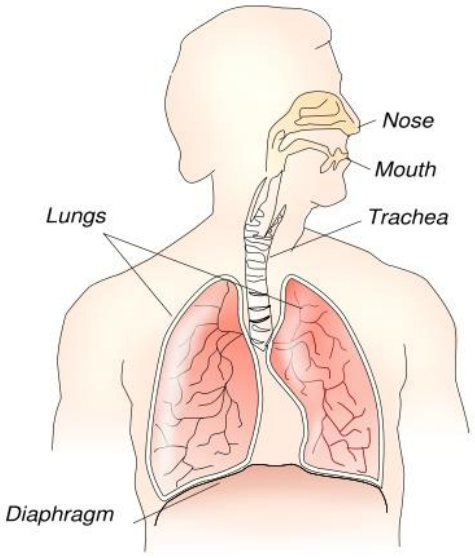

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Figure 2.6 - Respiratory System

Like the skin and the eye, the lungs are affected by irritants and allergens. They also respond in the forms of fibrotic pneumoconiosis and malignant disease to a variety of industrial agents.

Particles greater than 10 μm in diameter are filtered by the nose. The branching structure of the airways encourages deposition of 2-10 μm particles which can then be cleared by the mucociliary escalator. In the alveoli remaining particles either pass back up the bronchial tree freely or are phagocytosed by macrophages and taken to the mucociliary escalator or to the surrounding lymphatic system. Despite their efficiency, large volumes of particles can overwhelm these defence mechanisms.

Irritation caused by gases and fumes produces inflammation of the respiratory tract and the symptoms tend to be acute or delayed, depending on the solubility of the toxic agent. There can also be chronic effects. Chronic effects from prolonged exposure may be chronic bronchitis and permanent lung damage.

Allergic reactions to substances can cause occupational asthma. Symptoms include severe shortness of breath as well as wheezing, coughing and chest tightness. Certain substances such as isocyanates (used in paints), flour dust and various fumes can cause asthma. These substances are called 'respiratory

sensitizers' or asthmagens. They can cause a change in people's airways, known as the 'hypersensitive state'.

Not everyone who becomes sensitized goes on to get asthma. But once the lungs become hypersensitive, further exposure to the substance, even at quite low levels, may trigger an attack.

Pneumoconiosis is the reaction of the lungs to inhaled mineral dust and the resultant alteration in their structure. The major causes are coal dust, silica and asbestos and they all lead to scarring of the lungs known as collagenous fibrosis. Pneumoconiosis may not produce any symptoms for years. However, as the lungs become less flexible and porous their function is greatly reduced. The symptoms include shortness of breath, cough, and general ill feeling. The shortness of breath usually begins only with severe exertion. As the disease progresses, shortness of breath may be present all of the time. The cough initially is not associated with sputum, but may eventually be associated with coughing up blood. Due to poor oxygenation of the blood by the damaged lungs, the nails and lips may appear pale or bluish.

Chronic obstructive pulmonary disease (COPD) refers to chronic bronchitis and emphysema. These are two lung diseases which often occur together and result in the airways becoming narrowed. This leads to a limitation of the flow of air to and from the lungs causing shortness of breath. Unlike occupational asthma, the narrowing of the airways is not easy to reverse and usually gets progressively worse over time. COPD can be triggered by a wide range of particles and gases which cause the body to produce an abnormal inflammation of the tissues.

Malignant tumours of industrial origin can affect the lungs and surrounding tissues. Lung cancer has been discovered in people working with asbestos (miners, insulators) and this risk is potentiated by cigarette smoking, arsenic (pesticides), chromium (pigment manufacturers), polycyclic aromatic hydrocarbons (coal gas manufacture, tar workers) and ionising radiation (uranium miners). Wood dust (hardwood furniture makers), leather dust and nickel dust have caused nasal sinus cancer.

2.7 The Gastrointestinal Tract

The gastrointestinal tract is the system used by the body to take in, break down and absorb nutrients as well as to excrete waste products. Ingestion as a toxic route of entry in industry is unlikely, but it can occur if people are allowed to eat or smoke at their work station thus risking contamination from their hands or from contaminated surfaces. Both vomiting and diarrhoea are natural defence mechanisms against ingested toxins, and gastric acid will neutralise alkaline intruders to an extent and also kill bacteria. Absorption of toxins is relatively less efficient than via inhalation. Nevertheless, any irritant or corrosive agent which could affect the mucous membranes of the respiratory tract can also cause swelling of the lips, mouth and epiglottis (leading to choking) and ulceration of the oesophagus and stomach.

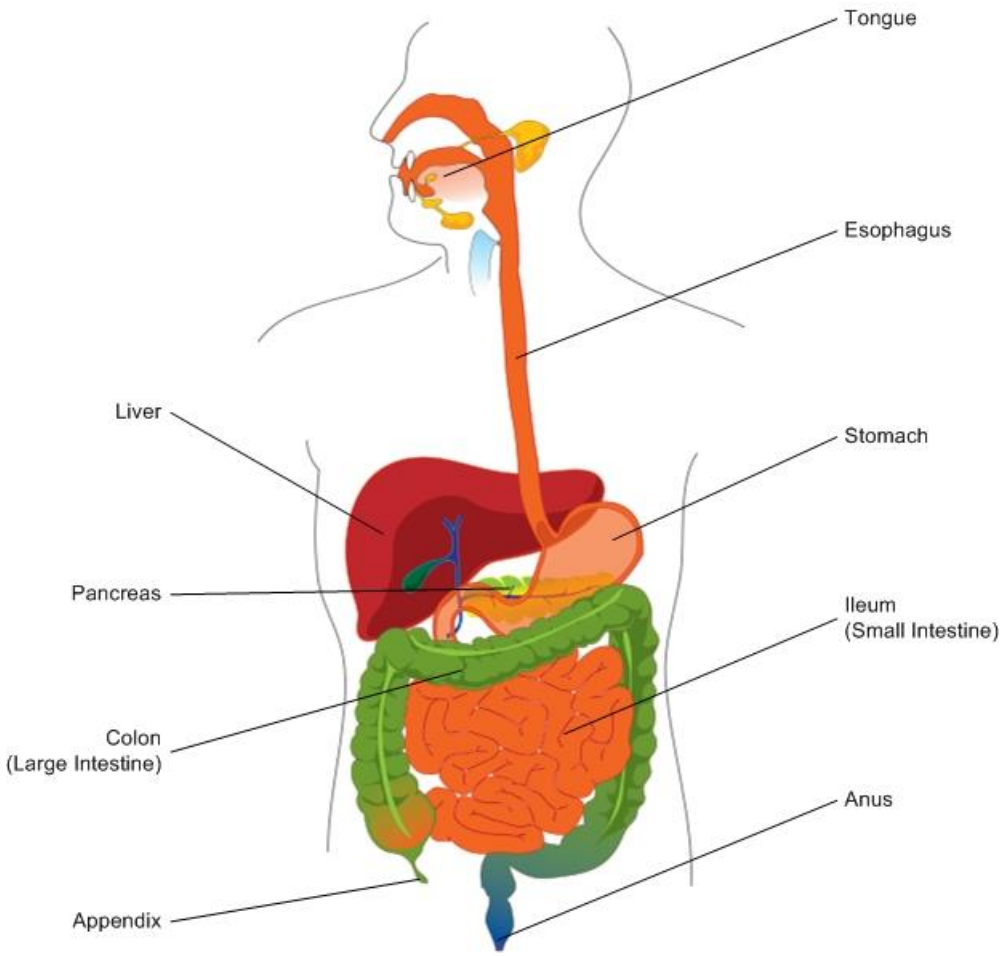

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Figure 2.7 – The Gastro Intestinal Tract

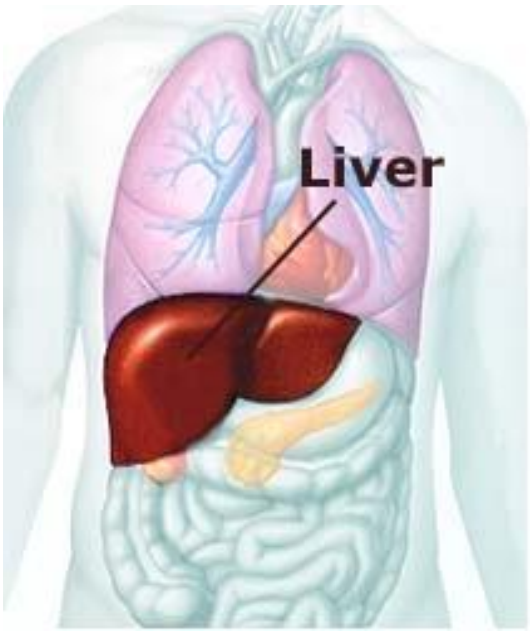
2.8 The Liver

The liver is a major metabolic organ used to process nutrients which have been absorbed into the blood from the gastrointestinal tract or via other routes such as inhalation. The fact that it is used to break down materials means that is particularly susceptible to any toxins within the body. Liver cells can regenerate after toxic damage, the most common cause of which is alcohol. However, continued absorption can overtake the regeneration process and cause permanent liver damage. Pre-existing liver disease makes this more likely.

Industrially, fat-soluble alcohols and halogenated hydrocarbons are particularly known for their liver cell damage. The most obvious sign of liver damage is jaundice.

Liver damage, usually cirrhosis, is an important precursor of hepatomas (liver tumours) and thus industrially induced long-term liver damage predisposes employees to liver tumours.

The liver is a protective organ itself in that its normal detoxification processes change potential toxins to safe forms (and sometimes vice versa).

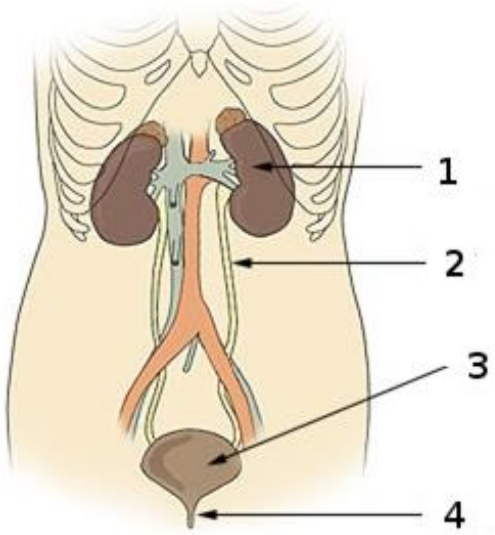


Source: Wikimedia commons

Figure 2.8 The Liver

2.9 Urinary System

The kidney plays an important role in the maintenance of fluid and electrolyte balance by filtration and selective re-absorption of them into the blood. It excretes (via urine) unwanted waste products (including toxins), made water-soluble by metabolism in the liver.



Source: US Federal Government via Wikimedia commons

Figure 2.9 – Urinary System

1. Kidneys, 2. Ureter, 3. Bladder, 4. Urethra

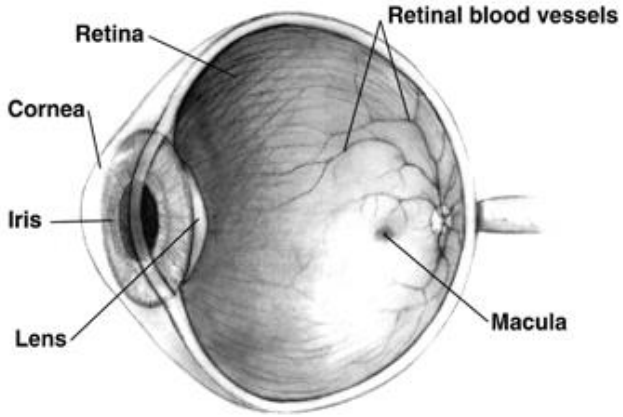
Toxins can damage the kidney which in turn affects calcium metabolism, acid-base balance and re-absorption of water. In acute renal failure, urine flow may cease altogether. Ionising radiation can cause renal cell damage and fibrosis. Because urine is concentrated and delayed within the bladder, exposure to this organ is far longer than to the rest of the urinary tract. It is thus far more susceptible to industrially induced cancers.

2.10 The Eye

Eyes are protected to an extent by the frontal bones above them and the eyelids, together with the blink reflex. Eyelashes keep dust particles away and tears provide a dilution factor for intruding chemicals and sterilisation against infecting agents.

Due to their fragile construction eyes are particularly susceptible to injury. Penetrating wounds can lead to corneal damage, cataract and retinal detachment, any of which can cause blindness. Damage to the iris can provoke a sympathetic reaction in the other eye and total blindness. Acids and alkalis will burn the cornea. Alkalis are especially dangerous as they sting less, and by the time the victim realises and washes them away, the front of the eye can have been dissolved.

Any irritant gases, like sulphur dioxide and ammonia can cause conjunctivitis (characterised by redness, discomfort and watering of the eyes). Allergens like plants and dyes sometimes produce a similar reaction. An extremely painful conjunctivitis including photophobia (unwillingness to look at light) follows a few hours after exposure to ultra-violet radiation used in welding. The condition is known as arc eye and usually involves the cornea as well as conjunctiva (keratoconjunctivitis). Cataracts (lens opacities) result from trauma (a penetrating wound or severe blow), heat (glass workers' eye) and irradiation (lasers and microwaves). Retinal burns can be caused by infra-red radiation and lasers. Cataracts can be removed and replaced by artificial lenses or contact lenses. Retinal burns and tears produce irrevocable damage to that area of vision (blind spots).



Source: Wikimedia commons

Figure 2.10 - The Eye

3 FUNDAMENTALS OF TOXICOLOGY

3.1 Introduction

Toxicology is the study of the adverse effects of substances on living organisms. Industrial toxicology is concerned with the adverse effects on workers of substances handled in the workplace, although interest usually extends to adverse effects of products on consumers and of workplace effluents on the general public.

Historically toxicology was the art and science of poisoning. It is today a discipline which makes use of information developed by a wide range of chemical, physical, biological and medical sciences in order to predict the likely adverse effects on man of an ever-increasing range of substances to which he is exposed.

3.2 Terms

Toxicity is the innate ability of substances to injure living things.

Hazard assessment is the prediction of the toxic effects that will be evident under defined conditions of exposure.

Risk assessment is the prediction of the probability that defined toxic effects will occur under defined conditions of exposure in a single person or a defined population.

Substance covers a wide range of materials including single chemical compounds or mixtures of these, simple or complex naturally occurring or synthetically produced substances and micro-organisms. Substances may be chemically pure or contain additives or impurities and may be in the form of solids, liquids, gases, dusts, fibres, fumes or aerosols. Some (e.g. fumes, dusts and aerosols) may be difficult to identify. Substances to which workers might be exposed include materials used, packed, collected, stored, handled, disposed of or otherwise encountered. They may be final products, formulations, intermediates, components, 'off spec' products, by-products, wastes and residues.

They may be materials used or which arise during maintenance or repair of plants or buildings or they may be formed or used during research, development or testing.

NB. The above terms are used loosely by many people. For example, the term toxicity is often used instead of toxic hazard, and toxic risk instead of toxic hazard. This is particularly so in relation to what people define as 'risk assessment'.

3.3 Basic Concepts

"All substances are poisons, there is none which is not a poison. The right dose differentiates a poison and a remedy" – Paracelsus (1525).

Every substance is toxic, i.e. capable of producing adverse effects under some condition(s) of exposure. It is possible to kill people by administering large volumes of water (particularly if the person suffers from certain diseases) and high oxygen levels in air can cause blindness in premature infants and lung damage in adults.

Occurrence of toxic effects depends on dose. In general high doses / exposures given over long periods produce a wider range and more intense toxic effects than low doses / exposures given over short periods.

There is generally a level of exposure below which toxic effects will not occur. A 10 g dose of caffeine causes convulsions and vomiting. The average intake of caffeine in UK (including in tea) is 315 mg and many people consume much more than this every day of their lives without occurrence of untoward effects. The fatal dose of salt is probably about 250 g but much lower doses cause vomiting; the average daily intake of salt in the UK is between 8 and 11 g/day. The UK Food Standards Agency recommends a maximum intake of 6 g/day but a minimum intake of 0.5 g/day is essential to life.

Different forms of exposure to a substance do not necessarily have the same effects. Exposure to high atmospheric concentrations of methylene chloride vapour depresses the nervous system (narcosis), causes heart arrhythmias and liver and kidney damage. More prolonged exposure allows a build up of

one of its metabolites, carbon monoxide - in the blood, reducing the oxygen carrying ability of the blood. Prolonged exposure produces cancers of the liver and lung in mice (but not in rats or hamsters and probably not in man).

Different species may react differently to substances. Dioxins cause severe liver damage and death in guinea pigs but skin disease (chloracne) in monkeys and man. Arsenic produces cancers in man but not in experimental animals. Small doses of atropine kill humans but not rabbits.

Different individuals may react differently to substances: Some people who smoke develop lung cancers; others do not. Penicillin is harmless to most people but produces severe allergic reactions in others.

The toxic effects of a substance depend upon:

- Its physical form.
- The dose.
- The route of entry.
- Its absorption, distribution, metabolism and excretion.

3.3.1 Physical Form

Solids	When ground or crushed, dusts result and can be inhaled, ingested or contaminate the skin.
Liquids	Can be swallowed or contaminate the skin
Gases	Can be inhaled or contaminate the skin.
Vapours	
Fumes	
Mists	
Aerosols	

3.3.2 Dose

Dose is the product of the concentration of the substance the worker is exposed to and duration of exposure. In simple terms it may be described as:

Dose = Exposure Concentration x Time

However in industrial circumstances both the exposure concentration and time of exposure can vary greatly. For example, a very high concentration for a short time may be lethal (e.g. alcohol) while prolonged exposure to smaller amounts does little harm. The dose may be the same in both cases.

3.3.3 Route of entry / absorption

The three main routes of entry of toxins into the body are via inhalation, the skin and ingestion. Injection is another potential route of entry in some circumstances, for example from needlestick injuries, spray paint or grease injection into the skin, tattooing and inoculation.

1 Ingestion: Ingestion is the least significant route of entry in industry while in environmental toxicology it is the most. During evolution, mechanisms have developed in the gut to regulate the uptake of essential elements. Toxic elements may have to compete so that generally only a fraction of any ingested dose is absorbed into the body (often 10% or less).

Possible causes of ingestion in industry are mouth pipetting in laboratories, swallowing dust which has been inhaled and cleared by the mucociliary escalator, smoking and eating at the workstation or simply having dirty hands where the hand later comes in contact with the mouth.

2 Inhalation: In the lung there are no similar mechanisms for selective uptake. Particles less than 10 micron in diameter may reach the alveoli. If soluble, approximately 40% are then absorbed. Insoluble chemicals are relatively safer, for example lead sulphide, whereas lead carbonate is highly soluble and causes poisoning quickly. Larger inhaled particles are less of a risk as absorption higher up the respiratory tract is less efficient.

It is important to remember that not only is the lung responsible for the uptake of substances into the body it is also acted on as a target organ. Materials which are not absorbed into the body can remain in the lungs and cause physical and / or chemical damage to them.

Inhalation accounts for approximately 90% of industrial poisoning.

3 The Skin: In the skin there is again no selective uptake. Fat-soluble compounds are absorbed readily as are organic solvents. Percutaneous absorption through healthy intact skin can occur with nitrobenzene, phenol, mercury, and aniline. Absorption of phenol through just a few square inches of intact skin can be lethal. Impervious protective clothing like gloves will increase the rate of absorption if accidental contamination occurs on the inside. Damaged skin also facilitates absorption of toxins.

Distribution: Once substances have entered the body they can be distributed around the body through the blood supply bound to plasma proteins or to red cells. They may concentrate differentially in the organs. Other toxic materials may be in solution or bound to lipids. Only lipid-soluble substances can pass the blood-brain barrier.

3.3.4 Metabolism

Substances which are distributed through the body then tend to be metabolised. The main site of metabolism is the liver, although the kidneys, lungs and skin can metabolise some chemicals. Metabolism can convert a toxic substance to a non-toxic one and vice versa e.g. n-hexane is metabolised in the liver to another compound which causes damage to the nervous system. Most detoxification is, however, beneficial. A typical detoxification process involves oxygenation stages followed by conjugation with glucuronic acid. The rate of metabolism depends on the rate of absorption (water-soluble compounds are less well-absorbed than fat soluble) and the extent of protein-binding (this reduces the concentration at sites of metabolism). Enzyme systems are poorly developed in the very young who thus metabolise more slowly. The liver renders hydrophobic substances (i.e. not soluble in water) to hydrophilic (water-soluble) forms so that they can be excreted by the kidney or into bile.

3.3.5 Excretion

This takes place mainly through the kidneys via the urine, but also via bile (high molecular weight compounds), lungs (volatile hydrocarbons excreted unchanged), gastric juices (nicotine), breast milk (pesticides) and skin (iron). The more rapidly excretion takes place the less likely is a toxin to damage the body. Excretion products are often used to monitor work exposure.

3.3.6 Response to toxins

The body's response to toxins depends on several variables:

Age	The elderly and very young tend not to cope as well as people in the normal working age group as their metabolic pathways are less efficient.
Sex	Women are more vulnerable to fat-soluble toxins because of their greater percentage of fat to lean body mass.
Underlying Illness	Some conditions, for example diarrhoea or reduced lung function will limit toxic effects by reducing absorption. Others, for example anaemia, would compromise even further the body's response to lead or carbon monoxide.
Medication	Drugs can affect enzyme systems, increasing or decreasing the effects of toxic substances.
Alcohol	May compromise liver function and thus detoxification processes.
Smoking	Smoking potentiates the action of some substances like asbestos.
Individual	People vary enormously in their responses to external agents, from noise to coal dust, and allergens to chemicals. This is probably a genetic effect.

Type of response

- Local effects at the point of entry e.g. irritation, burns.
- Allergic reactions e.g. dermatitis, asthma.
- Effects on target organs.
- Cancer.
- Reproductive effects e.g. sterility, abortions.
- Teratogenesis - congenital birth defects.
- Childhood tumours in offspring of those exposed.

3.4 Stages of Toxicological Evaluation

In assessing the risks to health arising from exposure to substances, answers are sought to the following questions:

3.4.1 What adverse effects can a chemical cause?

What is its toxicity and what are the toxic hazards under a variety of exposure conditions? This is determined by:

- Theoretical studies based on the already known physical and chemical properties of a substance.

- Experimentation on animals (used as models for man) and other living organisms or parts of organisms (bacteria, organs, tissues, cells in culture).

3.4.2 Are the effects seen in animals relevant to man?

To answer this will require knowledge of how the chemical is absorbed, distributed in the body and excreted (pharmacokinetics) and how it is broken down in the body into other substances (metabolism). An indication of the mechanism of toxic action is needed – this may require special investigations including studies in man. Epidemiological studies on exposed groups may be needed to prove relevance.

3.5 Safety Data Sheets

The interpretation of toxicological reports should be left to those who are trained and experienced in such activities. Much of the work involved in assessing workplace hazards can be carried out by accessing Safety Data Sheets (SDS), previously referred to as Material Safety Data Sheets (MSDS). The SDS is a standard way of communicating toxicology and other relevant information about substances.

In many countries it is a legal requirement or common practice that a company supplies an SDS for each of the products that they sell. These can seem complicated and difficult to understand, but they are a reliable source of the data you need to handle chemicals safely. They typically provide data on the physical and chemical properties of the material concerned as well as relevant toxicological information.

The content of the SDS will vary depending upon local legislative requirements but it is likely to contain the following information:

1. **Composition / Data on components:** This gives details of the different chemicals contained within the material. It will often list the Chemical Abstracts Service (CAS) number for each chemical is contains. The CAS number is a unique number which is assigned to most of the chemicals used in industry.

2. **Identification of substance:** This includes the trade name, as well as manufacturer / supplier details. It may also give emergency information such as contact names and telephone numbers.
3. **Hazard identification:** The material will be classified under a number of categories and described with pictograms.
4. **First aid measures:** Advice about how to deal with workers who have been exposed under different circumstances.
5. **Fire fighting measures:** Do's and don'ts of fire extinguishing e.g. what type of fire extinguisher to use.
6. **Accidental release measures:** The procedures to be followed in case of accidental release of the chemical, including methods to be used to clean up spills.
7. **Handling and storage:** Giving information on the precautions such as flammables cabinets and temperature limitations.
8. **Exposure controls and personal protection:** Outlines requirements such as Personal Protective Equipment and ventilation.
9. **Physical and chemical properties:** e.g. the form (solid / liquid / gas), colour, odour, melting and boiling points.
10. **Stability and reactivity:** Properties such as thermal decomposition and conditions to be avoided.
11. **Toxicological information:** Details such as acute and chronic effects on man and animals.
12. **Ecological information:** How the material might affect the environment if it is released beyond the workplace.
13. **Disposal considerations:** Any special requirements associated with disposal of the material.
14. **Transport information:** generally as a list of codes indicating the dangers associated with the chemical.
15. **Regulations:** Relevant legislation for the country in which the material is used.
16. **Other information:** Any information which is relevant.

4 EXAMPLES OF HAZARDOUS SUBSTANCES / PROCESSES

4.1 Crystalline Silica

Crystalline silica or quartz (SiO_2) is the most widely occurring of all minerals and it is found in most rocks. The most commonly occurring form of silica is the sand found on beaches throughout the world. In the dry form, fine crystalline silica constitutes a toxic hazard since its inhalation as airborne dust could give rise to silicosis. Silicosis is a pulmonary fibrosis which is regarded as the most common and severe of all pneumoconioses. The risk of developing the disease depends on three factors, namely; dust concentration in the atmosphere; the percentage of free silica in the dust, and the duration of exposure. Silica is encountered during many processes which use minerals e.g. quarrying and mining, brick, tile and refractory manufacture, pottery and ceramic, sandblasting, glass manufacture.

At the beginning of this century, fatal cases of silicosis with a rapid evolution period (1-3 years) were not uncommon among workers who inhaled enormous amounts of dusts containing a high quartz content. In many instances, death was due to the superimposition of tuberculosis. In developed countries the introduction of improved working conditions and modern methods of dust control, this rapidly evolving form of silicosis has virtually disappeared but has been replaced instead by the very slowly developing (15-30 year) form of the disease.

The initial stages of silicosis are asymptomatic and are only revealed by periodic radiological examination of workers exposed to free silica. The first symptoms of silicosis are "loss of breath" on exertion. In the serious cases, the symptoms occur even on very slight exertion or when the patient is at rest. As a rule there are no other subjective symptoms. Thus, the diagnosis of silicosis is largely by clinical examination and radiology.

The ability to bring about lung changes is somewhat dependent upon the crystalline form that the silica can be in, and this is reflected in some exposure standards. The current UK Workplace Exposure Limits, together with the particle size likely to be found, is an example.

Silica, Amorphous

Total Inhalable Dust 6 $mg.m^{-3}$ 8 hour Time Weighted Average

Respirable Dust 2.4 $mg.m^{-3}$ 8 hour Time Weighted Average

Silica, Fused

Respirable Dust 0.08 $mg.m^{-3}$ 8 hour Time Weighted Average

Crystalline Silica (Cristobalite, Tridymite)

Respirable Dust 0.1 $mg.m^{-3}$ 8 hour Time Weighted Average

4.2 Machine Made Mineral Fibre (MMMF)

Machine Made Mineral Fibres (MMMF) includes ceramic fibers, special purpose fibers and continuous filament fibers. The material is normally made from molten glass, rock or slag. The material exhibits good resistance to heat and chemicals and can be woven. It is therefore widely used in thermal and acoustic insulation of buildings and process plant and as structural fire protection in the form of rolls, slabs, blown cavity wall filling, plasterboard laminates and pipe insulation. Use of MMMF has accelerated as asbestos materials have been phased out.

Since their introduction in the late 1800's it has been recognised that mineral wools cause irritations of the skin and eyes, and during excessively dusty conditions they lead to irritation of the upper respiratory tract. The irritation of skin and eyes is caused by coarse fibres.

While most skin becomes resistant after a transitory period, some people need to take precautions to protect their skin and a small number need to move to other work.

Studies in which non-asbestos mineral fibres were implanted into the chests of laboratory animals have shown that mesothelioma tumours result, but other experiments in which animals inhaled high concentrations of mineral wool fibres have not indicated an association with excess occurrence of lung tumours.

Inhalation studies on animals have not led to clinically significant fibrosis. A large American industry mortality study showed no cases of mesothelioma. In this study an excess of lung cancer was observed in small groups of workers with more than 30 years since first exposure to mineral wool, but there was no correlation between either the intensity or length of exposure and the excess of lung cancer. In fact, X-ray and lung function studies on current workers have not shown exposure to mineral wool to be associated with lung abnormality.

4.3 Welding Fume

Welding fume consists of mixtures of airborne gases and fine particles which if inhaled or swallowed may result in risks to health. The degree of risk will depend on: the composition of the fume, the quantity of fume in the air which is breathed, the duration of exposure.

The main health effects are:

Irritation of the Respiratory Tract: Gases or fine particles of fume can cause dryness of the throat, tickling, coughing, tightness of the chest and difficulty in breathing.

Metal Fume Fever: The inhalation of many freshly formed metallic oxides, such as those of zinc, cadmium, copper etc may lead to acute flu-like illness termed metal fume fever. With the exception of exposure to cadmium fume serious complications are rare. Welding galvanised steel is the most common cause of metal fume fever.

Pneumonia: Welders are prone to a lung infection that can lead to severe and sometimes fatal pneumonia.

Systemic Poisoning: This can result from the inhalation or swallowing of substances contained in welding fume such as fluorides, manganese, lead, barium and cadmium. The presence of these substances in the fume depends upon the welding process being used and the material being welded.

Long Term or Chronic Effects: The inhalation of welding fumes can lead to the development of benign X-ray changes, referred to as Siderosis. Welding fume is internationally classified as possibly carcinogenic to humans (IARC

classification group 2B). Although primarily associated with stainless steel welding, this classification is not limited to stainless steel fume. It covers all welding fume.

4.4 Isocyanates

Isocyanates can be liquids or solids at room temperature and are mainly used in the production of polyurethanes, foams, adhesives, varnishes and paints.

They are irritating to the skin and mucous membranes. However, the most serious problems associated with exposure to isocyanates are those affecting the respiratory system. Isocyanates are widely recognised as one of the most common causes of occupational asthma. After varying exposure to isocyanates workers may respond to extremely low concentrations and this is known as respiratory sensitisation.

4.5 Wood Dust

Wood dust is produced whenever the machining or cutting of wood takes place. The hazards associated with wood dusts are mainly from inhalation and skin contact. The biological effects of wood dust gives rise to many different symptoms, the nature of which depends on the quantity, and composition of the wood.

Consequently, the symptoms of exposure range from dermatitis and conjunctival irritation to irritation of the upper respiratory tract. There is some concern over the progression of the nasal irritation into nasal cancer. However, this issue is complicated by the long onset period for the cancer being typically 40 years. IARC has classified wood dust as a Group 1 Carcinogen. In addition, some soft woods can act as respiratory sensitizers.

4.6 Pharmaceuticals

Working in the pharmaceutical industry can present specific hazards from particularly potent compounds. The different drugs which are manufactured can give rise to different health effects.

For example:

Allergic reactions: Some drugs can give rise to allergic reactions such as itching and redness of the eyes, runny nose, skin rashes, asthma, and occasionally shock due to an allergic reaction (anaphylaxis).

Vitamin deficiency: Workers with repeated exposure to antibiotics experience a change in the number and type of bacteria which are normally present in the intestines which break down and absorb vitamins in the intestines.

Fungal infections: Daily exposure to antibiotic dust can lead to fungal infections of the skin and nails. Additionally, women workers may develop vaginal yeast infections following exposure to antibiotics.

Nitroglycerin: commonly used in dynamite, is also the basis of several medicines for heart patients. Nitrates act on the blood vessels of the body and their effects are felt in several ways. Almost everyone exposed to nitro dust experience a severe pounding headache which is caused by the relaxation of the blood vessels within the skull. Nitrates dilate the blood vessels and make blood pressure fall. As a result, dizziness and even fainting may occur.

Tranquilizers: can be habituating and additive. In combination with alcohol, they may cause a person to lose consciousness and in high doses, can lead to coma and death. Workers producing tranquilizers are at risk of these adverse effects and have found that they pass out over a beer after work. There is a real danger of accidents, both in the plant and on the way home, when workers become drowsy as a result of exposure to tranquilizers and barbiturates.

4.7 Petroleum Products

The petroleum industry presents a number of unique hazards both in terms of extraction production and in the finished products.

Lubricating Oils: Certain oils (particularly the highly aromatic oils) are irritant when applied to the skin for a period of a few hours. Many will, on repeated contact, remove natural fats from the skin, leaving it dry and susceptible to cracking, dermatitis and subsequent infection. Accidental contact with eyes

may cause transient irritation but no lasting effects. Effects are more pronounced with low viscosity oils.

Inhalation of oil mists and vapours may cause irritation of the eyes, nose and throat. Should sufficient oil be inhaled it will lead to a form of pneumonia.

Most formulations contain chemical additives of variable composition. The toxic properties of such formulations depend on the toxicity of the base oil(s) and additives. For many additives there are inadequate data on acute and chronic toxicity, carcinogenicity and the effects on reproduction or the immune system.

Gasoline: is a skin irritant and prolonged exposure may produce blistering. Repeated exposure de-fats the skin, leading to dermatitis. Accidental contact with the eyes causes severe irritation but this is generally short-lived. Inhalation of vapour may cause unconsciousness; prolonged inhalation of high concentrations may prove fatal due to central nervous system depression. Gasolines contain additives (which can include tetraethyl lead which is neurotoxic, and brominated compounds which are mutagenic); these are being replaced by alcohols (e.g. methanol) and ethers (e.g. methyl t-butyl ether - MTBE) in lead-free gasoline. Excessive exposure to methanol produces blindness; recent evidence on MTBE suggests that high concentrations in the atmosphere may be teratogenic.

Gas oils, fuel oils: These are similar in character to middle distillates or to heavy lubricating oils but they may contain catalytically cracked or other materials which tend to be carcinogenic when applied regularly to mouse skin, i.e. they may carry a carcinogenic risk.

Aromatic extracts: These contain high concentrations of carcinogenic polycyclic aromatic hydrocarbons and many have been shown to be carcinogenic through skin contact. Their toxicity is otherwise similar to that of lubricating oils.

Benzene: Direct contact produces de-fatting of the skin and dermatitis on repeated exposure. Exposure leads to central nervous system depression - headache, nausea and then unconsciousness. Repeated exposure to 50 ppm or above damages blood and blood forming tissues,

producing in some individuals, a complete failure to form new blood cells of all types (a fatal condition). Prolonged exposure to high concentrations cause a type of leukaemia (cancer of the blood) and damage to chromosomes (the bodies which carry genetic material in dividing cells).

4.8 Mining – Mineral and Metal Extraction

Mining of coal, metal ores and other minerals is undertaken extensively around the world. Historically mine workers have suffered higher incidences of ill health than workers in other heavy industry sectors. Coal mining has long been associated with the dust induced lung disease 'Pneumoconiosis' and other illnesses such as work related 'Emphysema'. Mining activities can present particular hazards to health from various substances. These may be from the mineral being extracted or may be present as undesirable by-products / contaminants. The main health hazard is exposure to dust in various forms.

Asbestos is still mined in a number of countries around the world, it is also found in trace quantities in deposits of other minerals such as talc. The hazards of asbestos are presented in a separate section of this manual.

Arsenic is present in metal deposits such as tin and copper. It may be encountered as an undesirable component during mining and processing but is also produced commercially as a by-product of the refining. Arsenic is toxic and can kill if large doses are either consumed or inhaled.

Silica is present in many minerals and particularly in stone extraction.

Mining can also present a range of physical hazards such as noise, vibration, radiation, heat stress, damp / humidity and changes in atmospheric pressure.

4.9 Metal Use and Refining

Many hard metals are present in small amounts within our bodies as essential elements and form an important part of our function. However if exposure to large quantities occurs then significant ill health effects can result.

Cadmium use has been restricted due to its toxicity, however it is still used within the aviation industry as an anticorrosive coating, and in NiCad batteries. The physiological effects of excessive cadmium exposure can be separated

into two distinct categories as follows; the acute effects which include nausea, vomiting and severe gastro-intestinal disturbances and the chronic effects which range from fatigue and emphysema to liver and kidney damage. In severe cases of acute poisoning, for example after flame-cutting of cadmium plated bolts, death can quickly follow from a chemical pneumonia.

Chromium is a steel-grey, hard metal element, which will take on a high lustre. Its high melting point, 1900^{o}C, together with its inert nature makes the metal useful as an alloying material and for electro-plating. It has a number of radioactive isotopes, which have found use in medicine.

It is capable of having a number of valent states and the range of salts reflects this i.e. chromous, chromic and chromyl. Some have irritant properties similar to chromium trioxide (chromic acid) causing dermal irritation, ulceration and allergic dermatitis. Inhalation will also cause primary irritation, nasal septum perforation, pulmonary irritation whilst carcinoma has also been associated with exposure to chromate salts.

Lead is a soft malleable metal with good anticorrosive properties. It has been used extensively in the construction industry as well as in the production of batteries, bullets and weights. It has also been mixed with other metals to form useful alloys such as tin lead solder. Its various compounds are toxic and can be inhaled, ingested or absorbed through the skin. Acute effects are rare, as lead is mainly a cumulative chronic poison, but some organo lead compounds [such as that used in leaded gasoline] can be quickly absorbed through the skin and affect the brain causing death in some cases. Chronic effects are observed with the slow accumulation of inorganic lead in the body, often being deposited in the bones and being latter released if a trauma occurs. Chronic effects range from stomach pains to lethargy and anaemia, ultimately causing death. It can give rise to brain damage especially to the young and unborn.

4.10 Diesel Exhaust

Diesel exhaust comes from the combustion of fuel in diesel engines. Diesel engines were invented in the 1890s by Rudolf Diesel. Although there are many advantages to using diesel fuel a negative result has been exposing a large

number of workers, to a complex mixture of toxic gases, adsorbed organics and particulate components.

The gaseous phase of diesel exhaust consists largely of the same gases found in air, such as nitrogen, oxygen, carbon dioxide and water vapour however small concentrations of toxic gases such as carbon monoxide and oxides of nitrogen are also present.

The particulate fraction of the diesel exhaust aerosol consists of a solid carbon phase and ultra-fine droplets of a complex mix of semi-volatile organic compounds. The solid particulate fraction consists mainly of very small particles (typically 15-30 nm diameter) that rapidly agglomerate together to form “chains” or clumps of particles, which are themselves typically <1 µm aerodynamic size. High resolution electron microscopy has demonstrated that the basic diesel particle consists of an irregular stacked graphitic structure, nominally called elemental carbon.

The graphitic nature and high surface area of these very fine carbon particles means they have the ability to absorb significant quantities of hydrocarbons (the semi-volatile organic carbon droplets and vapours) originating from the unburnt fuel, lubricating oils and the compounds formed in the complex chemical reaction during the combustion cycle.

In terms of health outcome, the very small particle size of DPM is important as this means it can reach the deep parts of the lungs.

- There are both malignant and non malignant health effects, adverse odour; reduced visibility when it is ‘hanging’ in the air as well as being nuisance pollution. The malignant effects are generally lung cancer and to a lesser extent bladder cancer. The non malignant effects include

- Irritation of eyes and respiratory tract
- Coughing
- Light-headedness
- Breathlessness
- Heart and lung disease

- Asthma

4.11 Nanoparticles

Nanotechnology involves the precision-engineering of materials at the nanoscale 10^{-9}-10^{-7} metres), at which point unique and enhanced properties can be utilised. These properties have led to the development of new products, procedures and processes as well as various health concerns (AIOH 2013). Nanomaterials are generally more toxic than the corresponding larger sized substance (Toxikos 2009). OSHA provides a detailed list of health effects, and assessment and control references on nanotechnology (OSHA 2015).

5 ASSESSMENT OF HEALTH RISKS

5.1 Introduction

The primary reason for conducting a workplace occupational hygiene assessment is to assess the risk(s) to the health of employees. Where a less than satisfactory situation is indicated, or if further improvements are available, there will be additional requirements:

- To specify steps to achieve adequate control.
- To identify any other actions that are required.

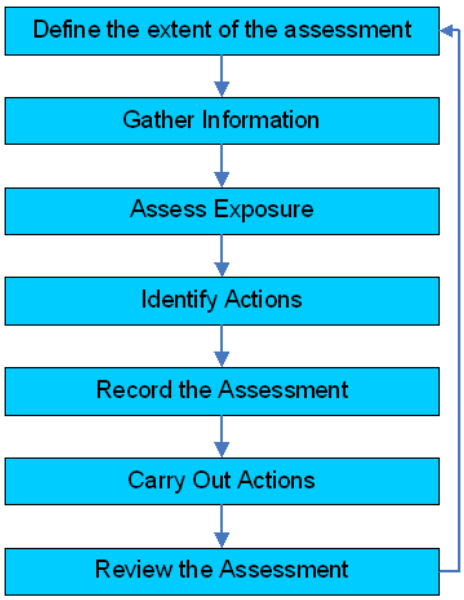
5.2 Hazard and Risk

When undertaking occupational hygiene risk assessments, it is important to have a clear understanding of the differences between hazard and risk.

- A hazard has the potential to cause harm if not controlled.
- The outcome or consequence is the harm that may result from exposure to the uncontrolled hazard.
- The risk is a combination of the probability or likelihood that the particular outcome or consequence will occur when exposed to the hazard.

5.3 Assessment of Health Risks

The process of assessing risks to health can be broadly described by the flow diagram below.



Communication and consultation is important in many of these steps.

5.3.1 Define the extent of the assessment

At first it is necessary to define the process or activity which is being assessed. This may involve one or more activities as well as one or more workers at a time. It may also be necessary to assess different hazards as part of different assessments, e.g. noise assessments are usually conducted separately from chemical risk assessments as they involve very different approaches. However, when assessing hazards from substances such as solvents it is often possible to group any chemicals under one assessment, as they possess similar properties and require similar controls.

5.3.2 Gather information

An assessment of the health risks in the workplace necessitates an appreciation of a number of factors in the decision making process, including some or all of the following - and therefore as a first step information regarding these factors has to be gathered.

- The nature of the process or operation, e.g. continuous or batch, indoor or outdoor.

- The substances used and produced (chemical, biological) as well as physical agents (noise, radiation) and other factors (eg. ergonomic) present. Some substances may be identified by trade names and their chemical composition will need to be understood.
- It is important to remember that most industrial exposures to chemicals (inhalation, skin contact) are to mixtures, not to single substances. In these cases, information about the mixture composition will need to be known.
- The form of the substances (gases, vapours etc.) and other agents plus a knowledge of where these are present in the workplace location task.
- An understanding of the effect(s) of the relevant agents factors (chemical, physical, biological, ergonomic) on the body.
- A knowledge of the types of work carried out (e.g. operator, maintenance, supervisory, laboratory) and the elements tasks of that work for which unacceptable exposures to chemical, physical or biological agents or an adverse ergonomic situation, may occur.

- Exposure estimates in relation to any relevant occupational exposure limits or guidelines that are relevant and applicable.
- The types and extent of occupational exposures.
- Work / shift pattern.
- The recommended operating practices and precautionary measures (including engineering control).
- Worker health experiences, e.g. check whether there are have been any cases of occupational ill-health, incidents, complaints or compensation claims.
- Any other relevant information. There is a need, for example, to put observations, data etc., in perspective and to ascertain how typical they are as compared to 'normal' practices and procedures.

The existence of inventories registers of substances, non-chemical agents (e.g. noise and radiation sources) and the types of job undertaken can be extremely useful in progressing an assessment.

The availability of relevant sources of information should also be explored and utilised, e.g.

- Safety data sheets (SDSs).
- Manufacturers' labelling.
- Literature sources on exposure limits such as the ACGIH TLV documentation.
- Other published (e.g. national, company, trade association, technical) and unpublished sources.

5.3.3 Assess the health risk(s)

The assessment should now be conducted. This involves keen inquiry and observation, for example, in relation to the operating practices and precautionary measures actually adopted in a specific task - (e.g. personal exposure monitoring).

Remember to ask about the existence and application of a work permit system and to check the scope and effectiveness of its application from a health protection viewpoint.

An assessment should be 'suitable and sufficient'. It should be conducted by a 'competent person' and the type of individual that constitutes such a person will vary from one workplace to another. In some cases the assistance of a fully qualified occupational hygienist will be necessary because of the more complex nature of the risk(s) being investigated.

A critical point is that the term 'assessment' is not synonymous with the 'measurement' or 'monitoring' of occupational exposures, but embraces wider considerations, such as the conditions on the day that the monitoring occurred which assist in interpreting the monitoring results.

The findings from measurements of occupational exposures to chemical, physical or biological agents in the workplace may form an important element of the overall assessment. In other cases such monitoring is unnecessary or inappropriate and a qualitative assessment will suffice.

Workplace Monitoring

It may be necessary to obtain exposure levels from occupational hygiene monitoring, as part of the overall assessment of health risks. Where workplace monitoring is required, the aim is to assist in ensuring the health protection of employees and the sampling strategy adopted should be appropriate to the basic reason for the type of survey to be conducted. The type of survey ranges from initial monitoring of a plant or operation, in order to establish a 'baseline' situation, to the periodic monitoring of a plant or operation in order to check, at regular intervals, that acceptable conditions are being maintained. A survey may also be required to evaluate whether the exposures comply with relevant occupational exposure standards.

5.3.4 Specify any action required

Where the assessment indicates a risk to health, it is necessary to specify the recommendations or steps to be taken to achieve effective control. This is an important, integral part of the assessment, which is NOT deemed to have been completed without this being addressed.

5.3.5 Record the risk assessment

Assessments are important in the preventative approach to health protection, however they are of limited value unless they are recorded in writing, and dated and signed by the assessor. The quality of an assessment is also likely to be enhanced when verification of verbal information pertaining to fundamental aspects of the assessment can be obtained, in one form or another, and documented This record may include an occupational hygiene report, an example of which is available on the BOHS and AIOH websites.

5.3.6 Carry out the actions

It is important to ensure that recommendations from any assessment are implemented effectively. Many assessments fail to control exposure because the actions are not implemented.

5.3.7 Review the risk assessment

Periodic re-assessments should be undertaken regularly and whenever it is suspected that the assessment is no longer valid. The following are the types of factor that should trigger a further assessment:

Significant changes to:

- The substances agents involved and / or their sources.
- The plant e.g. modified engineering control.
- The process or method of work.
- The volume or rate of production.

Adverse results from:

- Personal exposure monitoring.
- Health surveillance (e.g. audiometry, biological monitoring).
- Monitoring of process control (e.g. fugitive emissions).

Cases of occupational disease.

New information on the risk(s) to health of chemical, physical or biological agents.

In the absence of known changes / adverse results / cases / new information the period between reassessments should depend upon the nature of the

risk(s), the work and a judgement on the likelihood of changes occurring. In any event it is suggested that all assessments should be reviewed at least every two years.

5.3.8 Communication /consultation

At many steps through the risk assessment process it will be necessary to communicate and or consult with stakeholders such as workers who may be exposed, supervisors, engineers and other health and safety personnel.

5.4 Expert Systems and Control Banding

There are a number of expert systems which have been developed to assist employers in undertaking health risk assessments. These systems all use an approach called “Control Banding”. Control banding involves the following steps.

Hazard Classification – Hazard characteristics such as risk phrases, Occupational Exposure Limits (OEL) and hazard descriptions are used to classify the material(s) into groups or hazard bands.

Assessment of exposure potential – Simplified models are used to assess the level of exposure for the task, without conducting exposure monitoring.

Selection of control approach – These are automatically selected using pre-determined rules and guidelines. Depending upon the control banding approach adopted the rules and guidelines will have been generated and verified by qualified occupational hygienists. The control approach is described by selecting a document from a pre-written library of guidance sheets.

The ILO toolkit is an example of one of the control banding approaches. The toolkit is an internet based programmed and was originally developed from the UK’s COSHH Essentials.

6 MEASUREMENT OF AIRBORNE CONTAMINANTS

6.1 General Principles

Physical States - there are 3 physical states of matter:

1 Gas

2 Liquid

3 Solid

All materials can exist in all three states or in mixtures of states e.g. a cold drink may contain water as a liquid but may also contain ice (the solid form of water) and the air above the drink is a gas which contains some water (known as vapour). Depending upon the substance of interest and the type of activity being undertaken then the material in question will be present in a different form.

Vapour - the gaseous state of a substance which is liquid at 25°C and 760 mm Hg (STP).

Mist - liquid particles, large size generally produced by bubbling, splashing or boiling of a liquid.

Fume - Solid particles produced by condensation from a liquid or a reaction between two gases. The particle size of a fume is <1 micron (µm) diameter, anything larger is considered a dust particle.

Dust - particles of solid material in the broad size range of 1 to 100 micron (0.001 mm - 0.1 mm) in diameter that settles under the influence of gravity. Anything of a larger particle size is considered to be grit and will be too heavy to remain airborne.

Aerosol - general term for the dispersions of solid or liquid particles of microscopic size in a gaseous medium e.g. fog, smoke etc., although commonly used as a term for fine liquid spray (e.g. ‘aerosol can’).

Fibre - Solid particulate which are long and thin i.e. have a specific aspect ratio of length to breadth.

NB: Micron (µm) a unit of length corresponding to one millionth of a metre or one thousandth of a millimetre.

Not surprisingly different sampling techniques are needed for each of the above states of matter.

6.1.1 Sampling techniques

The fundamental requirement of any measurement technique is that it should be appropriate for the purpose of the measurement. This means it should provide information necessary for the decisions which will be made on the basis of that information.

‘Monitoring’ or ‘Sampling’ means the use of valid and suitable occupational hygiene techniques to derive a quantitative estimate of the exposure of employees to substances hazardous to health. Only validated monitoring methods should be used, these are published by organisations such as the HSE (Health and Safety Executive) in the UK and NIOSH (National Institute for Occupational Safety & Health) in the USA. Other countries also produce methods and in some cases these are specified as being compulsory within local legislation. In the case of airborne contaminants monitoring involves the periodic or continuous sampling of the atmosphere at the workplace and will usually require sampling in the breathing zone of the operative by means of personal sampling equipment.

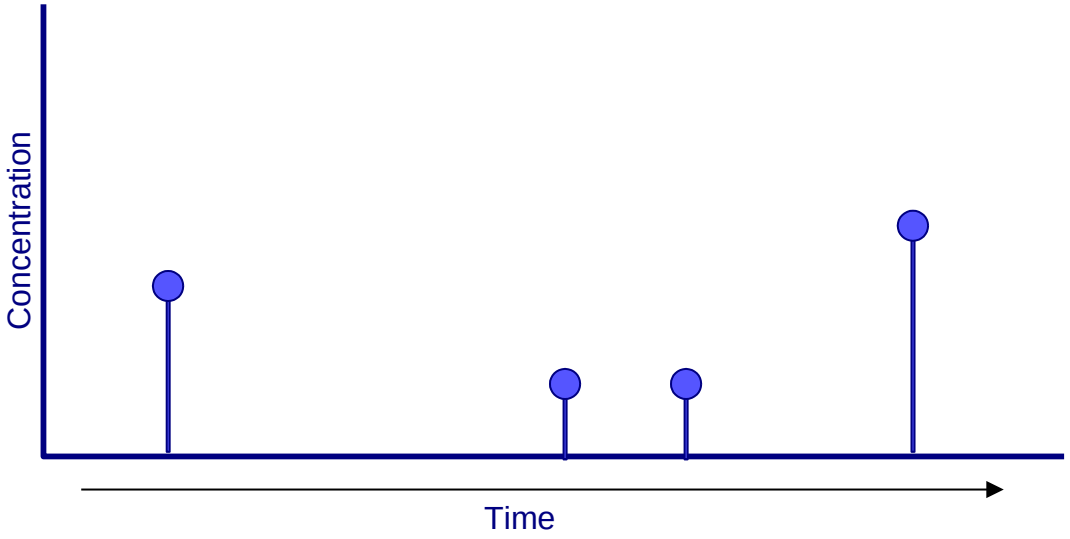
In addition to personal monitoring, fixed position static monitoring can also offer limited information as to an individual’s exposure. It can provide a guide to the sources of contaminants, effectiveness of control measures and the general workroom atmospheric concentrations.

6.1.2 Types of sampling

There are five main types of sampling:

1 Grab

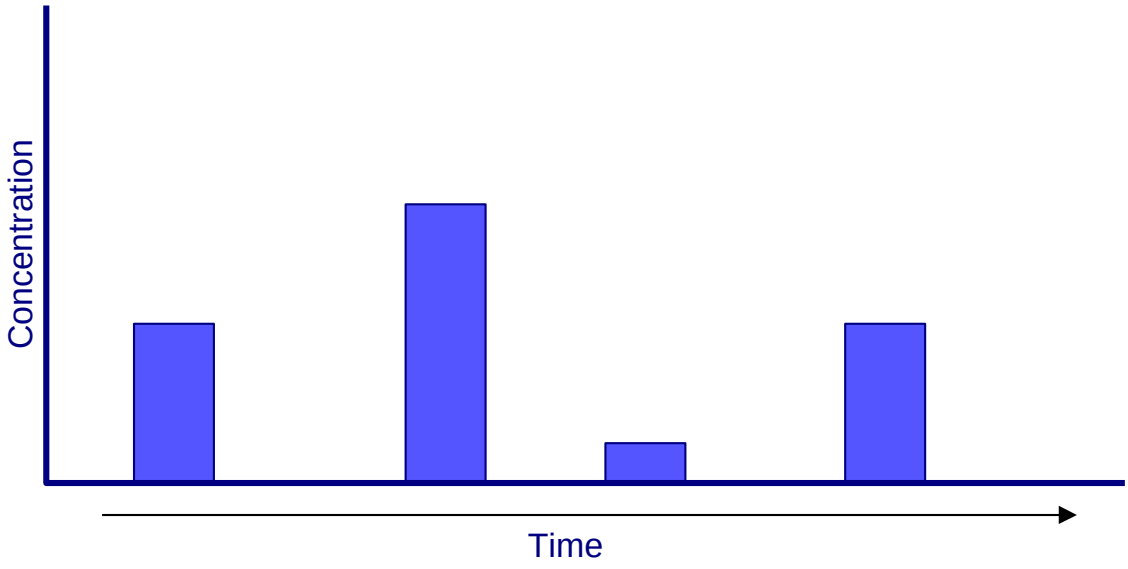
Grab or snap sampling can be used as a screening technique; it will give the concentration of a contaminant at a specific time and location and will help to confirm the presence of and or identify a suspected contaminant.



Source: Adrian Hirst

2 Short term

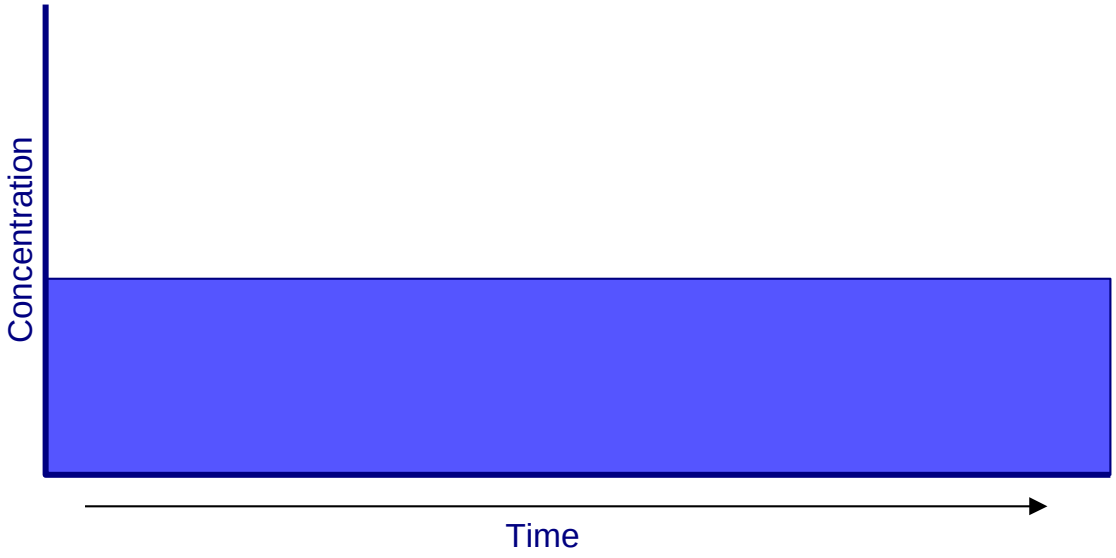
Short term monitoring will determine concentrations over a short time period, normally up to 10 or 15 minutes. Results are normally calculated as a time-weighted average (TWA) and can be compared with any relevant recommended short term exposure limits (especially WELs) and to quantify exposures to acute hazards e.g. chlorine, ammonia, butane.



Source: Adrian Hirst

3 Long term

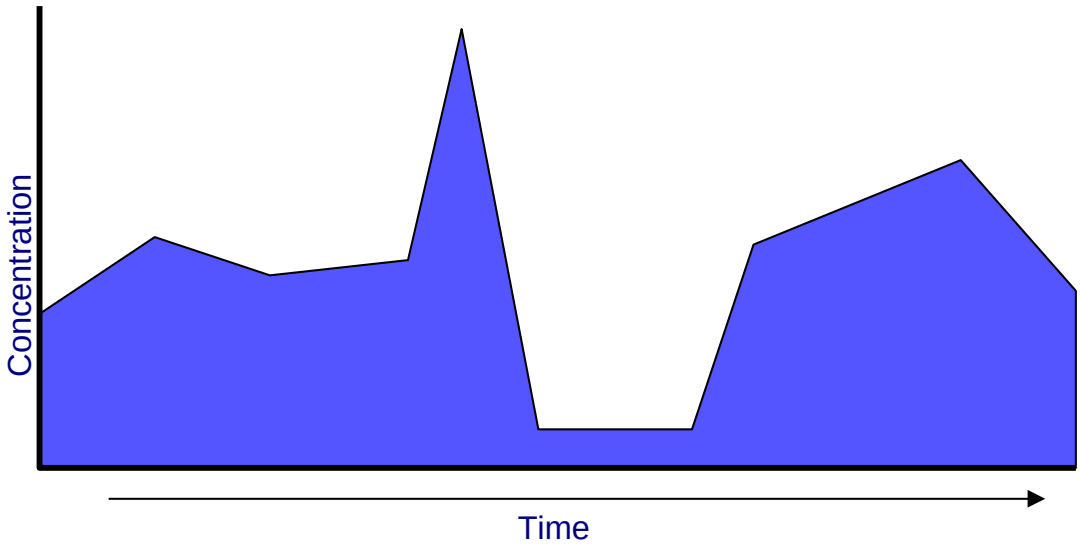
Long term monitoring is similarly determined on a time-weighted average basis and related to long term (8 hour TWA) recommended limits. Half shift (4 hours), or the time to complete a specific operation, a time representative of a full shift or full shift (nominally 8 hours) are normally the time periods monitored. Peaks and troughs may not be seen depending on the type of monitoring.



Source: Adrian Hirst

4 Continuous

Monitoring will indicate the variations in concentrations. Peak levels can be identified as well as the average concentrations exposures being determined. This can be used in the same way long term sampling is, however different devices allowing real-time monitoring are used.



Source: Adrian Hirst

5 Bulk

In some circumstances, bulk samples of the substances being handled may also be taken and analysed for identification purposes, but it is not possible to relate the results from bulk samples to the airborne samples collected. However, with some contaminants, such as asbestos, bulk sampling is an essential part of the identification process.

The sampling types described above and the exposure limits quoted in legislation or other directives are based on the assumption that inhalation is the main route of entry into the body. However, skin absorption and ingestion can also occur and the only sure way of measuring exposure to substances entering the body by these routes is to apply biological monitoring methods. Usually, such methods measure the amount of a substance or of one or more of its metabolites in one or other of the two accessible body fluids – blood or urine. Details of such sampling techniques will be covered in Section 8 of this course manual.

Measurements for particular substances at a particular time tell only part of the story, and it should be remembered that concentration can vary as process changes etc, occur. Proper sampling strategies must be adopted to decide which groups of workers, which plant locations and which shifts should be monitored.

One of the first questions you should ask about of any sampling technique is what will the results tell me. What are the norms against which they may be judged?

6.2 Sampling Equipment

The choice of sampling equipment devices depends on several factors including portability, ease of use, efficiency of the device, reliability, type of analysis or information required, suitability for specific purpose, and where personal monitoring is involved, user acceptability. The sampling equipment must not affect the workers performance in any way; it must be comfortable to wear and not inhibit dexterity or change his / her mode of operation. It also must

not be a hazard to the worker or area, e.g. some equipment will need to be intrinsically safe.

No single piece of equipment is available which is suitable for all types of sampling. The tendency is to produce special purpose monitors for specific contaminants or groups of contaminants.

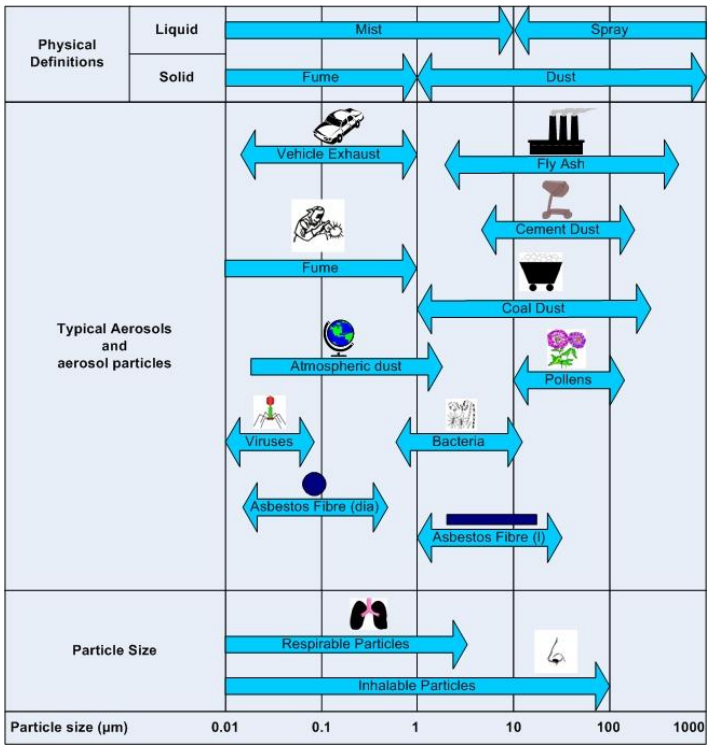
6.3 Sampling Records

Full details of the sampling performed should be recorded and retained. The record should indicate when and where the monitoring was done, who was monitored, details of the equipment used, the operations in progress at the time of the survey, controls available, their condition and if they were used and the results obtained. In most countries records of monitoring should be available to employees or their representatives.

6.4 Sampling for Airborne Particulates

6.4.1 Particle size

Most industrial aerosols contain particles of a wide range of sizes.



Source: Adrian Hirst

Figure 6.1 - Particle Sizes

The behaviour, deposition and fate of any particular particle after entry into the respiratory system and the body's response depends on the nature of the particle e.g. solubility and size. In general there are two size fractions of interest to occupational hygienists and these are termed *total inhalable* and *respirable.*

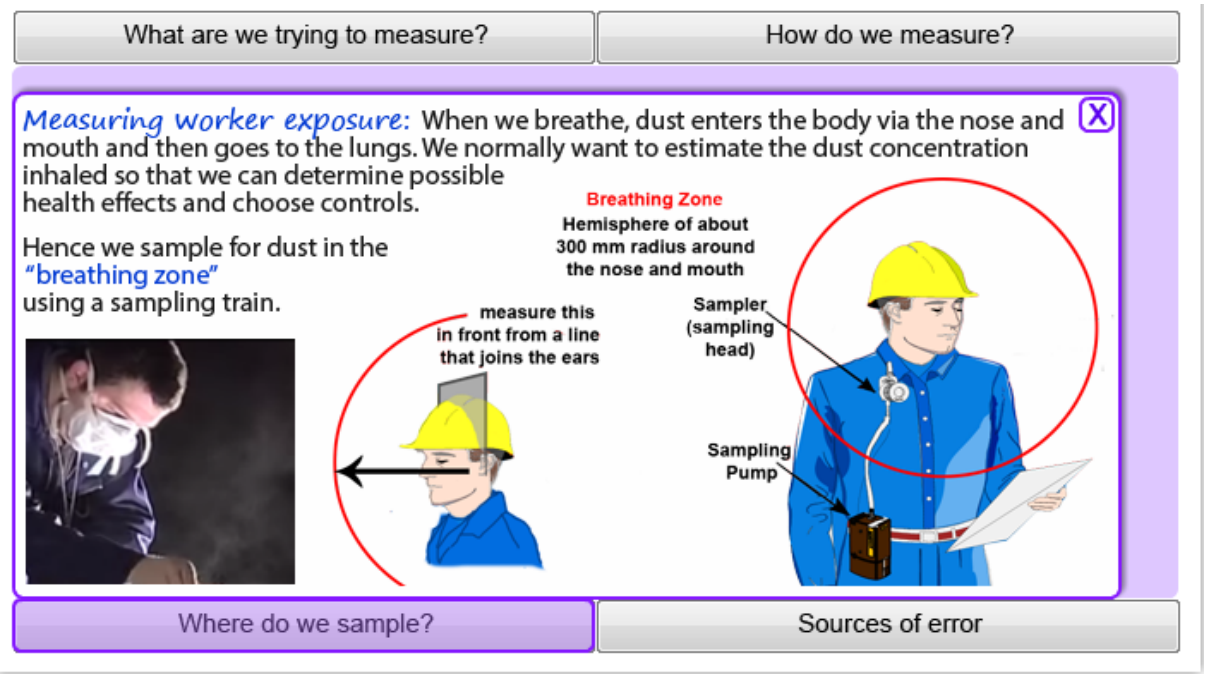
Total inhalable dust is the fraction of airborne material which enters the nose and mouth during breathing and is therefore liable to deposition anywhere in the respiratory tract. The particle sizes of total inhalable dust has a 50% cut-off at 100 microns (ISO 1995). This means that 50% of 100 µm particles are collected when sampling. As the particles get bigger, less percentage is collected. A maximum size is not defined.

Respirable dust is that fraction that penetrates to the deep lung where gas exchange takes place. The particle sizes of respirable dust has a 50% cut of approximately 4 µm up to a maximum of 16 µm (ISO 1995) (ISO 7708).

It is important to appreciate that particle behaviour is dependent on factors such as particle shape and density, wind speed and direction, breathing rate and whether breathing is by the nose or mouth. In practice the number (and mass) of particles of >50 microns in a typical airborne dust cloud is small.

6.4.2 Elements of a sampling system

When performing personal monitoring for airborne particulates there are three main sampling system components which go up to make the “Sampling train”. These are the Pump, Filter and Sampling Head. The pump is used to draw air into the sampling head and collect any particulates on to a filter.



Source: SKC Limited as amended by Michelle Wakelam

Figure 6.2 – Elements of a Sampling System

The pump is a battery powered device which is worn by the worker. The pump should be capable of operating at a constant flow rate (typically between 1 and 2.5 litres per minute) for prolonged periods of up to 12 hours. The calibration of the pump as well as the measurement of the sampling time allows us to calculate the volume of air which is being sampled.

The filters need to be capable of collecting all of the particulate material which is brought onto them and at the same time need to be compatible with any subsequent analysis technique. Typically these are glass fibre filters and membranes filters. The type of filter is specific to the contaminant and methods must be referred to prior to selecting the correct filter. The filters are weighed both before and after use so that a weight change can be determined. This change in weight can be used with the average flow rate and sampling time to arrive at a measured concentration using the equation below.

$$\text{Concentration (mg/m}^3\text{)} = \frac{\text{Weight gain (mg)} \times 1000}{\text{Flow rate (litre/min)} \times \text{Time (min)}}$$

Explanatory note – the figure of 1000 is needed in the numerator of this formula in order to convert the sample volume in the denominator from litres to m^3.

The above formula can also be expressed as:

$$\text{Concentration (mg/m}^3\text{)} = \frac{\text{Weight gain (}\mu\text{g)}}{\text{Flow rate (litre/min) x Time (min)}}$$

where the weight gain is expressed in the units micrograms (μg).

The sampling head allows the filter to be held in the correct position but can also act as a size separator. Total inhalable dust is typically measured using the IOM sampling head although other devices are also available. Respirable dust is measured using a cyclone pre-selector which removes the larger particles before they reach the filter.

Source SKC Limited

Figure 6.3 - IOM Inhalable Dust Sampling Head (left) and Cyclone Respirable Dust Sampling Head (right)

6.5 Sampling for Gases and Vapours

6.5.1 Sampling equipment

The majority of atmospheric sampling for gases and vapours is carried out using active methods i.e. by means of a mechanical sampling pump method. The

atmosphere to be monitored is drawn by the pump through a filtration adsorbent material over a fixed period of time at a known flow rate similar to a particulate sample.

For gases and vapours another main type of sampler has been developed, it is described as ‘passive’. Normally passive samplers work by diffusion of air across a permeable membrane on to a solid adsorbent for subsequent analysis.

The main types of equipment which can be utilised for the four main sampling techniques (excluding bulk sampling) are summarised in the tables below with a brief resume of their modes of operation and main advantages and disadvantages. However, the lists are not exhaustive as there are many different types of each available appropriate for the task in hand.

When sampling for a vapour, we must remember that the quantity of vapour given off from a liquid is essentially a function of the liquids boiling point. If a substance evaporates readily, it is usually termed ‘volatile’.

The lower the boiling point of a substance, the more vapour is produced. However, the molecular weight and structure of the substance are also involved. Other factors can also affect the production quantity of vapour, namely:

1. Surface area
2. Air movement agitation and splashing
3. Temperature.

Equipment used for taking grab samples

Equipment Type	Mode of Operation	Advantages	Disadvantages
Detector Tubes	Chemical reaction produces colour change	Instant result, easy to use	Not very accurate, often tubes are non-specific.
Gas sampling bags, syringes and containers	Pumps used to fill a bag or container to be sent for analysis	Simple, light, cheap	No concentration effect, losses can occur. Not instant.
Paper tapes impregnated filters	Air drawn through paper impregnated with chemical reagents producing a colour change	Direct reading, can be used for other sampling techniques	Stain can fade. Personal samplers bulky. Non-specific.
Electrochemical Detectors	Substance interacts with electrochemical detector cell	Direct reading, simple, lightweight. Also used for other sampling techniques	Expensive, calibration required, non-specific.
Gold Film Mercury Vapour Analyser	Mercury vapour increases resistance of gold film sensor	Simple, lightweight specific	Expensive, requires regular cleaning and calibration.

Equipment used for taking short and long term samples

Equipment Type	Mode of Operation	Advantages	Disadvantages
Pumped samplers with solid sorbent traps e.g. charcoal or tenax	Air is drawn through a tube on which the substances of interest are collected	Accurate, reliable, used in many validated methods	Needs complex analysis systems, result not instant. Expensive.
Diffusive Samplers	Contaminant diffuses through a membrane on to a sorbent bed of filter material	Small, robust, cheap, acceptable to operators	May require validation in field conditions. Needs complex analysis systems. Result not instant. Expensive.
Bubblers / Impingers	Air is bubbled through a solvent or reactive solution	Solution obtained can be analysed directly	Wearer carries a glass vial. Devices bulky, losses can occur.

Equipment used for continuous sampling

Equipment Type	Mode of Operation	Advantages	Disadvantages
Flame Ionisation e.g. organic vapour analyser (OVA) or total vapour analyser (TVA)	Combustion of organics in an air / hydrogen flame produces ions – sensed by electrodes and converted into a voltage signal	Portable Usually intrinsically safe	Limited on range and specificity of contaminants
Infrared e.g. Miran Analyser	Absorption of IR radiation used to measure the concentration of substance	Semi-portable, Limited in the compounds it can detect	Bulky, non-intrinsically safe
Ultraviolet	Absorbance of ultraviolet	Portable	Interferences, calibration, not intrinsically safe.

6.5.2 Sampling methods

In deciding what sampling is required, numerous factors have to be considered. Several such as the site of the sampler and duration of sampling time have briefly been mentioned. However, a thorough knowledge of the processes involved and the likely contaminants to be monitored precedes all other considerations. Careful work done here can minimize the amount of sampling subsequently undertaken, and optimize the value of the results obtained. The type of analytical method to be used and criteria against which evaluations are to be made are also important considerations.

Validated methods of sampling and analysis such as those published by the HSE in their Methods for the Determination of Hazardous Substances (MDHS)

series, the National Institute of Occupational Safety and Health (NIOSH), OSHA Analytical Methods Manual should be used where practicable.

All instructions included in these methods such as sampling pump flow rates, calibration schedules, numbers of blanks and appropriate sample collection medium (e.g. adsorbent, filter paper) etc, must be strictly adhered to for the sampling methods to be valid.

In addition the following matters should be resolved before sampling commences:

The Amount of Material Required

- The analyst should be provided with enough material to ensure an accurate, representative result.
- Always consult the analyst before collecting samples to discuss the quantity required, packaging, transport, storage, etc.

Sample Handling

Inappropriate handling and transport of sampled materials may give rise to losses or contamination. Factors include the type of container used as well as any requirements to store at lower temperatures or away from sunlight. Advice should be obtained from the laboratory undertaking the analysis.

6.5.3 Fixed position sampling

This can be employed to provide information about contamination from fixed sources and effectiveness of control measures e.g. local exhaust ventilation. Similar apparatus to that employed above can be used for fixed position sampling as well as larger sampling pumps with sampling flow rates of up to 100 litres per minute. Care has to be exercised in interpreting the results as the particle sizes collected may be different with higher flow rates. In addition, fixed position samples cannot be used to establish personal exposures or be compared to hygiene standards.

6.6 Sampling Strategies

First of all we need to understand the reasons for monitoring and options are provided below. The measurement of personal exposure is most important to the occupational hygienist, however other reasons are covered briefly.

6.6.1 Identification of airborne contaminants

The identification of airborne contaminants requires a sampling technique that collects a representative sample. The technique itself is likely to be similar to those already described, although some alterations may be needed to ensure that sufficient sample is collected for the subsequent analytical technique.

6.6.2 Leakages and spillages

Leaks and spills require a continuously reading instrument with a rapid response. This type of equipment is normally employed for flammable gases and potentially oxygen deficient atmospheres, although gases with acute health hazards e.g. hydrogen sulphide, chlorine etc may need to be monitored in this way. The type of equipment can be portable or fixed position.

6.6.3 Assessment of the effectiveness of control measures

This would normally be performed by employing fixed position sampling devices providing time weighted average concentrations. Sampling can be repeated periodically and the results compared. Care has to be taken to ensure that the working conditions are the same during each sampling exercise. Continuous monitoring equipment may be employed to assess any changes that occur during short time periods.

6.7 Methods of Analysis

There are numerous analytical techniques available for the analysis of airborne contaminants. Many are dedicated branches of science in their own right and require trained and experienced analysts technicians. Not all techniques are suitable for all contaminants, but most chemical groups can be analysed by similar methods. The main methods are shown below:

6.7.1 Organic vapours

These are the most commonly occurring contaminants in a wide variety of industry e.g. used in various paints, coatings and cleaners. They are normally sampled by collection onto a sorbent tube and then desorbed either by heating and purging directly into a gas chromatograph (GC) complete with a flame ionisation detection (FID), or by desorption in a solvent and subsequent injection of aliquots of the liquid layer on to a GC. Both techniques are well established and can utilise automatic sampling procedures and computerised data control systems, so that multiple samples can be analysed and analysis performed 24 hours a day.

6.7.2 Inorganic gases

Separate techniques are needed for individual gases, whilst some can be analysed by GC thermal conductivity methods, sulphur gases need photometric and microcoulometry whilst carbon monoxide and dioxide can be detected by infra-red, and oxides of nitrogen and ozone by chemiluminescence. In practice it is often easier to measure inorganic gases using direct reading devices which do not require analysis.

6.7.3 Organic particulate matter

Particulate polycyclic aromatic hydrocarbons (PAHs) are collected on a filter paper medium and solvent extracted and analysed by high pressure liquid chromatography (HPLC). Oil mist is similarly collected and can be analysed gravimetrically or qualitatively by infra-red (IR) or ultraviolet (UV) means.

6.7.4 Metals and their compounds

Metal fumes are collected on a filter paper medium and analysed by Atomic Absorption (AA) or by Inductively Coupled Plasma Arc Spectroscopy (ICP).

6.7.5 Mineral dusts

Asbestos-in-air is a specialist technique involving collection on a cellulose ester membrane filter and analysis, by counting the number of asbestos type fibres present on the filter, using phase contrast microscopy. Crystalline silica is

similarly collected, and then the filter is analysed quantitatively either by x-ray diffraction (XRD) or by infra-red (IR).

6.7.6 Diesel particulate matter (measured as elemental carbon)

Diesel particulate matter is collected on a quartz-fibre 37mm filter. For measurement of diesel particulate matter in coal mines, a cyclone and impactor with a submicrometer cutpoint are required to minimise the collection of coal dust. A cyclone and or impactor may be necessary in other workplaces if high elemental carbon containing dusts are present. The sample is analysed using thermal-optical analysis with a flame ionisation detector (FID). Total carbon is determined with elemental carbon reported as the most appropriate surrogate for Diesel Particulate Matter.

6.8 Calibration and Quality Control

In order to achieve reliable results analysis of collected samples should only be undertaken by organisations that have suitable internal quality control systems in place. In addition they should take part in suitable external proficiency testing schemes such as LGC or RICE (UK), PTA Australia, or GEQUAS (Germany). In many countries the performance of testing laboratories may be independently assessed by an independent accreditation body such as UKAS (UK) or NATA (Australia).

Increasing emphasis is being placed on the "chain of custody" of samples, so that a link can be demonstrated between the devices placed on the operators and the actual samples analysed.

7 HYGIENE STANDARDS AND OCCUPATIONAL EXPOSURE LIMITS

7.1 Introduction

We have seen that most of the chemical and physical agents found in industry today are potentially harmful if they are not handled correctly or are present in excessive quantities in the workplace environment. The aim of occupational hygiene is to prevent or reduce exposure to such agents.

Hygiene standards or occupational exposure limits (OELs) are useful measures with which exposures to chemical and physical agents in the workplace environment can be compared. There are a few key points to remember about hygiene standards, namely:

- They are not an index of toxicity.
- They do not represent a fine demarcation between good and bad practice.
- They are based on the current best available information and are liable to change.
- If there is not a hygiene standard set for a chemical substance, it does not mean that the substance is safe.
- Good occupational hygiene practice is to keep airborne contaminants to as low a level as possible, not to just below the relevant hygiene standard(s).
- They apply to occupational exposure of adults. They are not applicable to environmental exposure where more susceptible groups exist e.g. pregnant women, children, infirm.
- For chemicals they generally relate to airborne concentrations (i.e. they only take into account the inhalation route of entry) however some do have a skin notation where absorption through the skin is possible.
- They generally refer to single substances, although some guidance may be given on mixed exposures.

7.2 Setting of Hygiene Standards and Exposure Limits

There are three main types of hygiene standards; 1, those for chemical agents such as gases, vapours, fumes, mists, dusts and aerosols; 2, those for physical

agents such as noise, vibration, heat, cold and radiation (ionising and non-ionising) and finally 3, biological exposure indices.

When setting hygiene standards for hazardous agents, the effects the agents might have on the body have to be considered namely:-

- Local toxic effects at the site of contact (skin, eye, respiratory tract etc.)
- Absorption
- Transport, metabolism, storage
- Systemic toxic effects, remote from the site of contact (any organ system e.g. blood, bone, nervous system, kidney etc.)
- Excretion
- Acute toxicity i.e. adverse effects which occur within a short time of exposure to a single dose, or to multiple doses over 24 hours or less e.g. irritation, asphyxiation, narcosis
- Chronic toxicity i.e. adverse effects which occur as a result of a repeated daily exposure over a long time span (weeks, years) e.g. systemic poisons, lung fibrosis, (carcinogens) and noise induced hearing loss.

The data for setting hygiene standards includes the use of

- Animal studies
- Human research and experience
- Epidemiology (the statistical study of disease patterns in groups of individuals)
- Analogy to similar types or groups of substances.

There are also biological variabilities; people (animals) react differently to the same dose of a chemical or physical agent (hypersensitive, average resistance). Thus the dose response relationships have to be considered.

7.3 Hygiene Standards for Chemical Agents

Only a few countries have organisations with the appropriate resources for determining and keeping under continuous review occupational exposure limits for chemical agents. Most countries have based their guidance criteria on one of the following sets of occupational exposure limits:

Limit	Country / Union
TLV – Threshold Limit Value	USA
MAK - Maximale Arbeitsplatz-Konzentration	Germany
MAC	Russia
WEL – Workplace Exposure Limit	United Kingdom
IOELVs (Indicative Occupational Exposure Limit Value)	Europe
WES – Workplace Exposure Standards	Australia
WES – Workplace Exposure Standards	New Zealand

7.3.1 Quantifying airborne concentrations of chemical agents

Airborne contaminants can be quantified in several ways, and these relate to the relevant hygiene standards:

- By volume - atmospheric concentration in parts per million (ppm)
- By weight - milligrams of substance per cubic metre of air (mg/m^3).

There is a correlation between ppm and mg/m^{-3}:

$$\text{Conc. by weight } (mg/m^3) = \frac{\text{Conc. by volume (ppm) x Molecular weight}}{24.06}$$

at 20°C and 760 mm Hg (1 atmosphere pressure).

Note: In the above equation the molar volume (24.06) will vary with temperature and pressure eg at 25^{o}C and 1 atmosphere it is 24.45. Different organisations use different temperature & pressures so students should be aware of the practice used in their country.

- Numerical - for fibres, fibres per millilitre of air (fibres/ml)

7.3.2 Categories of exposure limits

Long term exposure limits are expressed as a Time Weighted Average (TWA) normally over an eight hour period. This allows for exposures to vary through the working day so long as the average exposure does not exceed the limit.

Short term exposure limits (STELs), normally over a 15 minute period, are used when exposure for short periods of time occurs.

Ceiling Limits (Peak Limitations) are sometimes used and are concentrations that should not be exceeded during any part of the working exposure.

The above terminology refers to the USA however similar criteria exist for exposure standards used in Western Countries. In the sections below different acronyms are used which are referenced in the table above.

7.3.3 "Skin" notation

Substances that have been assigned a “Skin” notation can have a contributing exposure effect by the cutaneous route (including mucous membranes and eyes) either by airborne, or more particularly, by direct contact of the substance with the skin. The exposure limits for such substances relate to exposure via inhalation only; they take no account of absorption via skin contact.

7.3.4 Effects of mixed exposures

Where mixed exposures occur the first step is to ensure adequate control of exposure for each individual substance. WELs for defined mixtures should be used only where they are applicable and in addition to any relevant individual WELs. It is then necessary to assess whether further control is needed to counteract any increased risk from the substances acting in conjunction. Expert assessments for some particular mixed exposures may be available and can be used as guidelines in similar cases. In other cases, close examination of the toxicological data will be necessary to determine which of the main types of interaction (if any) are likely for the particular combination of substances concerned; the various types should be considered in the following order.

Synergistic substances: known cases of synergism are considerably less common than the other types of behaviour in mixed exposures. However, they are the most serious in their effects and require the strictest control. They are also the most difficult to assess and wherever there is reason to suspect such interaction, specialist advice should be obtained.

Additive substances: where there is reason to believe that the effects of the constituents are additive, and where the WEL’s are based on the same health effects, the mixed exposure should be assessed by means of the formula;

$$\frac{C_1}{L_1} + \frac{C_2}{L_2} + \frac{C_3}{L_3} \ldots < 1$$

where C_1 C_2 etc. are the time weighted average (TWA) concentrations of constituents in air and L_1, L_2 etc. are the corresponding WELs.

Where the sum of the C/L fractions does not exceed 1, the exposure is considered not to exceed the additive exposure limit. The use of this formula is only applicable where L_1, L_2 etc relate to the same reference period in the list of approved WELs. This formula is not applicable where the primary health effect is cancer or respiratory sensitisation. For mixtures containing these substances the overriding duty is to decrease exposure so far as is reasonably practicable.

Independent substances: where no synergistic or additive effects are known or considered likely, the constituents can be regarded as acting independently and the measures needed to achieve adequate control assessed for each separately. The controls needed for the mixture will be those for the component requiring the tightest control.

7.3.5 Calculation of exposure with regard to the specified reference periods

The 8-hour reference period

The term "8-hour reference period" relates to the procedure whereby the occupational exposures in any 24-hour period are treated as equivalent to a single uniform exposure for 8 hours (the 8-hour time-weighted average (TWA) exposure).

The 8-hour TWA may be represented mathematically by:

$$\frac{C_1 \times T_1 + C_2 \times T_2 + \ldots\ldots C_n \times T_n}{8}$$

where C_1 is the occupational exposure and T_1 is the associated exposure time in hours in any 24-hour period.

Example 1

The operator works for 7h 20min on a process in which he is exposed to a substance hazardous to health. The average exposure during that period is measured as 0.12 $mg.m^{-3}$.

The 8-hour TWA therefore is -
7h 20min (7.33 h) at 0.12 $mg.m^{-3}$
And 40min (0.67h) at 0 $mg.m^{-3}$
That is:

$$\frac{(0.12 \times 7.33) + (0 \times 0.67)}{8}$$

$= 0.11\ mg.m^{-3}$

The short-term reference period

Exposure should be recorded as the average over the specified short-term reference period (usually 15 minutes) and should normally be determined by sampling over that period.

If the exposure period is less than 15 minutes, the sampling result should be averaged over 15 minutes. For example, if a 5 minute sample produces a level of 150 ppm and is immediately followed by a period of zero exposure then the 15-minute average exposure will be 50 ppm.

That is:

$$\frac{5 \times 150}{15} = 50\ ppm$$

Exposure period is 15 minutes or longer

Measurements should be taken over a 15 minute period and the result is the 15 minute average exposure.

7.4 Biological Monitoring Guidance Values

Biological monitoring can be a very useful complementary technique to air monitoring when air sampling techniques alone may not give a reliable indication of exposure.

Biological monitoring is the measurement and assessment of hazardous substances or their metabolites in tissues, excreta or expired air in exposed workers. Measurements reflect absorption of a substance by all routes. Biological monitoring may be particularly useful in circumstances where there is likely to be significant skin absorption and or gastrointestinal tract uptake following ingestion; where control of exposure depends on respiratory protective equipment; where there is a reasonably well defined relationship between biological monitoring and effect; or where it gives information on accumulated dose and target organ body burden which is related to toxicity.

In most cases limits for Biological Monitoring are not statutory and any biological monitoring undertaken needs to be conducted on a voluntary basis (i.e. with the fully informed consent of all concerned). Biological monitoring guidance values (BMGVs) are intended to be used as tools in meeting the employer's primary duty to ensure adequate control of exposure. Where a BMGV is exceeded it does not necessarily mean that any corresponding airborne standard has been exceeded nor that ill health will occur. It is intended that where they are exceeded this will give an indication that investigation into current control measures and work practices is necessary. It should also be noted that BMGVs are not an alternative or replacement for airborne occupational exposure limits.

8 BIOLOGICAL MONITORING AND HEALTH SURVEILLANCE

This is a complex subject area and one where misunderstandings commonly arise between the various medical, health and occupational hygiene disciplines. Health Surveillance is often used as a generic term which includes any health investigation undertaken to assess, review or monitor an individual's health in order to identify or detect changes from their normal health status. In actual fact there should be a clear demarcation between the terms Medical Surveillance, Health Surveillance and Biological Monitoring.

In broad terms there are three main reasons for health investigations at work:

1 To identify adverse health effects related to the work at an early stage; sometimes this is a statutory regulatory requirement.

2 To check an individual's medical fitness for specific jobs or tasks, such as driving vehicles, fire-fighting, diving etc.

3 To promote general health & well-being.

From the Occupational Hygiene perspective only the first reason, above, is termed Health Surveillance.

The decision to undertake health surveillance is not a simple one and should depend on the findings of a health risk assessment. It should only take place when exposures are deemed sufficient to cause an adverse health effect or disease.

There must additionally be valid techniques for detecting the effect or disease, preferably whilst they are still reversible or where early detection and control can stop the progression of the effect or disease.

The techniques must be safe, preferably non-invasive and acceptable to the individual involved.

The techniques do not necessarily need to be clinical tests conducted by a medical or health professional – in some cases procedures such as skin inspection for dermatitis etc. may be carried out by line supervision.

The purposes of health surveillance, therefore, can be summarised as follows:-

- To maintain good health by the early detection of adverse changes attributed to the exposure, and
- To assist in the evaluation of the ongoing effectiveness of control measures, and
- To collect data relevant to the detection and evaluation of hazards to health, both now and in the future, e.g. epidemiology.

Results of health surveillance should lead to some actions that benefit the health of the individual and the methods of recording, analysis of results and criteria and options for action should be established before commencing any health surveillance exercise.

Biological monitoring may form an integral part of health surveillance and is the measurement of human tissues, fluids or behaviour in comparison with what is considered to be a normal range of values. Measurements on individuals must be treated as measurements made in clinical practice and medical confidentiality applies. Biological monitoring is also used in other health investigations mentioned earlier, such as fitness for task or health & wellbeing check-ups, but for the purposes of this course they will not be covered.

In contrast to environmental monitoring, biological monitoring can establish, not only exposure to a particular hazard, but also its effect on an individual or group of people. For example, personal exposure monitoring may give a good indication of the concentrations of a dust or toxic vapour that an individual may be exposed to, but cannot demonstrate its effect on the individual, given that work rate, lung and circulatory efficiency, fitness, age, genetic variability, percentage fat, sex, medication and alcohol all have an influence on how much is actually taken up and how it is later metabolised.

The risks to a worker from a toxic material, therefore, are more directly related to their uptake of that material than to its concentration in the working environment. There can be large differences in any one individual’s uptake under the same conditions and this may well justify biological monitoring, although the same criteria for the overall acceptability of health surveillance

should be applied e.g., safe, preferably non-invasive etc. The timing of biological monitoring will depend on the expected absorption, metabolism and excretion rates and the known half-life of the substance in question. Mean results of measurements for a number of individuals in a group provide a better index of uptake or dose than isolated measurements.

With scrupulous sampling techniques, analysis and quality control, biological monitoring can show up susceptible individuals, uptake within or outside acceptable levels and high exposure groups of people who may have been missed by personal exposure monitoring. Ideally the two forms of monitoring should go hand in hand.

Biological measurements can determine:-

- The content of a toxic material or its metabolite in blood, urine and breath (and in the case of arsenic - hair and nail clippings).
- Its effects on enzyme systems or metabolic pathways e.g. haem synthesis is upset by lead exposure and assessed by the blood or urine level of δ(delta)-aminolevulinic acid (ALA).
- early reversible tissue change e.g. gamma GT (gamma-glutamyl transferase).
- physiological changes (e.g. lung function tests).
- immunological changes (e.g. skin allergy tests).

Urine and blood are the most common media tested and levels of a toxic substance or its metabolite in urine or blood are measured, giving an estimation of absorption into the body of a particular substance e.g. finding cadmium in the urine denotes absorption into the body of cadmium, but if in addition low molecular weight protein is demonstrated in the urine (not a normal constituent) it may indicate kidney damage.

8.1 Urine

Urine can be tested for a wide variety of purposes:

- Cells (exfoliate cytology) - bladder cancer

- Level of toxin e.g. mercury
- Level of metabolite eg TCA (tricarboxylic acid)
- Protein (especially kidney damage)
- Bile (jaundice)

8.2 Blood

As with urine, blood can be analysed for a wide range of materials which indicate ill health or the level of a particular substance metabolite.

- Full blood count and haemoglobin - lead, benzene, alcohol, work in the tropics
- Serum (deep frozen) - baseline antibody levels in pathogen exposure
- Liver function tests - alcohol, hepatotoxic chemicals
- Renal function tests - kidney toxins
- Toxin levels - e.g. lead
- Metabolite levels - e.g. ɑ (delta) – aminolevulinic acid (ALA).

8.3 Skin

Visual appearance - together with knowledge of a substance and history of the individual, especially in the case of irritants.

Prick testing - A standardised solution of a substance is introduced just under the surface of the skin on a needle tip. A positive result is a 1mm or larger wheal (red swollen mark) often with itch and flare within five minutes of the test. This is used to monitor immunological reactions to some respiratory allergens like the enzymes used in biological detergents, or animal dander for those working in animal testing laboratories. The tests are also used to diagnose contact urticaria. Note; this is a specialist form of testing and is commonly used for diagnosis rather than health surveillance.

8.4 Breath

Exhaled breath is captured and tested - for example, Dichloromethane and carbon monoxide exposure. This technique is not simple as it is the concentration in the end tidal flow (last part of the breath) that is the most representative however accurate measurement is a challenge.

8.5 X-rays

Chest x-rays are useful for conditions such as infection e.g. TB, farmers' lung, and pneumoconiosis. In some countries they are also routinely undertaken on asbestos workers every two years.

Pneumoconiosis chest x-rays are classified under the ILO international classification system and compared with a standard set of films. Other X-Rays that may be used include Acro-osteolysis (VCM).

8.6 Neurological Tests

Mental function- IQ, dexterity, vigilance

Nerve transmission - Electromyography (neuromuscular transmission) and Nerve conduction velocity (Regular testing can prevent peripheral neuropathies by detecting very early changes).

Handwriting tests (detects early tremors) - mercury workers.

8.7 Audiometry

The lowest intensity at which a given pure tone can be heard is recorded. Values are expressed relative to a standard set of threshold values for normal young people at specific frequencies (these standards are set at 0 dB).

8.8 Lung Function Tests

8.8.1 Lung volume and forced expiratory volume (FEV1)

Forced Vital Capacity (FVC) and Forced Expiratory Volume in 1-second (FEV1) are measured using a spirometer (for example, a Vitalograph), and are then compared with predicted values. Predicted values depend on height, weight, sex, smoking, age and ethnic group. The subject blows through the machine 5 times and an average of the last 3 or the 2 highest readings are accepted as correct.

8.8.2 Airways resistance

Peak expiratory flow rate - This is measured with a peak flow meter. It is used for monitoring potential changes due to respiratory allergens and for diagnosing

asthma and its response to treatment. A series of readings are sometimes taken every two hours.

9 GENERAL APPROACHES TO THE CONTROL OF RISKS TO HEALTH

The various steps taken to prevent or control the release of airborne contaminants, or propagation of some physical agents - in the work environment are outlined and a range of examples given. These steps are commonly referred to as control measures and include combinations of engineering and operational / procedural systems aimed at preventing or minimising exposures.

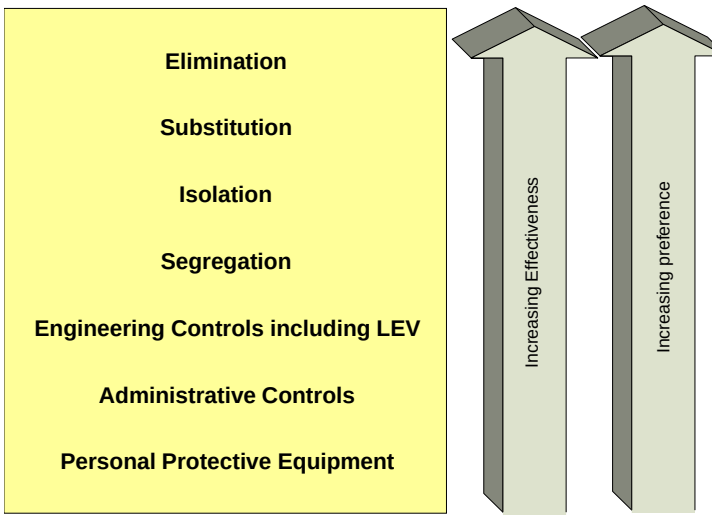
Effective control is probably the single most important topic affecting health at work and underpins much of the legislative efforts designed to address health protection at work.

If an occupational hygiene assessment survey identifies a risk to health, then additional improved control measures need to be considered and implemented.

9.1 Types of Control Measures

Exposure prevention is the principal aim of any control strategy, particularly when handling hazardous agents, capable of producing serious irreversible health effects; such as carcinogens and ionising radiation. In other cases, hazard effect, practicability, economics etc., may not require that all exposures be prevented – exposure minimisation may be considered sufficient.

A hierarchical approach combining varieties of both engineering and operational procedural control measures is universally accepted, and is presented below in decreasing order of desirability. In most cases effective control strategies will utilise combinations of several, if not all of the measures listed.



Source: Adrian Hirst & John Dobbie

9.1.1 Elimination / substitution

The most effective form of prevention control is to either eliminate the use of the hazardous agent, or the actual process in which it is used. This is not always possible or practicable, but quite commonly hazardous agents or processes can be substituted with relatively less harmful ones, e.g.

- Benzene replaced with toluene.
- Carbon tetrachloride replaced with methyl chloroform.
- Talc replaced with chalk.
- Sand blasting replaced by steel shot blasting.
- Dry handling techniques replaced by wet handling techniques. i.e. suppression of dust emission (e.g. removal of asbestos lagging).

9.1.2 Isolation

Where possible processes or operations, which create potential risk(s) to health, should be completely enclosed, with the operator(s) always located outside the enclosure. In practice, however, there are usually activities such as sampling, maintenance and cleaning that can prevent the ideal total enclosure.

9.1.3 Segregation

Hazardous processes or operations etc. can be segregated from lower risk ones by placing them, for example, at the far end of a workshop, in a separate

room, or in a separate building, thereby minimising the number of workers at risk.

9.1.4 Engineering controls

These are ideally an intrinsic part of a piece of equipment aimed at preventing or minimising exposure to the hazards arising from the equipment's use. They are typically examples of controlling a hazard at its source. For example a pump used to move hazardous products through pipework may have a variety of different seals to prevent the materials inside the pump coming into contact with the outside environment. Similarly by proper design the levels of noise emanating from a piece of equipment can be dramatically reduced, e.g. pump motor cooling fans designed to turn in one direction only can be made much quieter than an asymmetric fan designed to provide sufficient cooling whichever way it turns**.**

Ventilation

Processes capable of producing exposures to hazardous substances, are commonly controlled by the provision of mechanical air handling methods, of either one of the two types below or a combination of both. Refer to chapter 10 for more detail.

Local Exhaust Ventilation (LEV)

Local Exhaust Ventilation (LEV) sometimes known as Local Extract Ventilation – is the application of mechanical air handling techniques whereby potential airborne contaminants are captured near to the source of emission, extracted, and discharged to either a safe location or subjected to some form of 'air cleaning' technique. It is particularly valuable for situations that involve a point source release of toxic contaminants.

General / Dilution Ventilation

General / Dilution Ventilation - is widely used throughout industry for the ventilation of control rooms, photographic laboratories, workshops, office

spaces, mess-rooms and printing rooms. It is not normally suitable for the control of dust, mist of fume or for substances of moderate to high toxicity. It is not suitable in situations where the rate of generation of contamination is non-uniform or high.

Heating, Ventilation and Air Conditioning (HVAC) can also be used in a variety of ways to control hazards associated with the thermal environment.

9.1.5 Administrative controls

Administrative controls relate to how the interaction between people and the process operation are organised. Great care is needed to ensure that procedures, once adopted, are observed; particularly in the longer term, as shortcuts and non-observance can become ‘custom and practice’ over time, and once established can be difficult to overcome.

Sometimes the hazardous operation can be conducted during the evening or night shift when fewer workers are around to be exposed. Job rotation is another method of ‘protecting’ the workforce, through controlling work patterns.

The worker can often influence the extent to which they are exposed to airborne contaminants, e.g. for welding, by where they position themselves in relation to the weld and or working upwind of the weld.

Housekeeping

Good housekeeping is particularly important in processes and laboratories where hazardous materials may be handled. Clear labelling, with relevant health and safety advice, careful and appropriate storage and good work techniques all need to be addressed.

Handling of powders is a potentially hazardous operation and good housekeeping can help to minimise airborne contamination from spilled materials, waste (off-cuts) etc. these are commonly referred to as secondary exposures and in many cases can be higher than the primary exposures, as they are not effectively controlled by the main process.

A cluttered or untidy workplace may also impede or prevent access to essential system controls, such as LEV on off switches, which could discourage their

proper use. It can also make it difficult for workers to position themselves correctly in relation to the task, thereby potentially risking greater exposures, and maybe even leading to problems associated with poor ergonomics.

Proper preventative maintenance schedules and regular inspection leak detection of process plant; plus frequent maintenance, examination and testing of engineering controls, such as LEV facilities, coupled with rapid corrective actions where necessary, are essential if effective control is to be achieved and kept.

Personal factors are essential parts of all control strategies and are associated with the ‘management’ aspects from both the perspective of how the employer manages their workforce, and how the workforce ‘manage’ themselves.

9.1.6 Information, instruction and training

Education of the workforce on any health hazards in the workplace and the importance of correctly using all the control measures provided, adopting recommended operating procedures and wearing personal protection, if required, is needed in order to minimise the risk(s) to health. Induction courses, regular publicity, health and safety committees and positive line management can all play important roles in education.

Training of employees on the use of the appropriate control measures, operating practices etc., and the factors involved in the correct selection, use and maintenance of personal protective equipment (PPE).

Fault reporting encouraging prompt communication, through appropriate channels, of any problems encountered with the process, equipment, controls or PPE.

Good hygiene practices - these relate to the steps workers should take to protect their own health, and include following established decontamination procedures, where applicable, regular laundering of clothing, using approved methods facilities; (i.e. not taking contaminated items home), good personal hygiene – frequent washing / showering particularly before meal breaks; and never eating, drinking or smoking within designated process areas.

9.1.7 Personal protective equipment (PPE)

PPE is normally considered to be the last resort and only applicable when more effective control measures are either insufficient or not reasonably practicable in achieving a satisfactory work situation. At times PPE needs to be implemented initially while longer term, more appropriate controls are researched, designed and implemented. It is preferable that PPE does not remain as a long term solution. Careful consideration must be given to the choice of the PPE device. It is important that the protection is effective and comfortable; most personal protective equipment is not comfortable for extended use. Regular maintenance is vital for many types of PPE if effective protection is be obtained. PPE management programmes need to be adopted whenever the option of PPE use is deemed necessary, and very pro-active ongoing support to the programme will be required. Note too that the expectations around PPE effectiveness are all too often greater than the reality so ‘real world” protection factors should be looked at rather than manufacturers claims.

10 VENTILATION

The important features of ventilation systems are outlined, along with general principles associated with their design.

10.1 Types of Control

There are two main types of ventilation used to remove and reduce contamination with workplaces.

1) **General / dilution ventilation** reduces the concentration of background contamination by the addition of fresh, uncontaminated air. However, there is little, if any, removal or reduction of the contaminant at source. Dilution ventilation is appropriate to use if there is small amounts of low toxicity dispersed contaminant. It may also be appropriate for mobile contaminants of low toxicity. The initial costs are generally lower than LEV and require less maintenance but it is important to remember that the contaminant is not removed from its source, rather it is diluted. Opening a roller door, blowing air into a room with a large fan are examples of dilution ventilation.

2) **Local exhaust ventilation** (LEV) is one of the most effective means available for preventing hazardous materials entering the workplace atmosphere. It draws pollutants away from a process or operation that is likely to release a hazardous substance into the workplace. However, there are many cases where the LEV is not effective and this may be as a result of poor design or lack of understanding of its proper use. LEV removes the contaminant at source.

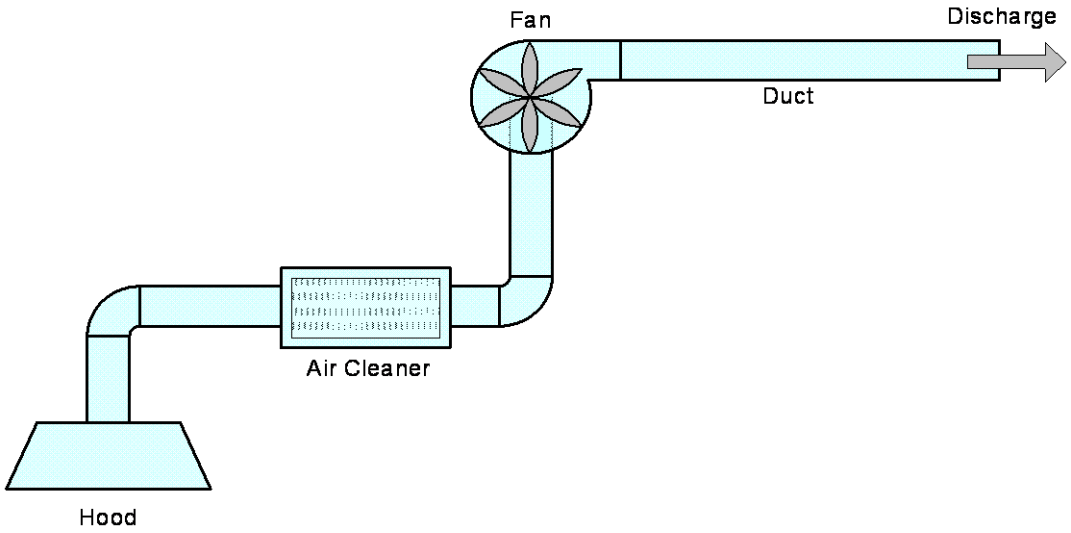
10.2 General Features of a LEV System

The fundamental components that are common to all LEV systems are:

- Inlet such as a booth, hood, slot or enclosure.
- Ductwork that may contain bends, junctions, changes of section and dampers, it may be circular or rectangular in cross section and be rigid or flexible.
- An air-cleaning device such as a dust filter, wet scrubber or solvent recovery device.
- A fan or other air-moving device.

- Discharge ductwork to atmosphere or a room via a stack, diffuser, grille or just an open duct.

A diagram of the components of a LEV system is shown below.



Source: Adrian Hirst

Figure 10.1 – General Features of an LEV System

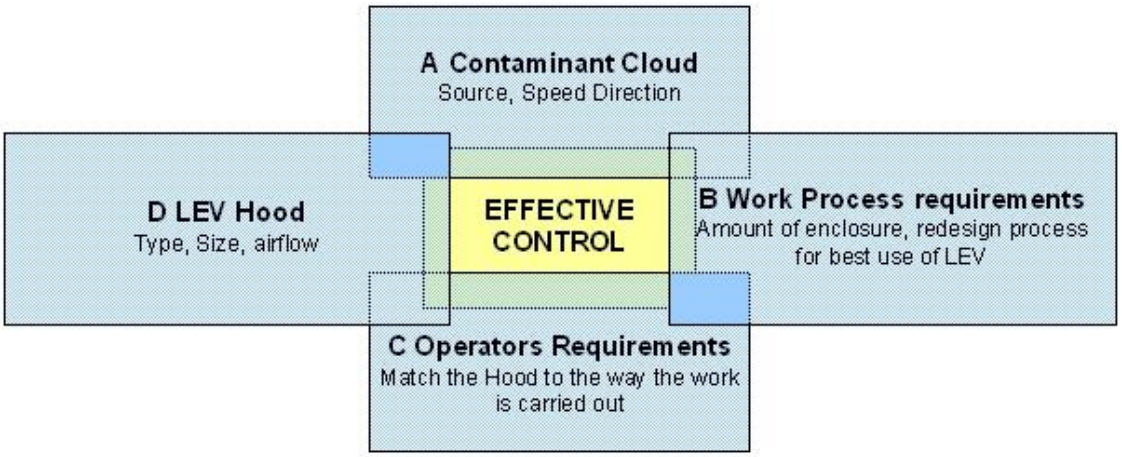
10.2.1 General considerations

LEV can be simple systems that serve a single machine or be complex and serve an entire factory. For a LEV system to be effective, all of the component parts must function correctly; a well designed and correctly positioned captor hood will be useless if the fan cannot provide the correct airflow. A LEV system removes air from the workplace and therefore there must be a means of ensuring a sufficient supply of make-up air to compensate for this. In large LEV systems this may mean that grilles or air vents have to be fitted to doors or walls and a supply fan may need to be installed. It should be remembered that the cost of heating air can be substantial, therefore, poor design may lead to unnecessary energy costs and it may be worthwhile installing a heat recovery system.

It's essential that any LEV system is designed for the process which it is intended to control. The diagram below shows the interdependent factors which lead to effective control. It is important that the nature of the contaminant being

controlled is fully understood. Gases released under ambient conditions will behave very differently to dust particles which are released with a high velocity. This affects the design of the capture system as well as any cleaning system which is incorporated.

It is essential to consider work process requirements as well as operator requirements. Inevitably some compromise occurs for both the operator and the process, however if this compromise is too great then the LEV is unlikely to be employed after it is installed.

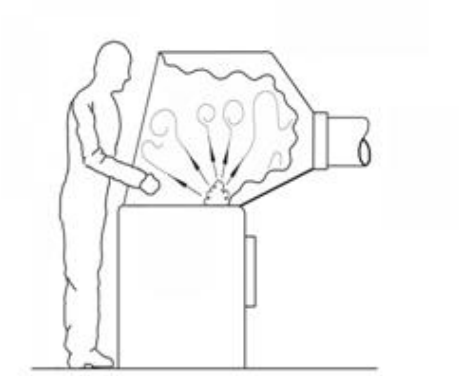


Source: Adrian Hirst adapted from HSE Publication – HSG 258

10.2.2 Inlets / hoods

The design of the LEV inlet is one of the most important factors in achieving effective control. Hoods can be broadly classified into three types:

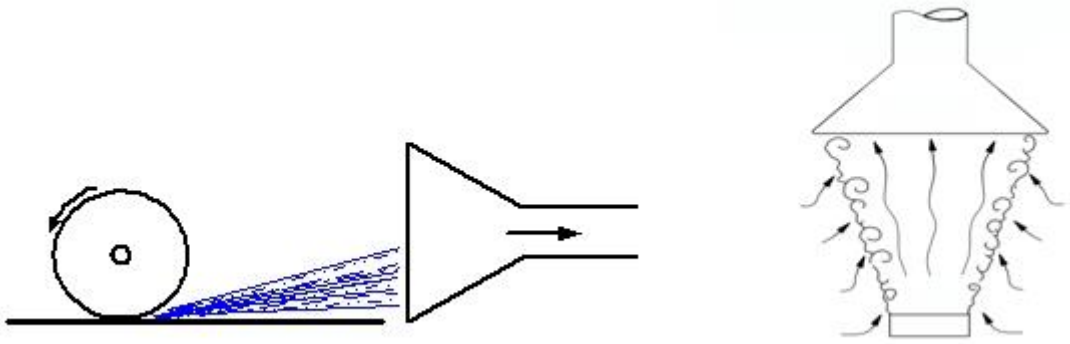
1 An **enclosing hood** is usually the most effective at capturing a contaminant as it contains and separates the contaminant from the worker. This is the type you might find in a laboratory fume cupboard (partial enclosure) or a shot blasting unit (full enclosure).



Source: HSE

Figure 10.2 - Enclosing Hood

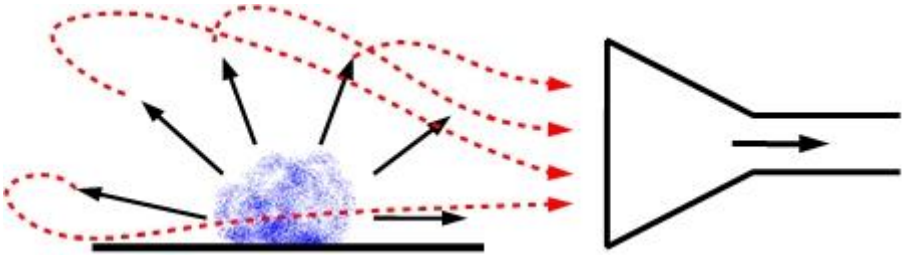
2 A **receptor hood** takes advantage of the any natural buoyancy or velocity which contaminants have causing them to move towards the hood. Whilst this type of hood gives minimum interference with the operator and process, it can be prone to effects from other airflows in the area.



Source: HSE

Figure 10.3 - Receptor Hoods

3 Capture hood is the most common type encountered and is one in which the contaminant is generated outside of the hood. The hood therefore has to generate sufficient airflow to “capture” and draw in the contaminant. This means that the velocity of air and the proximity of the hood to the source of contaminant are crucial. e.g. welding extraction.



Source: HSE

Figure 10.4 - Capture Hood

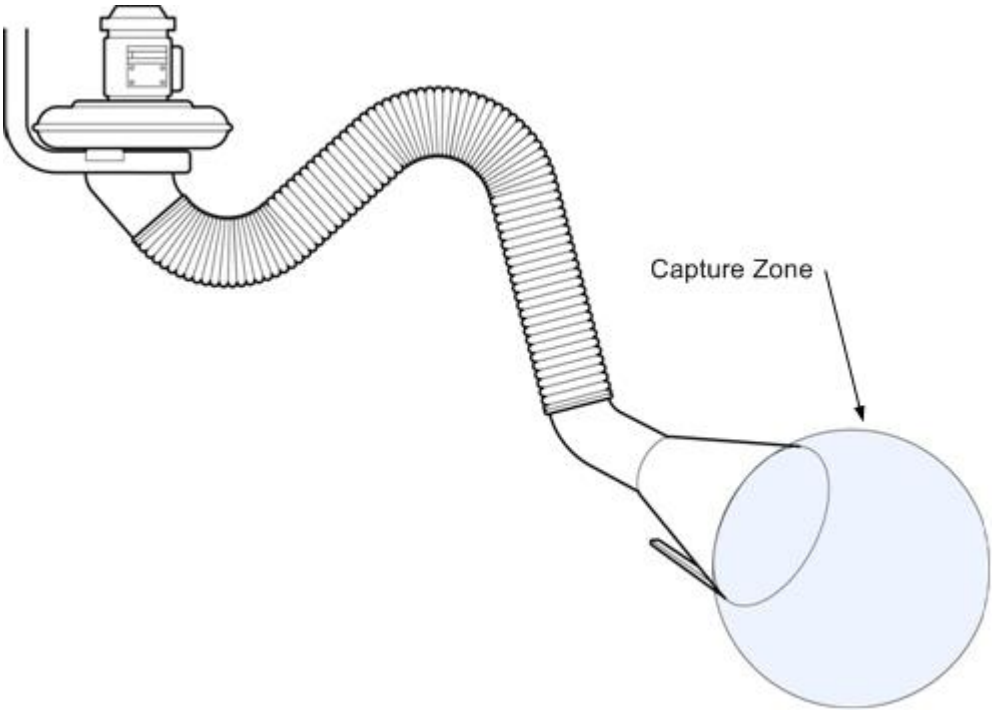
The precise design of each of these systems has to be tailored to the process it controls. The table below lists some examples of common industrial processes together with the types of LEV which can be installed to control exposures taking into account the type of hazardous substance that is present and the way in which it is released.

Types of LEV used for various processes

Industrial process	Nature of hazardous substance	Types of LEV
Welding	Welding fume: fine particulate with some natural buoyancy	Capture hood positioned close to the welding activity; or Tip extraction fitted to the end of the welding gun
Paint spraying	Mist and solvent vapours released in controlled direction with velocity	Walk in paint spray booth Down flow booth
Polishing	Metal and polishing dust released in controlled direction with high velocity	Receptor hood and enclosure around the polishing wheel
Shot blasting	Steel shot and metal dust from components released at high velocity in variable direction	Fully enclosed glove box type cabinet with airflow managed to compensate for compressed air input and shot recycling system
Hand held orbital Sander	Wood dust released in variable directions	Extraction integrated into the sander disc
Paint curing Ovens	Hot air and curing vapours with strong thermal buoyancy	Extract vent from top of oven combined with a receptor hood over the doorway
Laboratory analysis	Acid and solvent vapours released with low velocity and little direction	Partial enclosure and extraction within a fume cupboard

Source: HSE

The inlets to LEV systems can only exert effective control close to the inlet itself. For example, for a hood with a 0.3 metre diameter circular opening with a face velocity of 5 metres per second will only capture contaminant released within 0.3 metres of the opening. The velocity at one diameter distance (i.e. 0.3 m) from the opening drops to approximately 10% of the velocity at the opening (0.5 m/s). Outside this capture zone, external influences such moving machinery or personnel can overcome the capture effect of the inlet. This is illustrated below.



Source: HSE

Figure 10.5 - Capture Zone or Capture Bubble on a Welding Hood

Capture velocity is the air velocity required at the source of the emission so as to cause the contaminant to move toward the capture device and thus be removed. Typical capture velocities are provided in the below table, however this does not fully reflect the energy or location of the source and is thus only a guide.

Table 6.2 – Typical Capture Velocities

Conditions of Dispersion of Contaminant	Examples	Capture Velocity (ms^{-1})
Released into still air with no velocity	Evaporation of solvents from degreasing tanks, paint dipping/drying, etc	0.3 – 0.5
Released at low velocity into moderately still air	Welding Soldering Liquid transfer	0.5 to 1.0
Released at moderate velocity into moving air	Crushing Spraying	1.0 to 2.5
Released at high velocity into very turbulent airstream	Cutting Abrasive blasting Grinding	2.5 to 10

(Source: HSE – *reproduced with permission*)

Important considerations about the source of contamination that may need to be considered during the design and construction of captor inlets include:

- The size, shape and position of the source.
- The physical nature of the contaminant.
- The speed and direction of the source.
- The rate of generation of the contaminant.
- The nature of the operation.
- The positions and movements of plant and personnel.
- Any local air movements.

10.2.3 Ductwork

Ductwork carries the extracted air and the contaminant from the inlet to the air cleaning device. For particulate matter, the air velocity within the duct must be sufficiently high to ensure that the particles remain suspended in the air stream. Recommended transport (duct) velocities for various contaminants are given below.

Type of contaminant	**Duct velocity ($m\ sec^{-1}$)**
Gases (non-condensing)	No minimum limit

Vapours, smoke, fume	10
Light medium density dust (e.g. sawdust, plastic dust)	15
Average industrial dusts (e.g. grinding dust, wood shavings, asbestos, silica)	20
Heavy dusts (e.g. lead, metal turnings and dusts which are damp or that tend to agglomerate)	25

Ductwork should be sufficiently strong, well supported and capable of withstanding normal wear and tear. The number of changes of directions should be kept to a minimum and, where required, they should be made smoothly. Access to ducting may be required to facilitate cleaning, inspection and maintenance.

10.2.4 Air cleaners

There are three basic types of air cleaning devices.

1 Air filters

These are mainly used for cleaning air in ventilation and air-conditioning systems and are designed to handle large air volumes with low resistance to air flow. High resistance high-efficiency particle arresters (HEPA) filters are used for ultra-clean applications and where particularly hazardous dusts are found (e.g. asbestos).

2 Particulate dust and fume collectors

These are designed to extract large quantities of particulate from the airstream at much higher inlet concentrations than can be handled by air filters. These collectors include cyclones, fabric filters, wet collectors and electrostatic precipitators. These are the most common air cleaning devices associated with LEV systems.

3 Devices to remove mists, gases and vapours

Mists, gases and vapours can be removed from an air stream by a variety of means involving chemical absorption, combustion and condensation.

Others points to be considered:

- Greasy or waxy materials may clog filters.
- Abrasiveness of particulate.
- Flammability and explosion potential.
- Corrosiveness and oxidising capacity.
- Gases and vapours will not be removed by particulate filters.
- High temperature materials.

10.2.5 Air movers

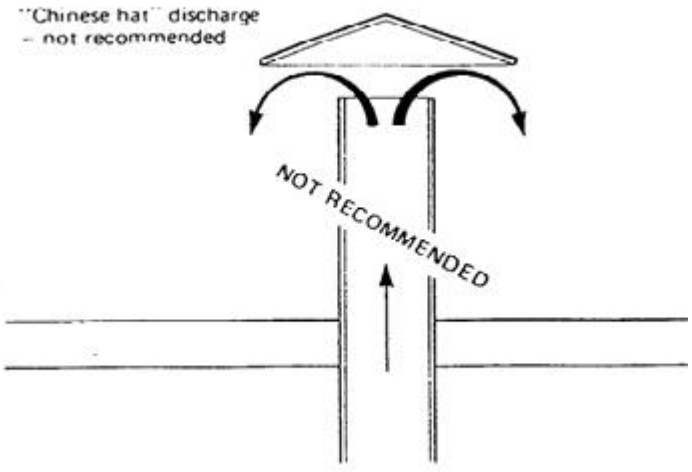
There are many types and sizes of fan, which can generally be grouped into two main categories - centrifugal and axial flow.

1 On a centrifugal fan air is drawn in the centre of the impeller, picked up by the rotating blades and thrown off at high velocity in the fan casing. The casing is designed to collect the air and guide it towards the tangential discharge opening. They can deliver required airflows against considerable resistance. They are used in all but the simplest of LEV systems.

2 Axial fans have a cylindrical casing, and are installed in-line with the ducting. Air passes along the duct and is accelerated by the rotating blades. Axial fans can overcome only low resistances to flow.

10.2.6 Discharge to atmosphere

Additional ductwork may need to be installed downstream of the air mover to ensure that any discharges do not re-enter the building. Discharge stacks may need to be extended above roof level and particular attention should be paid to the design of the discharge terminal. The 'Chinese hat' type terminal should never be used as it deflects the discharged air downwards for possible re-entry into the building, and has a very high flow resistance.



Source: BP International

Figure 10.6 – Discharge to Atmosphere

10.3 Maintenance, Examination and Testing of Ventilation Systems

Local Exhaust Ventilation (LEV) is one of the most effective means available of preventing hazardous materials entering the workplace atmosphere. However, in order to function correctly it must be in good working order. The general features associated with the maintenance, examination and testing of LEV systems are outlined.

10.3.1 Legal requirements

In some countries there is a legal requirement that control measures are maintained in an efficient state, in efficient working order and in good repair. For example in the UK, the COSHH Regulations requires that LEV is examined and tested, at least once every 14 months, and that suitable records are kept for at least 5 years. There is also a requirement to carry out weekly visual examinations.

10.3.2 Regular maintenance

Maintenance should include:

- Regular inspection of the plant, including a weekly check for signs of potential damage, wear or malfunction.

- Monitoring of performance indicators, e.g. air velocities, static pressures, electrical power consumption.
- Routine replacement of components known to have a limited working life.
- Prompt repair or replacement of components which are found to be worn or damaged.

The form of inspection will depend on the type and complexity of the plant. A visual check, at least every week, is essential to identify any obvious faults. This includes checking for:

- Incorrect positioning of hoods.
- Wear, tear and signs of malfunctions or damage to hoods, ductwork and dust collectors.
- Other outward signs of malfunction or damage.

The checking should also include the monitoring of any permanently fitted monitoring devices. A simple record should be kept of weekly inspections together with a written note of faults identified and actions taken to rectify them.

10.3.3 Thorough examination and testing

This is a periodic audit of the LEV system and its performance and will normally comprise:

- A thorough external and, where appropriate, internal examination of all parts of the system.
- An assessment of control, for example, by the use of dust lamps, fixed position air monitoring and / or smoke testing.
- Measurement of plant performance, for example by static pressure measurement behind each hood or enclosure, air velocity at the face of the enclosure or point of emission, pressure drop across filters, air velocity measurement in the duct and / or power consumption.
- Where air is circulated, assessments of the performance and integrity of the air cleaner or filter.

Some LEV systems return filtered air to the workplace and therefore these systems should receive a particularly high standard of maintenance etc.

11 ASBESTOS

11.1 Background

Asbestos is perhaps the most widely discussed hazardous substance. In 1898 the chief factory inspectors report in the UK spoke of “the evil effects of asbestos dust” and detailed a microscopic examination of asbestos revealing “sharp, glass-like, jagged nature of the particles” and the “effects have been found to be injurious”.

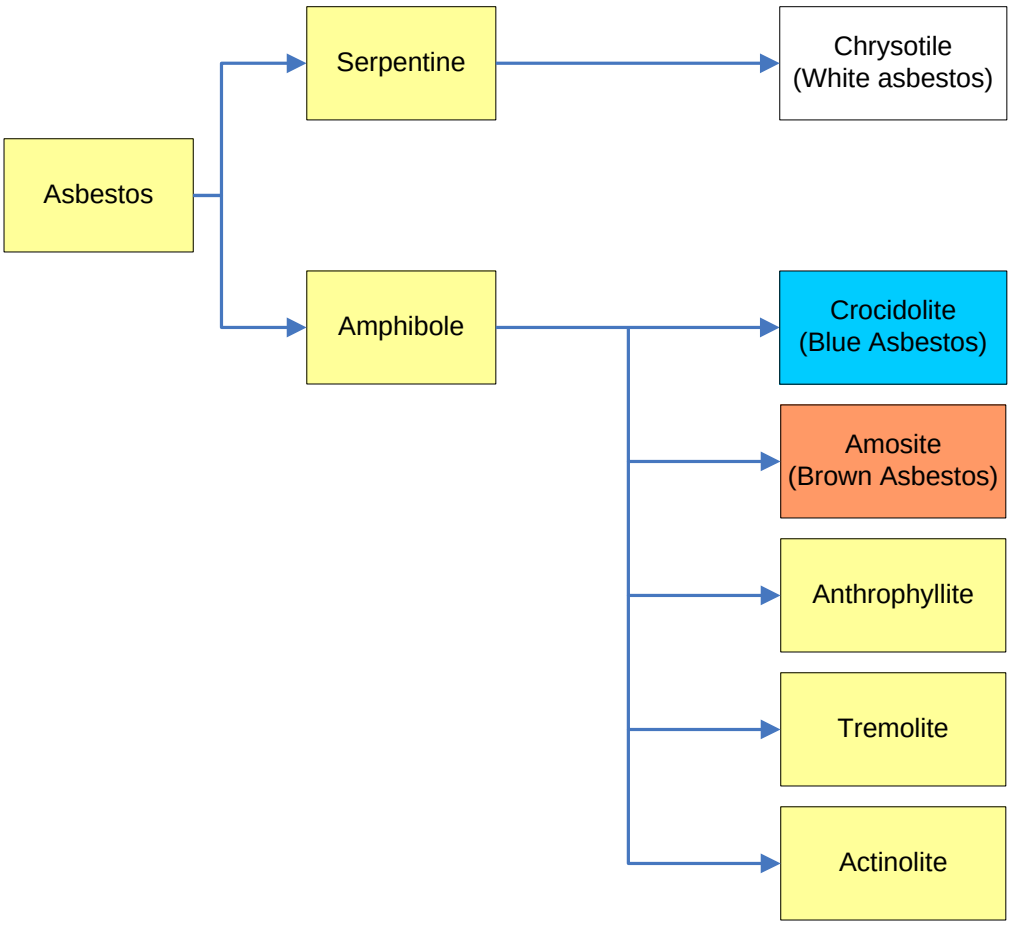
Source: Wikimedia commons – United States Geological Survey

Figure 11.1 – Electron Micrograph of Asbestos Fibres (Anthophylite)

11.1.1 Types of asbestos

The name asbestos refers to a group of naturally occurring, fibrous, crystalline silicates which are mined mainly in Russia, China, Canada and Southern Africa.

All types of asbestos occur as long fibrous crystals, which split longitudinally (i.e. along the length of the fibre to form progressively thinner fibres). The main types of asbestos are shown below:



Source: Adrian Hirst

The two groups of asbestos fibres have different crystalline structures and correspondingly different shapes and properties. When viewed under a microscope, Chrysotile (white asbestos) fibres appear to be slightly curly, whereas, Crocidolite (blue asbestos) fibres are straight and shorter. Amosite (brown asbestos) fibres are similar to Crocidolite but more brittle. It should be noted that colour is not a reliable means of identifying the types of asbestos, especially when it is incorporated into a product.

11.1.2 Properties of asbestos

The main properties, which have led to the extensive use of asbestos, include incombustibility, mechanical strength, chemical resistance, thermal insulation

and low cost. Various types of asbestos may exhibit these properties to different extents, which affects their usage.

11.1.3 Uses of asbestos

The most common applications of asbestos likely to be found on industrial premises are given below, together with the type and approximate content of asbestos. The uses and percentage content of the products listed below are provided for guidance only. Where asbestos is suspected of being present, surveys should be undertaken by competent and approved persons.

Common Applications of Asbestos in Industrial Premises

Product	Type of Asbestos	Approximate Content (%)
Cement Materials e.g. corrugated sheets, water tanks, pipes, prefabricated building components.	Chrysotile (occasionally incorporating Crocidolite or Amosite)	10 - 20
Fire-resistant Insulating Board.	Amosite (occasionally incorporating chrysotile or crocidolite)	15 - 40
Thermal, insulation, lagging, incl. pipe and vessel insulation.	Amosite, chrysotile & crocidolite	1 - 55
Sprayed coatings e.g. applied to structural beams and ceilings as fire protection and / or acoustic and thermal insulation	Amosite, chrysotile & crocidolite	60 - 90
Textiles e.g. heat resistant gloves, fire-blankets, fire-protective clothing & insulation mattresses.	Chrysotile (occasionally Crocidolite)	85 - 100
Jointings & packings e.g. gaskets.	Chrysotile (occasionally Crocidolite)	25 - 85
Friction materials e.g. automotive brake & clutch lining.	Chrysotile	30 - 70
Floor tiles.	Chrysotile	5 - 7
Filler & Reinforcements e.g. in felts, millboards, papers, underseals, mastics, adhesives.	Chrysotile (occasionally Crocidolite for some applications)	1 - 10
Reinforced thermo-setting plastics & battery cases.	Chrysotile, crocidolite & amosite	5 - 20

11.1.4 Airborne asbestos fibres

The physical structure of asbestos enables it to break up into small fibres, which are capable of remaining suspended in the air for long periods. These fibres may be inhaled and some may penetrate to, and be deposited in, the lungs.

A ‘countable’ fibre is defined as a particle having a length: breadth ratio of greater than 3:1, being less than 3 microns in diameter and greater than 5 microns in length.

11.1.5 Exposure to asbestos fibres

Asbestos fibres (asbestos dust) may be emitted into the workplace environment during the manufacture, use, machining (cutting, drilling, etc.), removal and disposal of asbestos-containing materials or products, and due to deterioration in the condition of asbestos containing materials (ACMs) in-situ. Building maintenance workers (plumbers, electricians, etc.) are thought to be particularly at risk as a consequence of the extensive use of asbestos in older buildings. It should be noted, however, that in some parts of the world asbestos is still being manufactured and used. In such cases the risks are likely to be greater due to the lack of a regulatory regime and excessive exposures not always being recognised. Examples of some typical exposures are given below:

Activity	**f/ml**
Dry removal of lagging	Up to 100
Drilling of asbestos insulation board	Up to 10
Hand sawing of asbestos insulation board	Up to 10
Drilling of asbestos cement	Up to 1
Hand sawing of asbestos cement	Up to 1
Use of a circular saw	Up to 20

11.2 Health Hazards of Asbestos

Inhalation of respirable asbestos fibres may give rise to a number of serious diseases.

Asbestosis: Prolonged exposure to airborne asbestos fibres at levels in excess of the commonly adopted Hygiene Standard of 0.1 fibres/ml may lead to local thickening of the lining of the chest (pleural plaques) and to the formation of fibrotic (scar) tissue in the deep lung, resulting in the progressive reduction in elasticity of lung tissue, impairment of respiratory function, and reduced life expectancy.

Cancer of the bronchus and lung: Asbestos workers have been shown to suffer an increased risk of bronchial and lung cancer. Cigarette smoking can also cause these cancers and it has been shown that cigarette smokers exposed to airborne asbestos fibres are at a significantly greater risk of developing cancer than similarly exposed non-smokers (a synergistic effect).

Mesothelioma: Exposure to asbestos, particularly crocidolite and amosite, can result in the development of mesothelioma, an uncommon and usually incurable cancer of the pleura (the lining of the chest wall and lung) or more rarely the peritoneum (the lining of the abdominal cavity). Mesothelioma may develop 20 or more years after a brief period of exposure.

11.3 Asbestos Register

11.3.1 Function of the asbestos register

The function of the Asbestos Register is to record the use presence of all asbestos and asbestos-containing materials at work sites. In areas where asbestos has been used extensively in the past, it may be necessary to develop the Register over a period of time. In the interim, it may be advisable to assume that certain insulation and building materials contain asbestos and, until their identity is established, the appropriate precautions taken. Register information can be used to:

- record the location of all asbestos materials on site.
- ensure that the condition of asbestos-containing materials are frequently inspected and any necessary remedial action is instigated.
- ensure that any work with asbestos or asbestos-containing materials is carried out in an approved manner.

- minimise the acquisition and use of materials or equipment, which may contain asbestos.

11.4 Remedial Treatment of Asbestos Containing Materials

11.4.1 Asbestos removal

Asbestos-containing materials should be removed if they are:

- Damaged and friable, i.e. in an easily crumbled condition, thereby having a potential for releasing airborne fibres.
- Expected to deteriorate in future.
- If it is likely that they will be disturbed during maintenance, construction or demolition.

Asbestos removal work should only be carried out by personnel who have been trained in the correct control measures to minimise both their exposure and those of anyone else who may be in the vicinity of the work. Detailed guidance on suitable methods that can be used to control exposures is available – for example, from HSE in the UK or regulatory authorities.

11.4.2 Asbestos repair / encapsulation

Asbestos materials that are slightly damaged or impractical to remove, due to the function of the material or its location, can be encapsulated to prevent the release of asbestos fibres. This can be performed in several ways depending upon the extent of the damage and the type and function of the asbestos-containing material. Suitable methods include:

- Wrapping the outer surface with, for example, canvas or aluminium.
- Sealing with an encapsulant that seals the fibres together. Several products are available, some of these form a membrane around the external surface of the material and others penetrate the material to bind the fibres together in a matrix.

Asbestos or ACMs that have been subjected to repairs using encapsulation should ideally be scheduled for removal as soon as practicable and subject to enhanced inspection. These should be recorded in the site Asbestos Register.

11.5 Asbestos Management Programme

In practice the management of asbestos in the workplace has proven very difficult so consideration should be given to appointing an asbestos Coordinator who can write and implement an Asbestos Management Programme (AMP).

The Asbestos Coordinator should have the training, experience, resources and authority needed to:

- Understand any applicable laws and regulations;
- Write and maintain the AMP; and
- Choose the right people or contractors to carry out the different parts of the AMP.

The asbestos coordinator should have the authority and resources they need to write the AMP and to make sure that the approved AMP is applied properly.

12 BIOLOGICAL HAZARDS

12.1 Introduction to Biological Hazards

A fundamental difference between chemical and biological hazards is that biological agents, whether bacteria, viruses or moulds have the ability in the right conditions to rapidly replicate themselves. This means that the focus on control is not only avoidance of contact with the agent, but also on ensuring that conditions favourable for growth of the organism are prevented.

The three main categories of biological agents that we will be covering with examples of, are bacteria, viruses and fungi.

1 Bacteria - single celled micro organisms that live in soil, water and air. There are many thousands of different types of bacteria – many are harmless, or even beneficial, but some bacteria are pathogenic - that is they cause disease. Examples of diseases caused by bacteria include Legionnaires disease, various types of food poisoning (e.g. salmonella) and anthrax. Antibiotics are used to treat bacterial infections.

2 Viruses – tiny parasitic organisms that can only reproduce within living cells. They consist of nucleic acids (RNA or DNA) with a protein coat. Largest known virus approx 1000 x smaller than the average bacteria. Viruses cause many diseases including the common cold, influenza, measles, rabies, hepatitis and AIDS. Antibiotics are ineffective against viruses but many viral diseases are controlled by vaccines.

3 Fungi – simple plants lacking chlorophyll and normal plant structures (e.g. leaves, stems etc). Fungi include yeasts, moulds, mildews and mushrooms.

Parasites - organisms that live and feed on or in an organism of a different species and cause harm to the host, are another category of biological agent.

The response of each individual to exposure to micro-organisms depends on his or her state of immunity, i.e. the power of the individual to resist disease. There are many factors involved in immunity including:

- whether the individual has already experienced a particular illness
- immunisation levels
- individual resistance
- fatigue
- age

To simplify how risks from different organisms should be managed they are categorised into different risk groups. Control measures required should be matched to the risk group:

- **Risk Group 1 -** (low individual and community risk). An organism that is unlikely to cause human or animal disease.
- **Risk Group 2 -** (moderate individual risk, limited community risk). A pathogen that may cause human or animal disease and which might be a hazard to laboratory workers, but is unlikely to spread to the community, livestock or the environment. Laboratory exposures may cause serious infection, but effective treatment and preventive measures are available and the risk of spread is limited.
- **Risk Group 3 -** (high individual risk, low community risk). A pathogen that can cause serious human disease but does not ordinarily spread from one individual to another.
- **Risk Group 4 -** (high individual and community risk). A pathogen that usually produces serious human or animal disease and may be readily transmitted from one individual to another, directly or indirectly.

There are also four Biosafety levels which give the containment precautions which need to be used to control different biohazards. The levels of containment range from the lowest biosafety level 1 to the highest at level 4.

- **Biosafety Level 1** – Little containment or segregation of the facility but with precautions such as separation and labelling of waste materials.
- **Biosafety Level 2** – Staff have specific training in handling pathogenic agents, access to the laboratory is limited when work is being conducted, extreme precautions are taken with contaminated sharp items; and certain procedures in which infectious aerosols or splashes may be created are conducted in biological safety cabinets.

- **Biosafety Level 3** – All procedures involving the manipulation of infectious materials are conducted within biological safety cabinets or other physical containment devices, or by personnel wearing appropriate personal protective clothing and equipment. The laboratory has special engineering and design features such as double-door access zones.
- **Biosafety Level 4** – The facility is either in a separate building or in a controlled area within a building. The facility has controlled ventilation maintaining it under negative pressure. All activities are carried out in Class III biological safety cabinets, or Class II biological safety cabinets used with one-piece positive pressure personnel suits ventilated by a life support system.

12.2 Legionella and Humidifier Fever

12.2.1 Legionella

Legionnaire's disease was first recognised in 1976, when an outbreak occurred among delegates attending an American Legion convention in Philadelphia. The causative agent was identified later as *Legionella pneumophila.*

The bacterium causes two patterns of disease in humans; Pontiac Fever (a mild flu-like illness) and Legionnaires Disease. It enters into the body when fine droplets of contaminated water are inhaled. The bacterium is not transmitted from person to person.

Pontiac fever is a short 'self-limiting' illness with a shorter incubation period and milder symptoms than Legionnaires disease. Pontiac Fever does affect a greater percentage of those exposed, but has so far not been fatal.

Legionnaire's disease is an illness characterised mainly by pneumonia and flu-like symptoms. It is fatal in about 10 - 15% of cases. Men are more likely to develop the illness than women; other risk factors include age and general health status.

Legionella are widespread in natural fresh water including rivers, lakes, streams and ponds. There is a strong likelihood of very low concentrations of the bacteria existing in all open water systems, including those of building services. The most common sources of outbreaks of Legionnaires disease

have been cooling towers and water systems in large buildings, particularly hospitals and hotels.

The primary ways of preventing and controlling the spread of Legionnaires disease are to control the initial growth of the bacterium in water systems and prevent the generation of aerosols.

Areas most at risk include:

- Cooling towers
- Water storage tanks and calorifiers
- Hot and cold water services in premises where occupants are particularly susceptible (homes for the elderly, hospitals etc.)
- Humidifiers and or washers that create a spray of water droplets and in which water temperature exceed 20°C
- Spa baths and pools
- Fire sprinkler systems and fountains.

Factors affecting growth include:

- Water temperature **-** Temperatures in the range of 20-45°C favour growth (optimum temperature 37°C). Proliferation of the bacteria is unlikely below 20°C, and the organism does not survive above 60°C.
- Water being stagnant favours multiplication
- The presence of sediment, scale and sludge
- The presence of other micro-organisms (algae, amoeba and bacteria) or a biofilm (a layer of micro-organisms contained in a matrix which may form a slime on surfaces).

Control:

- Measures must be taken to minimise the risk of exposure by preventing the proliferation of Legionella in the system or plant and to reduce exposure to water droplets and aerosol
- Minimise the release of water spray

- Avoid water temperatures between 20°C and 45°C (major control mechanism).
- Avoid water stagnation
- Avoid use of materials that can harbour or support the growth of bacteria and other organisms
- Keep the system clean (avoid sediments etc.)
- Use of suitable water treatment systems including biocides
- Ensure that the system operates safely and correctly and is well maintained.

Sampling to assess water quality is an essential part of the water treatment regime and should include both chemical and microbiological tests.

12.2.2 Humidifier fever

Humidifier fever is associated with exposure to many different types of micro-organisms including various bacteria and fungi found in humidifier reservoirs and air-conditioning units. The micro-organisms have been found in both large ventilation systems as well as in small units. Significant concentrations of these organisms can be dispersed into the environment in the aerosol mist generated by the humidifiers during normal operation.

Humidifier fever generally causes a flu-like illness with fever, chills, headache, muscle ache and fatigue. These symptoms usually occur a few hours after exposure and usually subside within a day or so. However, in some cases it may manifest as an allergic alveolitis.

Controls to prevent humidifier fever centre on ensuring that the bacteria and fungi do not multiply and reach high concentrations in the water reservoir. Approaches include regular cleaning and maintenance schedules, coupled with disinfection.

12.3 Blood Borne Diseases

Transmission in the workplace can occur through sharps injuries and contact of infected blood and other body fluids with mucous membranes or non-intact skin.

The risk of occupational acquisition of a blood borne virus relates to:

- The prevalence of the virus in the patient population
- The efficiency of virus transmission after a single contact with infected fluid / tissue
- The nature and frequency of occupational blood contact
- The concentration of the virus in the blood.

Occupations at greater risk include health care and emergency service personnel as well as those who travel and work in countries which have high prevalence of the illness.

Protection comes from avoidance of blood to blood contact by precautions including:

- Wearing protective gloves and face masks
- Covering cuts and wounds with a waterproof dressing
- Care with sharps
- Ensuring all equipment is appropriately sterilized
- Safe disposal of infected material
- Control of surface contamination
- Good hygiene
- When appropriate, immunisation of ‘at risk’ workers (e.g. hepatitis B).

12.3.1 Hepatitis B

Hepatitis B is a blood-borne and sexually transmitted virus which causes inflammation of the liver. Many infected people have no symptoms, but others have a flu-like illness with nausea and jaundice. Hepatitis B can cause hepatitis (inflammation of the liver) and can also cause long term liver damage.

Hepatitis B is more common in parts of the world such as south-east Asia, Africa, the middle and Far East and southern and eastern Europe. WHO estimates that there are 350 million chronically infected people world-wide.

The virus may be transmitted by contact with infected blood or body fluids from an infected person. The failure to clear hepatitis B infection after six months

leads to the chronic carrier state. Many people who become chronic carriers have no symptoms and are unaware that they are infected.

General precautions include protecting against blood to blood contact. In addition all healthcare workers should be immunised against hepatitis B infection and should be shown to have made a serological response to the vaccine. Universal precautions should be adhered to in the hospital setting.

12.3.2 Hepatitis C

Hepatitis C is a blood-borne virus which causes inflammation of the liver. There is no vaccine available to prevent hepatitis C infection. Hepatitis C infection affects different people in different ways; many experience no symptoms at all while others experience extreme tiredness. Reported symptoms include fatigue, weight loss, nausea, 'flu-like' symptoms, problems concentrating, abdominal pain and jaundice.

It is estimated that around 15-20% of infected people clear their infections naturally within the first 6 months of infection. For the remainder, hepatitis C is a chronic infection that can span several decades and can be life-long

In the 80-85% of individuals who fail to clear their infections naturally, the outcome of infection is extremely variable. Many people never develop any signs or symptoms of liver disease in their lifetime, and may not even know that they have been infected. Other people go on to develop serious liver disease.

The World Health Organisation estimates that there are 170 million carriers of hepatitis C worldwide. The virus is spread when blood from an infected person gets into the bloodstream of another. Prevention is centred on stopping the blood from infected individuals from coming into contact with others.

Injecting drug users are at high risk of infection, sterile injecting equipment should always be used. In a health care setting, universal precautions should be adhered to; all blood and body fluids should be treated as potentially infectious at all times.

12.3.3 HIV - (Human Immuno-deficiency Virus)

HIV is the infection which through progressive destruction of specific immune cells leads to AIDS. HIV is a sexually transmitted and blood-borne virus.

- People with HIV usually have no symptoms for a prolonged period of time, while the virus acts slowly to weaken the body's immune system
- When a person's immune system has been broken down, he or she is susceptible to other illnesses, especially infections (e.g. tuberculosis and pneumonia) and cancers, many of which are not normally a threat to a healthy person. At that severe stage of infection the person is often diagnosed as having AIDS (Acquired Immunodeficiency Syndrome)
- Usually the cause of illness and eventual death in a person with HIV is not the virus itself, but illnesses to which the virus has made the person vulnerable. With treatment a person with AIDS may recover from an illness, but will usually succumb to another. People with HIV infection will almost certainly die prematurely.

HIV is a serious infection. Without treatment most people are expected to die from their infection.

Currently there is no vaccine or cure for HIV. However, there is now treatment called highly active antiretroviral treatment (HAART). The treatment suppresses the HIV virus and can reverse the damage to the immune system for some time, prolonging the lives of those infected. The virus is continually changing, sometimes becoming resistant to current drugs, so HAART may not be a long term solution and it is not a cure.

12.4 Zoonoses

Zoonoses are infections that are naturally transmitted from animal to humans. There are over 150 known zoonoses which range from ring worm to anthrax and rabies. Zoonoses primarily affect people who work closely with animals and animal products such as farm workers, laboratory workers, vets, forestry workers and those working in the wool and tanning industries.

Infection can occur through contact with:

- Animal and animal products (meat, bone meal, fur, feathers, skins, wool)
- Animal tissue & body fluids (blood, saliva etc)
- Birth products (placenta etc)
- Waste products (urine, dung, faeces)
- Contaminated materials (ground, fencing, clothing etc)

Infection may occur via inhalation, ingestion or through broken skin or contact with mucous membranes.

12.4.1 Anthrax (ACDP Group 3)

The disease is caused by the spore forming bacteria Bacillus anthracis. Many animals may carry the anthrax bacteria or spores including cattle, horses, goats and sheep. Spores on hides, wool and animal hair may be a problem for subsequent manufacturing processes using these products. The spores are very resistant and grazing land may remain infected for many years.

There are two main forms of anthrax disease that may occur in humans; cutaneous anthrax(a skin disease) or pulmonary anthrax (affecting the lungs).

Cutaneous – the most common form following skin contact. A red spot at the site of the infection develops to a pustule with a black centre. Without treatment, the lesion normally begins to heal after about 10 days. In a small proportion of cases, bacteria from the lesion enter the blood stream producing a septicaemia which may be fatal.

Pulmonary or inhalation anthrax – due to the inhalation of spore containing material. The spores enter the lungs and are taken up by the immune system. Initial symptoms are similar to those of influenza but these develop rapidly as the spores germinate in the lymphoid tissue, multiply and produce a powerful toxin. The disease progresses with breathing difficulty, skin discolouration and disorientation, leading to coma and death within 24 - 48 hours.

The main occupations at risk include agricultural workers, abattoirs, animal by-product processing, vets and the wool and tanning industries.

Control measures include elimination of anthrax in farm animals, high standards of personal hygiene including the covering of cuts with waterproof dressings and information and training.

12.4.2 Leptospirosis (Hazard group 2)

The main form of leptospirosis is Weil's disease which is a potentially life threatening illness caused by the Leptospira bacteria passed from rats via urine. Symptoms include flu-like symptoms such as fever, headache, vomiting, muscle pains, pneumonia and possible kidney failure and death.

The disease may be transmitted through contact with rat's urine or watercourses contaminated with it. It may enter the body through abrasions, cuts in the skin and through the lining of the mouth, nose and conjunctiva.

At risk occupations include farmers, farm workers, fish farmers, construction workers, water industry workers, leisure industry workers, sewer workers and laboratory workers.

12.4.3 Salmonellosis

Salmonellosis is the name given to an infection caused by any of the Salmonella group of bacteria. Salmonella bacteria may be carried by most types of farm animal. Infections are usually associated with ingestion of contaminated food or may result from contact with farm animal dung e.g. using contaminated hands to eat, drink or smoke.

Symptoms develop suddenly about 12 to 24 hours after infection and include malaise, headache, nausea, abdominal pain, diarrhoea and fever. Symptoms normally last 2 to 3 days but can persist longer. Dehydration or septicaemia (blood poisoning) may also occur.

12.4.4 Q Fever

Q fever is an infection caused by *Coxiella burnetii*, a type of bacterium found worldwide except New Zealand. The infection is almost always related to direct or indirect contact with animals such as cattle, sheep or goats, although a wide range of animals including cats, dogs and kangaroos may carry the infection.

12.5 Moulds

Moulds are microscopic fungi that grow in the form of branching threads or filaments. They reproduce by means of microscopic spores which can give rise to new mould growth which in turn can produce millions of spores.

If inhaled, fungal spores may cause allergic rhinitis or other allergic responses such as alveolitis.

Moulds can be found wherever there is moisture, oxygen and a source of nutrients. They grow on dead organic matter such as on rotting vegetation and dead leaves, especially in moist shaded areas.

In industrial situations bakeries, breweries, dairies and greenhouses are examples of ideal places for moulds to grow. Any areas where fresh food is stored are also potential sites where mould growth is possible. Well documented examples include grain stores or silos, particularly if the grain has been stored slightly damp.

Indeed, in any indoor environment, mould may grow in damp places such as in poorly ventilated basements, bathrooms, and humidifier and air-conditioning units. Indeed they can thrive in any area where surfaces or materials are damp. Reduction of moisture and humidity levels is the most important factor in mitigating mould growth.

12.6 Pandemics

A pandemic can be defined as an epidemic of an infectious disease that spreads over a wide geographic area (several countries, a continent or even worldwide) and affects a large proportion of the population.

A pandemic can start when the following conditions occur:

- Emergence of a disease, or a particular strain of a disease, new to a population
- The agent affects humans, causing serious illness
- The agent spreads easily and sustainably among humans.

There have been many pandemics in the past including those caused by typhoid, cholera, bubonic plague and influenza viruses. Bubonic plague killed

tens of millions of people in Europe in the middle ages. The most severe influenza virus pandemic recorded occurred between 1918 and 1920 when 'Spanish Flu' was estimated to have killed at least 40 million people. More recently 'Hong Kong Flu' was estimated to have resulted in about 1 million deaths in the late 1960's.

New strains of the influenza virus continue to emerge in animals with the potential that any particular new strain could cause a future pandemic. These new strains of the influenza virus occur when they are transmitted to humans from another animal species such as pigs, chickens or ducks.

A recent example of a new variant strain of influenza virus is H5N1 ('Bird Flu') which was found in 2004 in birds in Vietnam. By 2007 numerous cases had been found across Asia and much of Europe. There have been human fatalities among people who have had close contact with infected birds. There has been no, or limited, transmission of the disease from person to person.

H5N1 bird flu is not categorized as a pandemic as the virus cannot yet spread easily or sustainably among the human population. However, if the virus combines with a human influenza virus strain a new sub-type may evolve that could be highly contagious in humans.

Another concern related to pandemics is that many micro-organisms are becoming resistant to many of the antibiotics currently in use. These antibiotic resistant micro-organisms (sometimes termed 'superbugs') may contribute to the re-emergence of many diseases which are currently well controlled e.g. tuberculosis.

A range of common bacteria are also becoming more resistant to antibiotics leading to a rise in the number of healthcare acquired infections. A well known example of this is methicillin-resistant Staphylococcus aureas (or MRSA).

12.7 Genetic Modification

Genetic modification is a technology developed in the past 30 years for altering the characteristics of living organisms, such as plants or animals. It involves the addition of new genetic material into an organism's genome.

Genetically modified organisms (GMO) have widespread applications. They are used in biological and medical research, production of pharmaceutical drugs and agriculture. So far the largest application of genetic modification has been in the production of food crops which are more resistant to disease, or to insect attack, or with increased crop yields.

The benefits of genetic modification are potentially enormous. Potential benefits in the future include new treatments for diseases, crops that are more resistant to pests and diseases, food of greater nutritional value and the production of pharmaceuticals from plants.

However, there are a number of concerns with regard to this technology. Some people have concerns in principle about the alteration of biological systems that have evolved naturally. In addition, many people are concerned that we are not yet able to understand all the potential ramifications of genetic manipulation.

A particular concern has been the possibility of genetically modified plants cross pollinating (or 'outcropping') with other 'natural' crop varieties to produce another variety whose properties have not been assessed. The safety of genetically modified organisms in the food chain has also been questioned.

As a result of these concerns, strict controls have been implemented in the use and production of genetically modified organisms.

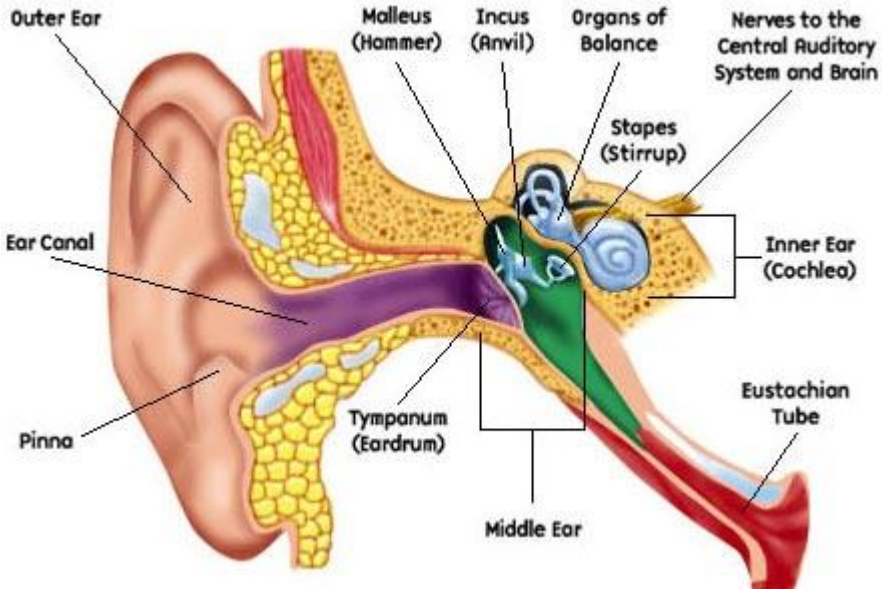
13 NOISE

13.1 Background

It has become common practice to define noise, as unwanted sound and it has been known for many years as a cause of hearing loss in industry. So what exactly is sound and how do we hear it? Sound is the sensation that is perceived by the human or animal brain as a result of longitudinal vibrations of molecules of the air impinging on the ear.

Sounds are actually pressure waves caused by a vibrating body, which radiate from the source. The human ear can sense and perceive small and rapid pressure waves as sound (noise) and convey information on their size (amplitude) and frequency to the brain.

13.2 The Ear



Source: Wikimedia Commons

Figure 13.1 - A Simplified Diagram of the Human Ear

The external ear, i.e. the part we can see, receives the pressure waves and passes them along the auditory canal to a membrane - the tympanum (eardrum), which is situated just inside the skull for protection. The eardrum vibrates in response to the sound pressure waves and this vibration is transmitted through the 3 small bones of the middle ear malleus, incus and

stapes (hammer, anvil and stirrup) to another membrane, the oval window of the inner ear.

The middle ear also contains the eustachian tube, which provides an opening to the throat and so maintains the middle ear at atmospheric pressure. This pressure equalisation is necessary because the eardrum is required to respond to rapid, small fluctuations in pressure, not to absolute pressure.

The oval window in turn passes the vibrations on to the cochlea, a snail shaped organ containing liquid and some 25,000 receptive cells (nerve endings). The vibrations generate pressure waves in the liquid of the cochlea, and these stimulate the nerve endings which transmit corresponding electrical signals to the brain. Each receptive cell has its own pitch response and thus is able to analyse and separate out a mixture of incoming signals into their individual frequency components. This facility enables the human ear to identify individual notes amongst the incoming volley of sound.

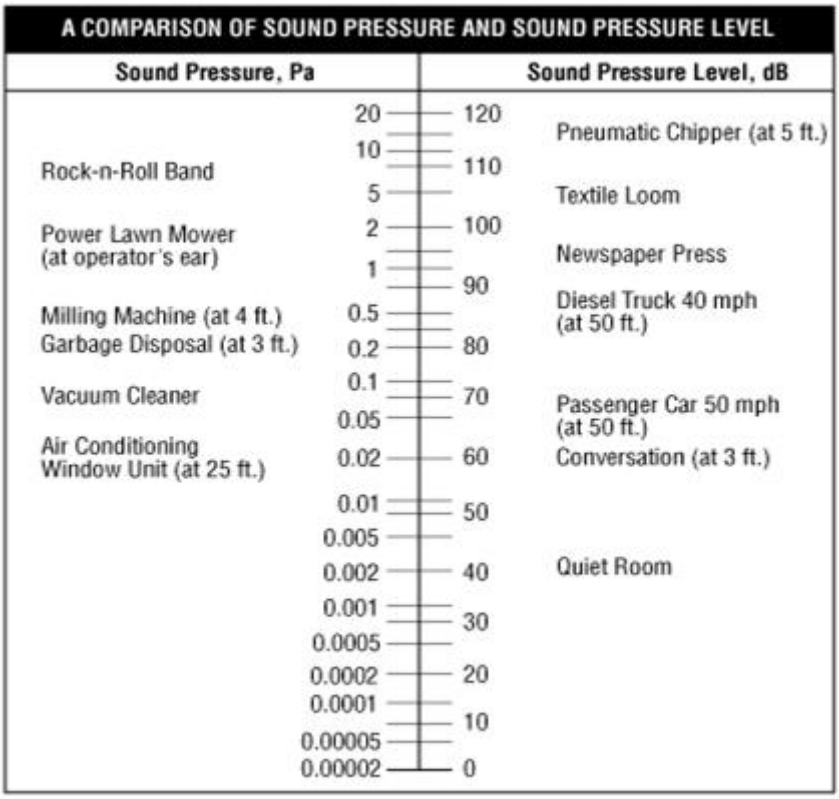
13.3 Audible Sound

Two key features of sound are frequency and intensity. The number of pressure waves vibrations per second is known as the frequency, and is expressed in the unit Hertz (Hz), the more fluctuations per second the higher the pitch of the sound. The frequency range of the human ear is normally quoted as being between 20 Hz and 20,000Hz (20 KHz). Middle C in music is at approximately 260 Hz (musicians opinions vary between 255 – 278 Hz), and doubling the frequency raises the pitch one octave, hence the octave above middle C (260 Hz) has a frequency of 520 Hz.

Intensity (I) refers to the amplitude (size) of the pressure waves and is defined as the average amount of energy passing through a unit area in unit time, expressed in watts per metre squared (W/m^2).

It becomes very complicated to quote noise levels in measurements of sound pressure (Pascals) or intensity (W/m^2), as the numbers are very unwieldy. We therefore relate them to a reference level (in this case, the threshold of hearing) and using a logarithmic scale for the result, a much more manageable figure can be produced. This is called the decibel which is one tenth of a Bel. The

decibel (dB) has no dimensions; it is just a unit of comparison arranged in a logarithmic scale, so that increasing the number corresponds to a multiplication of intensity. The loudness of noise is a function of both the intensity and the frequency.



Source: Canadian Centre for Occupational Health and Safety

13.4 Health Effects of Excessive Noise

It has long been known that regular exposure to high intensity noise can result in damage to the hearing mechanism, the degree of damage being proportional to the total integrated noise energy incident upon the ears. The damage is related to the intensity, nature (continuous or intermittent) and duration of the noise exposure, and has microscopically visible effects on the inner ear that are essentially irreparable and incurable. There are five possible health effects of noise:

1 **Noise Induced Hearing Loss (NIHL)** is a cumulative effect from repeated exposure. It is due to damage to the hair cells of the cochlea in the inner ear. First indication of hearing loss occurs with a reduction in the ability to

hear around the 4 kHz frequency range. Over time, if the exposure continues, the noise-induced hearing damage shows as an increase in the depth of the hearing loss and a widening of the 4 kHz notch to both lower and higher frequencies.

2 Tinnitus - Noise heard in the ear without an external cause; it frequently accompanies deafness.

3 Temporary Threshold Shift (TTS) - Damage to the hair cells of the inner ear which can impair hearing temporarily, resulting from exposure to high noise levels. Recovery occurs once exposure to high noise levels is reduced, typically over a period of several hours.

4 Physical damage to the eardrum and ossicles induced by excessively high noises e.g. explosions. This type of hearing loss is referred to as conductive hearing loss.

5 Annoyance stress, which is difficult to measure and quantify, but may cause psychological effects such as poor concentration, irritability and stress.

Besides causing temporary or permanent hearing loss, noise can also be a safety hazard. Most obviously, noise interferes with verbal communication, leading to errors and failures to respond to warning sounds and shouts.

Hearing damage can be induced by continuous exposure to levels in excess of 85 dB(A) but an individual's response varies within a population. Continuous exposure to levels in excess of 90 dB(A) is estimated to result in 20% of the exposed population suffering from NIHL.

Regular exposure to **High Intensity Noise**, i.e. greater than 80 dB(A), will almost invariably produce some degree of noise-induced hearing loss in those whose hearing is susceptible. There is no way to predict in advance which particular individuals are more likely to suffer from noise-induced hearing loss.

Moderate Intensity Noise, i.e. 55-80 dB(A), although not a potential hazard to hearing, may adversely affect concentration and will interfere with speech communication if greater than 65 dB(A).

Low Intensity Noise, i.e. less than 55 dB(A), may still result in complaints from the general public of 'annoyance' such as sleep disturbance.

13.5 Addition of Sound Levels

When two sounds are being emitted at the same time their total combined intensity is not the numerical sum of the decibel levels of each sound. For accurate calculations they must be added as logarithms. Alternatively a reasonable approximation of additions of decibel levels can be made using the table below:

Difference in dB (A)	Add to the Higher
0 or 1	3
2 or 3	2
4 to 9	1
10 or more	0

Thus if two machines are both emitting noise levels of 90dB(A) the sum total noise level is 93 dB(A). N.B. A doubling of the sound level results in an increase of 3dB(A).

13.6 Frequency Analysis

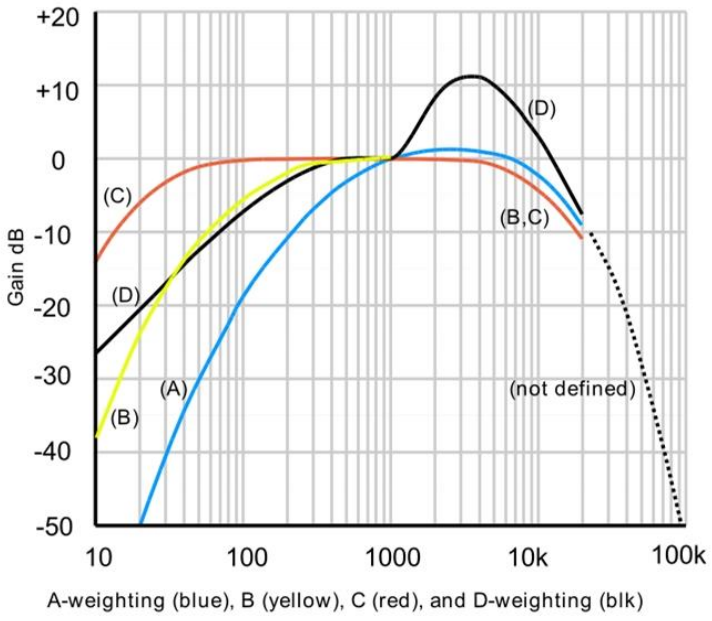
Unless a sound is a pure tone, which is unusual, most noises are made up of sounds of many frequencies and intensities, and when assessing noise for health or annoyance reasons it is useful to understand what the levels are over a range of frequencies, that is, to produce a sound spectrum. For convenience it is usual to divide the range of frequencies into octave bands by using an instrument which measures the intensities over an octave, and quoting the result as the intensity at a particular mid-octave frequency. The mid-octave frequencies chosen for this are as follows:

31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz and sometimes 16 kHz

Thus a noise spectrum will quote the intensities at each of the above mid-octave frequencies. The human ear is most sensitive to frequencies between 20 Hz - 20 kHz of which the frequency of speech lies between 500 Hz - 4 kHz, the vowel sounds being at the lower frequencies and the consonants at the higher.

13.7 Decibel Weightings

As noise is a combination of sounds at various frequencies and intensities, the noise intensity can be either expressed as a spectrum, or as a combination of all frequencies summed together in one value. As the human ear is more sensitive to certain frequencies than others, it is possible to make allowances for that in the electronic circuitry of a sound level meter. That is, certain frequencies are suppressed whilst others are enhanced in order to approximate to the response of the human ear. This technique is known as weighting, and there are A, B, C and D weightings available for various purposes. The one that has been adopted for a workplace spectrum is given in dB(A). If the A-weighting is applied to a measurement in dB, the corresponding level in dB(A) is a good indication of loudness as perceived by the human ear.

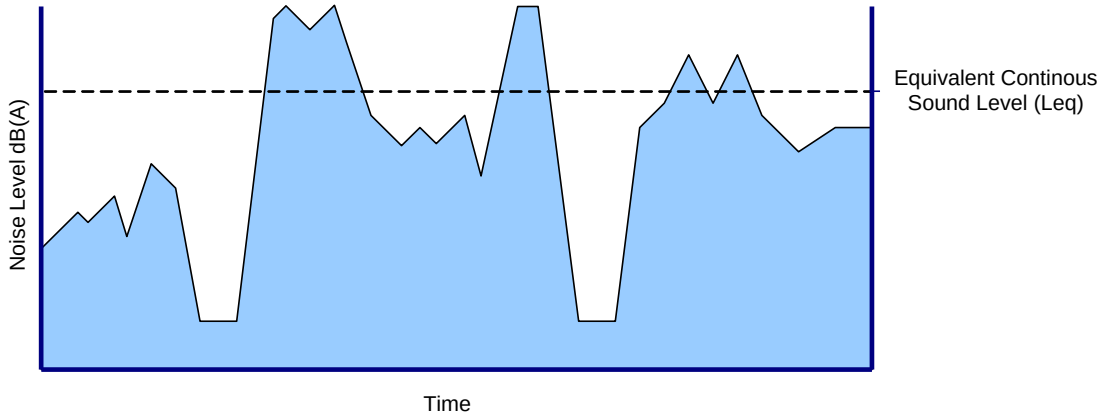


Source: Public Domain Wikimedia Commons

Figure 13.2 - Graph Showing Frequency Weightings and Relative Response

13.8 Equivalent Continuous Sound Level (Leq)

Expressing noise exposure from the standpoint of its potential to cause noise-induced hearing loss is simplified by using dB(A) instead of dB to remove the frequency dependent factor. However, as well as varying in frequency, industrial noise varies in its intensity throughout the day and from day-to-day and is often intermittent in nature. Some sort of average is therefore needed and the equivalent continuous sound level (Leq) has been established for this purpose.



Source: Adrian Hirst

Leq can be defined as the steady sound pressure level, which over a period of time has the same energy content and consequently the same hearing damage potential, as the actual fluctuating noise.

13.9 Noise Dose

In Europe the Physical Agents (Noise) Directive (2003/10/EC) specifies that an employee's daily personal noise exposure ($L_{EP,d}$) should not exceed 85 dB(A). This limit is equivalent to an Leq of 85 dB(A) for 8 hours per day, and represents a Noise Dose of 100%. By utilising the energy concept of the Leq an increase of 3 dB in the sound pressure level halves the allowable duration of exposure. For example, an increase in sound level from 85 dB(A) to 88 dB(A) must be accompanied by a halving of the exposure duration from 8 hours to 4 hours.

Duration per Day (hours)	European Limit (Leq) dB(A)
16	82
8	85
4	88
2	91
1	94
30 mins	97
15 mins	100
7.5 mins	103
3.75 mins	106

13.9.1 Calculating Lep,d

A variety of spreadsheets and nomograms are available for calculating Lep,d. See: http://www.hse.gov.uk/noise/calculator.htm (accessed March 2016)

13.10 Noise Limits

In Europe the Physical Agents (Noise) Directive also places duties on employers in the individual countries as follows:

- The employer is obliged to assess the risks associated with exposure to noise
- Protect employees from exposure to noise by:
- Eliminating and controlling noise risks
- Providing appropriate hearing protection
- Provide appropriate information, instruction and training to employees about the risks, control measures, hearing protection and safe working practices.
- Provide health surveillance (hearing checks) for employees who are at risk.
- Undertake maintenance of equipment, in particular on any equipment which is provided to control noise.
- Review the risk assessment and appropriate actions on a regular basis (normally at least every two years).

The regulations specify action and limit values, as follows:

- **Lower exposure action values:** a daily or weekly personal noise exposure of 80dB (A-weighted) and a peak sound pressure of 135dB (C-weighted).
- **Upper exposure action values:** a daily or weekly personal noise exposure of 85dB (A-weighted) and a peak sound pressure of 137 dB (C-weighted).
- **Exposure limit values:** a daily or weekly personal noise exposure of 87dB (A-weighted) and a peak sound pressure of 140dB (C-weighted).

13.10.1 Other limits

Noise limits have become more stringent during the past two decades. In Europe a limit of 85 dB(A) Lep,d is used, whereas a limit of 90 dB(A) is specified in Canada. In the USA a more complex set of criteria is used which correlates dose with sound pressure level and time. This is known as a 5 dB doubling concept and is not normally used outside of the USA.

From a practical point of view the standard adopted in a company, or nationally, and the extent to which that standard is achieved by engineering control measures is dependent on an interpretation of the risk assessment, and then on what is deemed to be 'reasonably practicable' to implement.

13.11 Hearing Conservation

The aim in introducing hearing conservation programmes in industry is to prevent occupational hearing loss by ensuring the assessment and control of exposure to excessive workplace noise. This can be achieved by programmes that incorporate the following essential features.

13.11.1 Assessment of workplace noise

The primary interest as far as workplace noise is concerned is with occupational noise exposure and compliance with an occupational noise exposure limit. Therefore a noise survey should be undertaken in areas where it is suspected that persons could be exposed to workplace noise in excess of the noise exposure limit, i.e. the First Action Level in EC member countries.

In workplaces where the noise levels are reasonably constant, the survey should establish a noise level contour map, the typical full shift individual noise exposures for the jobs concerned, or both. Although compliance with the noise exposure limit is the primary concern, this may be achieved by specifying and ensuring compliance with a work area limit that is numerically equal to the noise exposure limit (ie the use of an administrative control). Hence the contour approach. Three circumstances could prevail:

1 If only the contour approach is adopted, locations where the noise level is numerically equal to or greater than the noise exposure limit should be designated clearly, e.g. as Noise Hazard Areas. No person should be permitted to enter these areas without wearing suitable hearing protection irrespective of the duration of stay.

2 If the typical full shift individual noise exposures are determined, these should be compared with the noise exposure limit. For those jobs for which the limit is normally expected to be exceeded, suitable hearing protection should be worn in areas where high noise levels prevail.

3 If both a noise contour map and noise exposure data are obtained, a noise level numerically higher than the noise exposure limit may be used for defining designated areas, provided it can be shown that the noise exposures are consistently below the noise exposure limit.

Noise levels may be determined using a simple sound level meter (Type 1 or Type 2), but it is essential that the instrument is used correctly if meaningful data are to be obtained, e.g. attention to calibration, account taken of type of noise, etc.

In workplaces where the noise levels fluctuate (e.g. workshop areas) the survey should establish the typical full shift individual noise exposures for the jobs concerned for comparison with the noise exposure limit. For those jobs or job elements for which the limit is normally expected to be exceeded, suitable hearing protection should be worn.

Apart from checking compliance with an exposure criterion, noise exposure measurements are also useful for indicating priority areas for noise control, for

highlighting those personnel most at risk, and for hearing conservation education purposes.

13.11.2 Control of workplace noise

Where engineering control is indicated to minimise workplace noise, the following general approaches are recommended, in decreasing order of preference:-

- Reduction of noise at source - best achieved at the design stage.
- Enclosure of noisy equipment - although heat dissipation and access for maintenance can be a problem.
- Screening of noisy equipment from the worker and or increased separation of the worker from the noise source(s).
- Absorption of sound by the cladding of appropriate surfaces with sound absorbent material where reverberation can be a problem.

These measures should be coupled with regular maintenance of machinery as this can contribute significantly to minimising noise emission.

Noise specifications should be developed for all new machinery. These should take account of the existing workplace noise environment and the prevailing noise exposure limits.

13.11.3 Protection of personnel at risk

It is necessary to protect the worker from exposure to excessive noise in the work environment if engineering measures and or other means of control are insufficient or not reasonably practicable. One or more of the following approaches may be adopted:

- Provision of Noise Refuges in designated areas, e.g. in boiler houses. If 50 per cent of the working day is spent in the acoustic refuges, exposure is effectively halved – that is, the noise dose is reduced by 3 dB(A).
- Alteration of the Work Pattern, e.g. via job rotation (although this may be difficult to administer) to reduce the exposure time in designated areas and so reduce exposure.

- Use of Personal Hearing Protection Devices, e.g. ear muffs, ear plugs. The appropriate selection, correct use and regular maintenance of these devices are of paramount importance to ensure that efficient protection is achieved. Where available, real-world attenuation data should be taken into account in the selection procedure.

13.11.4 Information instruction and training

All persons who are potentially exposed to noise at work in excess of the noise exposure limit should be instructed in the risk of hearing loss, the preventive measures and their role in the hearing conservation programme.

Instruction to employees potentially at risk should include information on:-

- The nature of noise and the mechanism of hearing.
- The effects on hearing of exposure to noise in excess of the noise exposure limit.
- The principles of hearing conservation.
- The requirements for the effective implementation of the hearing conservation programme.

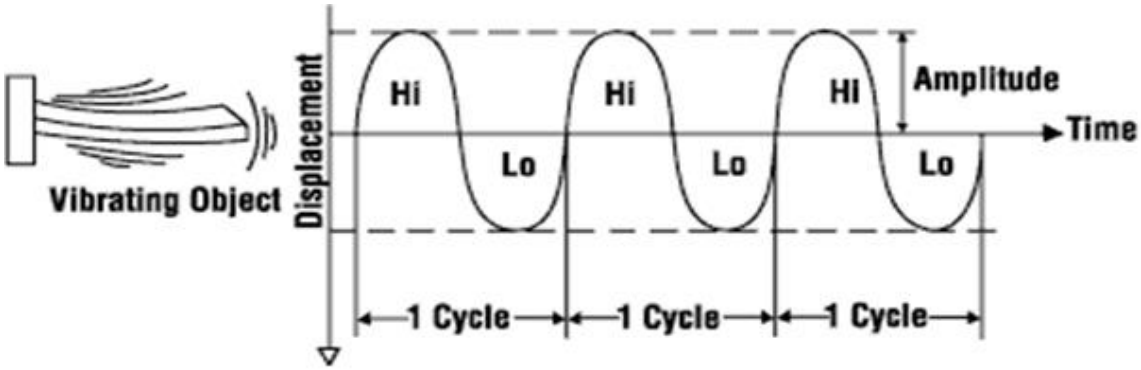
14 VIBRATION

14.1 Introduction

Vibration is the mechanical oscillations of an object about an equilibrium point. The oscillations may be regular such as the motion of a pendulum or random such as the movement of a tyre on a gravel road. The study of health effects of vibration require measurement of the overall "pressure waves" that are generated by vibrating equipment or structures.

Vibration enters the body from the part of the body in contact with vibrating equipment. When a worker operates hand-held equipment such as a chain saw or jackhammer, vibration affects hands and arms. Such an exposure is called hand-arm vibration exposure. When a worker sits or stands on a vibrating floor or seat, the vibration exposure affects almost the entire body and is called whole-body vibration exposure.

If we could watch a vibrating object in slow motion, you could see movements in different directions. Any vibration has two measurable quantities. How far (amplitude or intensity), and how many times the object moves in a defined period (frequency) helps determine its vibrational characteristics. The terms used to describe this movement are frequency, amplitude and acceleration.



Source: Canadian Centre for Occupational Health and Safety

Figure 14.1 - Representation of the Measures of Vibration Exposure

14.1.1 Frequency

A vibrating object moves back and forth from its normal stationary position. A complete cycle of vibration occurs when the object moves from one extreme position to the other extreme and back again. The number of cycles that a vibrating object completes in one second is called frequency. The unit of frequency is hertz (Hz). One hertz equals one cycle per second.

14.1.2 Amplitude

A vibrating object moves to a certain maximum distance on either side of its stationary position. Amplitude is the distance from the stationary position to the extreme position on either side and is measured in metres (m). The intensity of vibration depends on amplitude.

14.1.3 Acceleration (measure of vibration intensity)

The speed of a vibrating object varies from zero to a maximum during each cycle of vibration. It moves fastest as it passes through its natural stationary position to an extreme position. The vibrating object slows down as it approaches the extreme, where it stops and then moves in the opposite direction through the stationary position toward the other extreme. Speed of vibration is expressed in units of metres per second (m/s).

Acceleration is a measure of how quickly speed changes with time. Acceleration is expressed in units of metres per second per second, or metres per second squared (m/s^2). The magnitude of acceleration changes from zero to a maximum during each cycle of vibration. It increases as the vibrating object moves further from its normal stationary position.

14.2 Exposure to Vibration

Exposure to vibration normally occurs during the operation of powered machinery such as hand tools or whilst travelling on vehicles. Some examples of exposure are given below. Vibration tends to be classified into the following types depending upon the nature of the exposure.

Hand-arm vibration is mechanical vibration, which when transmitted to the human hand-arm system, can result in vascular, bone or joint, neurological or muscular disorders.

Whole-body vibration is the mechanical vibration that when transmitted to the whole body can result in lower-back disease and trauma of the spine.

Examples of occupational vibration exposure

Industry	Type of Vibration	Common Source of Vibration
Agriculture	Whole body	Tractors
Boiler making	Hand-arm	Pneumatic tools
Construction	Whole body Hand-arm	Heavy equipment vehicles Pneumatic tools, Jackhammers
Diamond cutting	Hand-arm	Vibrating hand tools
Forestry	Whole body Hand-arm	Tractors Chain saws
Foundries	Hand-arm	Vibrating cleavers
Furniture manufacture	Hand-arm	Pneumatic chisels
Iron and steel	Hand-arm	Vibrating hand tools
Lumber	Hand-arm	Chain saws
Machine tools	Hand-arm	Vibrating hand tools
Mining	Whole body Hand-arm	Vehicle operation Rock drills
Rivetting	Hand-arm	Hand tools
Rubber	Hand-arm	Pneumatic stripping tools
Sheet Metal	Hand-arm	Stamping Equipment
Shipyards	Hand-arm	Pneumatic hand tools
Shoe-making	Hand-arm	Pounding machine
Stone dressing	Hand-arm	Pneumatic hand tools
Textile	Hand-arm	Sewing machines, Looms
Transportation	Whole body	Vehicles

14.3 Health Effects of Vibration

Vibration induced health conditions progress slowly. In the beginning it starts as a pain. As the vibration exposure continues, the pain may develop into an injury or disease. Pain is the first health condition that is noticed and should be addressed in order to stop the injury.

Vibration-induced white finger (VWF) is the most common condition among the operators of hand-held vibrating tools. Vibration can cause changes in tendons, muscles, bones and joints, and can affect the nervous system. Collectively,

these effects are known as Hand-Arm Vibration Syndrome (HAVS). The symptoms of VWF are aggravated when the hands are exposed to cold. Workers affected by HAVS commonly report:

- Attacks of whitening (blanching) of one or more fingers when exposed to cold.
- Tingling and loss of sensation in the fingers.
- Loss of light touch.
- Pain and cold sensations between periodic white finger attacks.
- Loss of grip strength.
- Bone cysts in fingers and wrists.

The development of HAVS is gradual and increases in severity over time. It may take a few months to several years for the symptoms of HAVS to become clinically noticeable. HAVS is a disorder, which affects the blood vessels, nerves, muscles and joints of the hand, wrist and arm and it can become severely disabling if it is ignored. Vibration white finger (VWF) is a common complaint for workers who regularly use power tools and or drills, which can be triggered by cold or wet weather and result in severe pain in the affected fingers.

14.4 Measurement of Vibration

Vibration is usually measured by the use of accelerometers connected to something similar to a sound level meter. The measurement probe needs to be small and light so as not to alter the vibration pattern of the machine being measured; or if it is attached to the hand of a worker, the measured acceleration. Unlike sound level measurements, vibration measurements can have a subjective element to them in that the accelerometer may be held against a vibrating tool by hand; may be fixed to it for example by plastic ties; or may be fixed to the operator's hand. These alternatives can give different results and expertise is needed to ensure consistent and meaningful results.

15 THERMAL ENVIRONMENT: PRINCIPLES, EVALUATION AND CONTROL

The human body can be considered as a processing plant, using complex chemical reactions to produce mechanical energy; as a consequence of the inevitable inefficiency of these reactions heat is produced as a by-product. In order to function effectively we need to maintain our bodies at a constant temperature within the range 36.5 - 37.5^{o}C.

15.1 Human Response to the Thermal Environment

Temperature regulation centres in our brain are sensitive to small changes of blood temperature and also get feedback from sensory nerves at the skin, our brains then use this information to adjust our bodies responses to heat.

15.1.1 Physiological responses to heat

When exposed to heat the blood vessels in our skin expand and our pulse rate increases. This increases blood flow to the surface of the body, thus increasing the potential for heat transfer from body core to skin and surroundings. Sweating also increases heat loss due to latent heat of evaporation. This also has the added effect that it increases our water requirements.

In very hot conditions, sweating offers the greatest potential for regulating body temperature. When relocating from a cool to a predominantly warmer climate it is necessary to allow the body to acclimatise by increasing blood volume and sweat capacity while decreasing salt losses in sweat. There are many variations to the following concept. Acclimatisation requires physical activity under heat-stress conditions similar to those anticipated for work. This will mean at least two continuous hours in a similar environment for 5 out of 7 days or 10 out of 14 days to become acclimatised (ACGIH 2015). This increased sweat capacity is lost after a few days in a cooler environment. Noticeable acclimatisation loss occurs after 4 days and is completely gone after three to four weeks (ACGIH 2015).

Possible adverse effects of exposure to excessive heat include; fatigue, behavioural modification (including reduced concentration), heat cramps due to salt loss, fainting, heat exhaustion and heat stroke.

15.1.2 Physiological responses to cold

When exposed to cold the blood vessels in our skin contract and heat flow to the body surface is reduced, thus minimising heat loss from the body. Heat production is increased by physical activity and shivering. Unlike heat acclimatisation it is difficult to find situations where human acclimatisation to the cold could develop and be clearly demonstrated. Evidence of this adaptation is varied and often conflicting.

The Korean amas (female pearl divers) are subjected to daily, whole-body cold stress greater than any other group of human subjects studied (0ºC air, 10°C water in winter). It should be emphasized that amas dive throughout the year wearing only cotton bathing suits. They start diving at 12 years of age and continue until they are past 50. Because they are exposed repeatedly to severe cold over a long period, amas make a convincing example of acclimatization to cold, including the metabolic component of this process (Doi, Ohno, Kurahasi & Kuroshima 1979).

Possible adverse effects to excessive cold include; lassitude listlessness, chilblains, frost bite and hypothermia.

15.1.3 Psychological responses to the thermal environment

People will regularly modify the way they work depending on the thermal environment. Often they will try to modify their local work environment e.g. moving to a more comfortable area, changing clothes, increasing or decreasing ventilation etc. Performance and efficiency can also be affected by adverse thermal conditions.

15.2 Heat Transfer from the Body

Formulae are available for calculating the heat load and balance of a person, providing enough data is available. This is a very complex area and is beyond the scope of this course. However, an understanding of the mechanisms and factors involved in the heat balance mechanisms is useful to understand the evaluation of thermal stress issues.

In terms of assessing or evaluating thermal environments, there are six parameters that may be taken into account. Two of these are associated with the individual and four with the environment, namely:

$$S = M \pm C \pm R - E$$

Where M = Rate of metabolic heat production
C = Convective heat loss or gain
R = Radiant heat loss or gain
E = Evaporative heat loss
S = Heat gained or lost by the body

Two more parameters, W (external work done) and K (conduction) are usually small and not considered so the simplified form is often used.

The heat balance mechanisms over a period of time are affected by 6 parameters, 2 associated with the individual and 4 with the environment, namely:

1	Work rate (i.e. activity or metabolic rate)	Person
2	Clothing	
3	Air temperature	Environment
4	Radiant temperature	
5	Air Velocity	
6	Humidity (moisture) conditions	

15.3 Evaluating the Thermal Environment

15.3.1 Metabolic rate

Metabolic rate is expressed in watts (W) or watts per square metre of body surface area. It ranges from about 45 W/m^2 at rest, about 70 W/m^2 standing up to about 500 W/m^2 for typical maximum work rate. Metabolic rates are often estimated from comparing the work task with tables of types of activities.

Activity	Metabolic Rate (W/m^2 body surface)
Sleeping	43
Resting	47
Sitting	60
Standing	70
Slow Walk (2.5 kph)	107
Walking (5 kph)	154
Running (16 kph)	600
Sprinting (25 kph)	2370

15.3.2 Personal insulation

Personal insulation (clothing) - The thermal resistance of clothing is expressed as a Clo value, where 1 Clo = 0.155 Km^2/W. Personal insulation tends to be self-regulating in that people tend to add or remove clothing according to their own feelings of comfort. Tables of typical Clo values for clothing assemblies are available for reference.

Clothing Ensemble	I_{clo} (clo)
Naked	0
Shorts	0.11
Long trousers	0.22
Daily non-work clothing (underpants, shirt, light-weight trousers, socks & shoes	0.6
Work Clothing (Underpants, shirt, trousers, socks & shoes)	0.75
Indoor clothing – suit	0.96
Heat protective clothing (briefs, shirt, trousers, aluminized hip length coat, socks & shoes	1.36
Heavy suit with vest	1.49
Chemical resistant coverall with hood, respirator, helmet, rubber gloves & boots and full length underwear	2.0
Cold protective clothing (expedition suit)	3 – 4

Source: Di Corleto 2015 (Based in part on ISO 9920)

15.3.3 Duration of exposure

The duration of exposure to a thermal situation can in many cases, be varied either voluntarily or by means of work rest regimes thus reducing the risk of prolonged exposure to heat or cold. The rest period should preferably be taken in an environment that is less extreme.

15.3.4 Dry bulb temperature

Dry bulb temperature (air temperature) is measured by a thermometer with the sensor kept dry and shielded from radiant heat.

Simple thermometer

- thermal expansion of fluid (mercury or alcohol) in a fine capillary tube
- inexpensive
- can be accurate
- limited temperature ranges
- fragile
- can be slow to respond

Electrical devices - e.g. thermistor or thermocouple

- can be robust
- accurate
- convenient
- often built into anemometer devices or thermal meters

15.3.5 Globe temperature

This is measured via a black copper sphere with a simple thermometer projecting into its centre. The globe temperature is utilised in a number of heat stress indices such as the WBGT. It can also be used in the calculation of mean radiant temperature.

15.3.6 Mean radiant temperature

Mean radiant temperature is the hypothetical temperature of a uniform black enclosure which would exchange the same amount of radiant heat with the body as the non-uniform enclosure.

When the air temperature and air velocity are known, the mean temperature of surroundings can be calculated using basic calculations, or with the help of nomograms.

Pyrometers or thermopiles - Directional devices which when pointed at a surface of known emissivity can be used to determine radiant temperature of that surface. With sufficient data the mean radiant temperature can be calculated.

15.3.7 Air velocity

Heat will be removed from the body by convection when an air current is passed over it unless the air temperature is higher than the temperature of the skin. Air movement will also affect the rate of evaporation of moisture from the skin unless the air is 100% saturated, or its vapour pressure is greater than that on the surface of the skin.

Vane anemometer - 'propeller' type. directional, electrical or mechanical. Can be used for measuring fluctuating, uni-directional air flows.

Resistance anemometer - sensitive, fragile, uni-directional device.

Kata thermometer - an alcohol in glass thermometer with a large silvered bulb at its base and a small bulb at the top. It is heated until the liquid expands into the top bulb, heat is then removed to allow the airflow to cool it. As the liquid contracts back into the lower bulb its fall is timed between two marks on the stem. The air velocity can be calculated from this 'cooling time'. This is a dated method rarely used these days.

Tracer smoke - extremely valuable for visualising air flow and measuring very low velocities.

15.3.8 Moisture content

Convection and evaporation play a major role in dissipating body heat and thus the temperature and moisture content of the air are important parameters. They are interrelated and the study of their relationship is known as 'psychometry'.

The driving force which makes water evaporate is the difference in 'vapour pressure' between the air and water surface. The maximum vapour pressure that can occur at any temperature is called the 'saturation vapour pressure' and this varies with temperature according to the curved line (100% saturation) on the psychometric chart. This curve forms the basis of the psychometric chart which shows dry bulb, wet bulb, moisture content, percentage saturation (relative humidity). The effect of water vapour pressure on the environment is measured indirectly by either measuring the dew point (the temperature at

which water vapour condenses out of the air), or by measuring the depression in temperature of a thermometer bulb covered in a water soaked wick.

Natural wet bulb - a simple thermometer whose bulb is covered with a muslin wick dipped in distilled water.

Forced wet bulb - e.g. whirling hygrometer. In this case air movement of a least 4 m/s is induced over the wick.

Note: the forced wet bulb is used for psychometric work, whereas the natural wet bulb is used to calculate WBGT indices.

15.3.9 Personal monitoring

In extreme thermal conditions (heat) it may be necessary to undertake monitoring of individuals - e.g. heart rate and core temperature. This is particularly important when calculated exposure times are less than 30 minutes. The sweating mechanism, which is one of the bodies key control mechanisms does not fully engage in most individuals for 10 – 15 minutes. Therefore during this initial period the body can be at higher risk. Also in situations where high levels of PPE are being worn such as Hazmat suits, physiological monitoring should also be considered.

Physiological monitoring allows the occupational health professional the ability to monitor in real time how the body is coping with the heat stress. The two most useful and utilised methods are, core temperature and heart rate. There are a number of criteria that can be utilised when assessing via this method.

The AIOH heat stress guideline (DiCorleto, Firth & Mate 2013) suggests that excessive heat strain may be marked by one or more of the following measures, and an individual's exposure to heat stress should be discontinued when any of the following occur:

- "Heart Rate Limit" = 185 – 0.65A (see ISO 9886) (ISO 2004b), where A = Age in years; or
- "Thermal Heart Rate" increase is greater than 30 bpm per 1°C increase in core temperature; or

- Recovery heart rate at one minute after a peak work effort is greater than 124 bpm; or
- Body core temperature is greater than 38.5°C for medically selected and acclimatised personnel; or greater than 38°C in unselected, unacclimatised workers; or
- There are symptoms of sudden and severe fatigue, nausea, dizziness or lightheadedness.

Where any uncertainty exists in relation to the fitness of individuals required to undertake this level of work, medical advice should be sought in such circumstances.

15.4 Heat Stress Indices

None of the parameters mentioned should be taken in isolation to represent a thermal condition. Various researchers over the years have devised indices to combine some of various parameters impacting heat into a single figure to which a standard could be applied. Some of these include:

- **Wet Bulb Globe Temperature:** A simple index calculated after measuring the dry bulb, natural wet bulb and globe temperatures. The resultant figure can then be used against published data on the recommended limits of work and rest.
- **HSI (Belding and Hatch Heat Stress Index):** Calculated using a range of environmental measurements as well as work rate and is often used by engineers to assess the effect of varying one or more of the factors included in this index.
- **P4SR (Predicted Four Hour Sweat Rate):** Calculated from charts and used to assess physiological limits. The maximum sweat rate permitted for fit young men is 4.5 litres in 4 hours, but a sweat rate below 2.7 litres is preferred.
- **Thermal Work Limit (TWL):** has been proposed by Brake & Bates (Brake & Bates 2002) who consider the heat stress indices currently in use are either difficult to apply or poorly applicable in many situations.

  TWL uses five environmental parameters (dry bulb, wet bulb and globe temperatures, wind speed and atmospheric pressure) and

accommodates for clothing factors to arrive at a prediction of a safe maximum continuously sustainable metabolic rate (Wm^{-2}) for the conditions (ie the TWL). The TWL is defined as the limiting (or maximum) sustainable metabolic rate that euhydrated, acclimatised individuals can maintain in a specific thermal environment, within a safe deep body core temperature (<38.2°C) and sweat rate (1.2 kg/hr).

- **Predicted Heat Strain:** This index is a comprehensive, albeit complex, index that considers many factors that affect the body's response to heat and was subsequently adopted in ISO 7933:2004 - *Ergonomics of the thermal Environment – Analytical determination and interpretation of heat stress using calculation of the predicted heat strain (ISO 2004a).*

  It describes a method for calculating the heat balance as well as the required sweat rate that the human body should produce to maintain this balance in equilibrium.

  The information required includes measurement of:

- dry bulb temperature
- wet bulb temperature
- humidity
- air velocity
- globe temperature
- together with estimates of factors relating to thermal insulation, property of clothing, metabolic work rate and posture

This allows the calculation of the predicted core temperature (for the maintenance if thermal equilibrium) from the adaptation of the basic heat equation.

A good understanding of the use of these indices is needed before they are used. There are many available, and they are not all relevant to all situations.

15.5 Thermal Comfort

Thermal comfort is very subjective and people will feel differently about what is the 'ideal' thermal environment. Issues of thermal comfort manifest themselves at much less extreme conditions than those that may cause thermal stress. Indices have also been generated in an attempt to measure thermal comfort.

e.g. The Fanger Index and Predicted Mean Vote and Predicted Percentage Dissatisfied in ISO 7730:2005 - “Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of PMV and PPD indices and local thermal comfort criteria”(ISO 2005).

15.6 Cold Stress

The wind chill index applies to the cold end of the scale and relates the cooling effect of air temperature and wind velocity to an equivalent temperature in still air obtained from a chart. There are a limited number of other indices relevant to cold stress.

15.7 Controlling the Thermal Environment

Where comfort is concerned, it is always worth checking that it is the thermal environment which is at fault. What often manifests as a complaint about the ‘temperature’ may be caused by other factors, e.g. general dissatisfaction, complaints about neighbours and their habits, ergonomics, etc.

When dealing with thermal comfort problems it is worth remembering that it is rare to be able to satisfy all of the people all of the time due to differing individual preferences.

By understanding how the thermal environment affects people, and having data on the parameters of interest, it is possible to predict the effect of modifying each of those parameters.

15.7.1 Modifying comfort conditions

Separate people with differing clothing requirements and activity levels modify their environments separately. Some examples of people in the same environment undertaking different tasks and therefore likely requiring different clothing are: Welders vs. assembly workers; shop assistants vs. customers.

- Modify clothing, activity or behavioural patterns
- Modify environment locally e.g. radiators, air movers
- Heat ventilate total environment
- Air conditioning

15.7.2 Modifying hot environments

- Alter environment locally
- Modify radiant conditions by screening, insulating or painting radiating surfaces with low emissivity paint
- Cold radiators
- Increase air movement
- Modify behavioural patterns
- Work rest regimes
- Provide air-conditioned refuges
- Increase distance from local 'hot spots'
- Air cooling
- Dehumidification
- Protective clothing
- Provide readily accessible and palatable drinking water
- Allow time for employees to acclimatise after time-off

15.7.3 Modifying cold environments

Given that one of the most critical factors in the onset of cold stress is wind chill, any engineering process that can reduce exposure to the wind and thus the cooling power of the air is useful. The two common approaches are the use of wind barriers and refuges. Wind barriers (shields) have been found to be effective outdoors or against circulated air indoors in freezer rooms. The provision of local refuges, equipped with warm drinks and warm conditions so that workers can retreat to rest, are an essential engineering control. If the refuge can be constructed around the work area so that the required task is performed inside, this presents an excellent work environment. Other engineering controls that should be considered include:

- For work below 0°C, metal handles and bars should be covered by thermal insulating material. Avoid metal tools if possible.
- Provision of local heating, hot air jets, radiant heating if bare hands have to be used.

- The use of mechanical aids should be encouraged so as to reduce manual handling requirements (hence reducing the potential for perspiration).
- Machines and tools should be designed so that they can be operated without having to remove mittens or gloves.
- Designing workplaces so that operators are not required to sit or stand for long periods in cold conditions.
- Reducing air velocity in cool rooms chillers while workers are required to work inside.

Provide dry protective clothing, paying particular attention to head and extremities. Provide conditioned facilities for changing if clothing is likely to get wet.

- Modify behavioural patterns.
- Alter environment locally, radiators etc.
- Heat total environment.

15.8 Specific Environmental Problems

15.8.1 High radiant components

If the radiant temperature is high and exceeds the dry bulb temperature, then the radiant component contributing to the environment is likely to dominate. High mean radiant temperatures can occur for a variety of reasons each of which may require a different solution.

In some work places all the surfaces surrounding the worker such as the walls, floor ceiling and items of plant and equipment may have a surface temperature several degrees above that of the ambient air. Such conditions could occur in boiler rooms, engine and compressor houses, power generating stations and inside military vehicles such as tanks and aircraft.

Lightweight buildings in strong sunlight can also have similar properties. In these cases it would be impracticable to shield the worker from the source as it occurs from all sides. If the air dry bulb temperature is below skin temperature then a simple increase in air velocity may well ease the situation. Even in

situations where the air temperature is above skin temperature, the increase of air velocity can promote increased sweat evaporation and hence better cooling. Care should be taken once the air temperature exceeds approximately 42ºC as the evaporative cooling capacity can be exceeded by the additional heat load. If the air velocity is already high, or if there are other good reasons, it may be necessary to use either air-conditioning using air chillers, or if relative humidity is very low, evaporative coolers. In the case of military aircraft the pilots wear cooled clothing assemblies and this solution could be applied elsewhere. However, the lines providing the cooling to the clothing can often make their use impractical as they can become entangled in other equipment in the environment.

Shielding the source of radiant heat is appropriate to the conditions found in metal smelting, furnace areas, steel making and foundry work where some surfaces have extremely high temperatures. This is particularly when molten red or white hot metal is handled. Air conditioning (cooling) can be used, but often the source of radiant heat is far more intense than the maximum cooling effect of the chilled air supplied, so that shielding or heat-reflecting clothing may also need to be used. There is a tendency for heat shielding to absorb heat, raise the temperature and thus itself become a heat emitter. To minimise this, the shield should have highly reflecting surfaces or be cooled by air or water. The same is true of clothing. Unfortunately, shields restrict visibility and accessibility to the work and provision must be made for this. Holes for visibility can be covered with heat-reflecting glass, whilst the problems of manual manipulation can be eased by the use of remote control devices.

Certain outdoor situations in direct sunlight, particularly in the dry tropics have a similar radiant component and shade cover can also be a useful control.

15.8.2 High humidity conditions

In laundries and some mines, as well as in textile and certain other manufacturing processes, the dry bulb temperature is high and the wet bulb temperature is close to it. This is indicative of high humidity. Many places in the humid tropics have similar ambient conditions. A supply of dehumidified air, as from air-conditioning systems in many industrial situations can be limited to an

area not much larger than the supply jet area. If this air jet is diffused and projected into an occupied area then the increase in air velocity over the workers can be effective in improving comfort and relieving stress.

15.8.3 Hot dry conditions

These conditions can occur in deep dry mines, inside buildings in the dry tropics, and in many manufacturing processes where heat is emitted from items of plant and machinery. The simplest solution is to increase the air velocity over the worker, but if this is impracticable other measures such as the introduction of cooled air may be required.

16 INTRODUCTION TO LIGHTING AND NON-IONISING RADIATION

16.1 Introduction

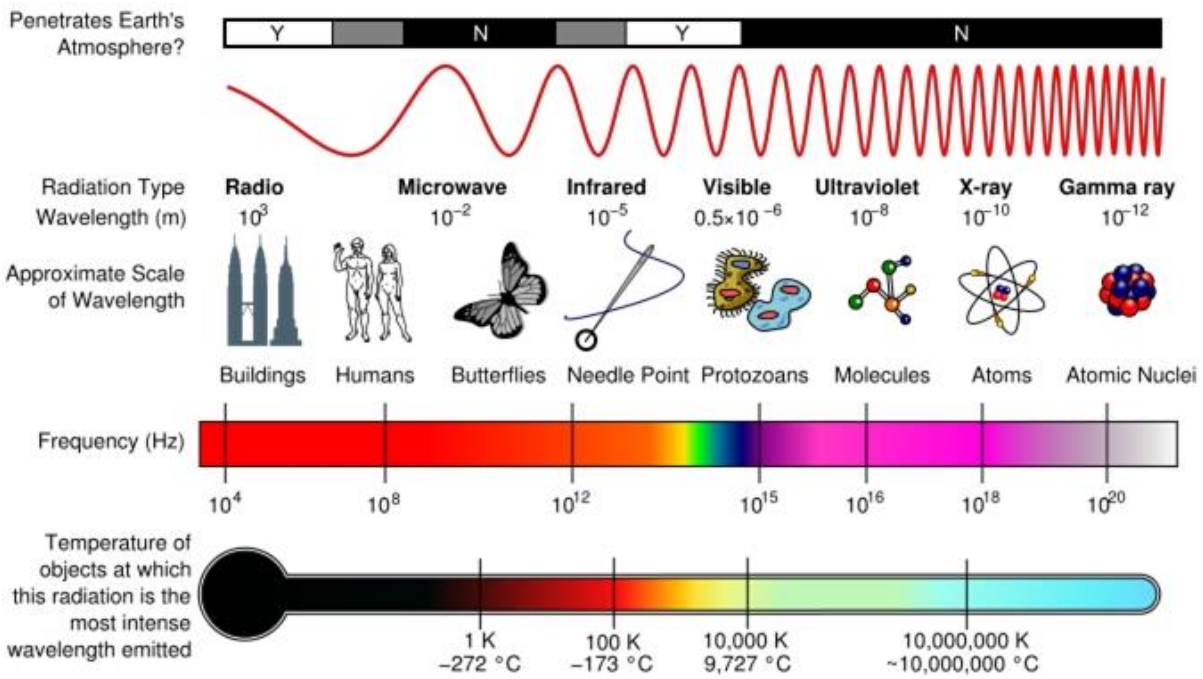
Electromagnetic waves are produced by the motion of electrically charged particles. These waves are also called "electromagnetic radiation" because they radiate from the electrically charged particles. They travel through empty space as well as through air and can penetrate some substances. Radio waves, microwaves, visible light, and X-rays are all examples of electromagnetic waves.

As with sound energy, Electromagnetic Radiation can be described in terms of its frequency (or wavelength) and its intensity. The frequency (Hz) is inversely proportional to the wavelength (nm), so higher frequencies have shorter wavelengths:

$$f \propto \frac{1}{L}$$

Where: L = wavelength and f = frequency

The intensity (mW/cm^2) is expressed in terms of the amount of energy incident upon a unit area. This intensity varies inversely as the square of the distance from the source. The electromagnetic spectrum covers a wide range of frequencies. Terms such as visible light, microwaves and infrared are used to describe different parts of the spectrum.



Source: US Federal Government via Wikimedia commons

Figure 16.1 - The Electromagnetic Spectrum

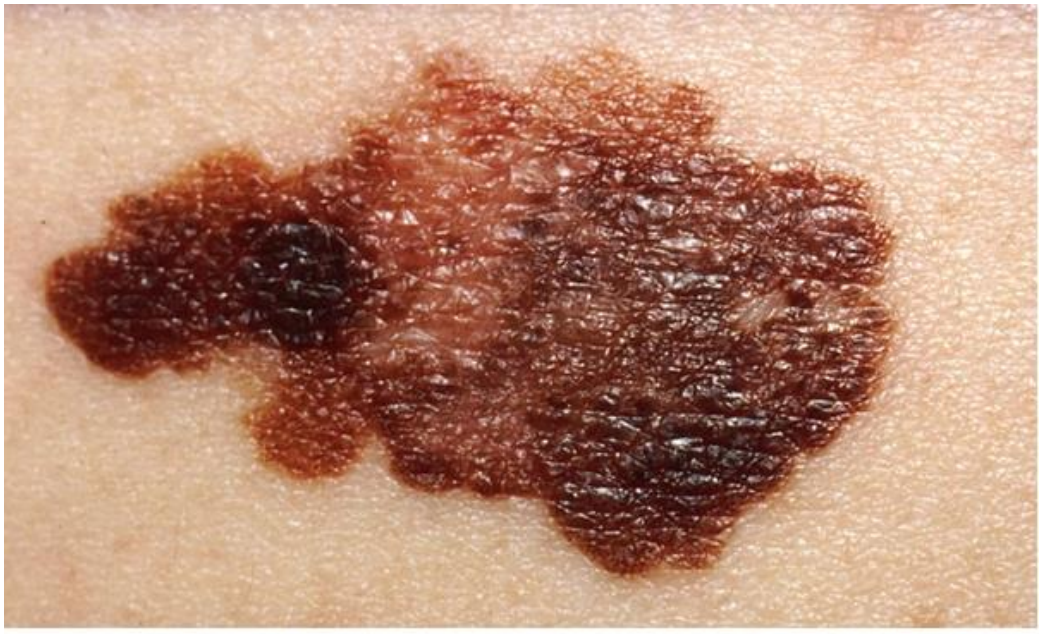
The electromagnetic spectrum can be divided at a wavelength of about 10 nm, which distinguishes NON-IONISING RADIATION and IONISING RADIATION. Visible light, infrared and microwaves are types of non-ionising radiation. X-rays and Gamma rays are examples of ionising radiation. The distinction between non-ionising and ionising radiation is simply one of associated energy. For the ionising region of the electromagnetic spectrum, the energy incident upon a material is large enough to remove an electron from an atom orbit to produce ionisation, whereas for the non-ionising region the energy is not normally sufficient to produce ion pairs. Ionising radiation will be covered in Chapter 17.

16.2 Types of Non-Ionising Radiation

16.2.1 Ultraviolet (UV) radiation

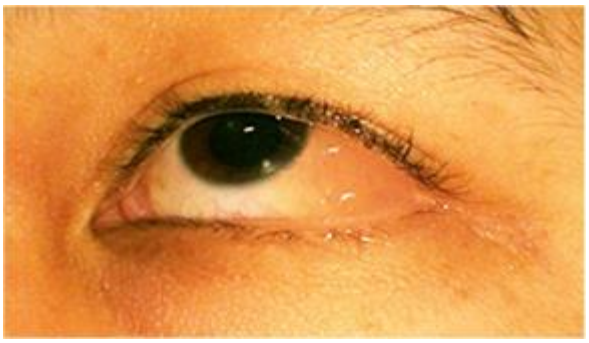
UV is invisible radiation produced naturally by the sun (solar radiation) and artificially in industry via arcs (e.g. welding) operating at high temperatures. The ordinary fluorescent lamp generates a good deal of UV radiation inside the bulb, but it is absorbed by the fluorescent phosphor coating, which fluoresces emitting longer wavelength visible radiation.

UV radiation is readily absorbed by human tissue and therefore the eyes and skin are particularly vulnerable. The most common exposure is from the sun, which can produce sunburn, and in severe circumstances, blistering of the skin. Prolonged skin exposure can result in premature ageing and thickening (keratosis) of the skin. Most serious of all is skin cancer, which is now the most commonly diagnosed type of cancer. Melanoma, caused by damage to melanin cells in the skin, is the most serious form. By World Health Organisation estimates, 132,000 cases of malignant melanoma (66,000 deaths) and more than 2 million cases of other skin cancers occur annually. It is the most common cancer in the young population (20 – 39 age group) and it is estimated that approximately 85% of cases are caused by too much exposure to sunlight. This has implications for occupational exposure of outdoor workers, including gardeners and construction workers. Furthermore, exposure to some substances used at work, such as coal tar or cresols found in road tars, can make the skin exceptionally sensitive to the sun.



Source: Wikimedia Commons

Figure 16.2 - Melanoma



Excessive exposure of the eyes produces conjunctivitis, a delayed, painful irritation similar to having sand in the eye. Welders experience it as "arc eye" and a similar condition occurs in "snow-blindness". In the long term ocular damage can lead to cataract formation.

Ultraviolet radiation is subdivided into three bands of decreasing wavelength; UVA being the longest wavelength, UVC being the shortest and UVB being in the middle. The longer the wavelength the less energy is associated with the radiation and the less damage that it does to the body. e.g. UVA is the type of light used in “black lights” and is not responsible for skin cancer.

16.2.2 Infrared (IR) radiation

IR radiation is emitted by hot bodies, e.g. furnaces and gas torches. Its primary effect is heating of surface tissues. Excessive exposure to radiant heat will produce immediate discomfort and therefore a suitable warning of impending damage is provided, usually before burning can occur. However, the eyes do not possess such an early warning mechanism and excessive exposure can result in lens damage and cataract formation; retinal damage can also occur.

16.2.3 Laser radiation

The name laser is an acronym for 'Light Amplification by Stimulated Emission of Radiation'. Laser machines emit a concentrated beam of non-ionising radiation - of a single wavelength or a narrow wavelength band - in the visible and infrared region of the electromagnetic spectrum and are potentially hazardous, particularly to the eye, because they are of high intensity and the parallel rays may be focused to a point image by the eye. Damage ranges from repairable burns to permanent blindness.

Cataract formation may also occur. Lasers have widespread use, e.g. in communications, construction, medical applications, research, surveying.

Lasers have been classified by wavelength and maximum output power into four classes and a few subclasses under standard IEC60825-1. The classifications are briefly summarised in the table below.

Table of Laser Classes

Class 1	Safe.
Class 1M	Safe provided optical instruments are not used.
Class 2	Visible lasers. Safe for accidental exposure.
Class 2M	Visible lasers. Safe for accidental exposure providing optical instruments are not used.
Class 3R	Not safe. Low risk.
Class 3B	Hazardous. Viewing of diffuse reflection is safe.
Class 4	Hazardous. Viewing of diffuse reflection is also hazardous. Fire risk.

16.2.4 Microwave radiation

Microwaves are produced by molecular vibration in solid bodies and are usually described by the wave frequency generated. Examples of microwave energy sources are transmitter antennae and medical applications. The primary effect on the body is thermal and microwaves of certain frequencies are used as a means of rapidly cooking food. The main risk, therefore, is thermal burning of the skin and eyes. Prolonged exposure to low level microwave radiation has been linked with headaches, sleeplessness, irritability, fatigue and memory loss.

Microwaves are widely used in applications like wireless computing and mobile phone networks. Much public concern has been raised about the possibility of

serious long-term health effects such as cancer. As yet, research has failed to demonstrate such a link conclusively.

16.2.5 Other effects of non-ionising radiation

Ozone may be produced as a result of electrical discharges or ionisation of the air surrounding non-ionising radiation sources, e.g. UV, high power laser, microwave, and short duration exposure in excess of a few tenths ppm can result in discomfort (headache, dryness of mucous membranes and throat).

16.3 Evaluation of Non-Ionising Radiation

Portable hand-held meters are available to measure Non-Ionising Radiation. They incorporate a suitable photo emissive material (e.g. UV, visible or IR) so that incident radiation releases electrons from the surface. These electrons are collected by an anode and made to flow as an electric current which is measured by a suitably calibrated ammeter (see below).

The radiation data obtained are assessed against appropriate occupational exposure limits. In fact ACGIH has adopted or proposed TLVs for each of the following:

- Ultraviolet radiation
- Visible and near infrared radiation.
- Laser radiation.
- Microwave and radio-frequency radiation.

The radiation intensity limits are expressed in mW/cm^2.

16.4 Lighting

16.4.1 Recognition

The visible radiation portion of the electromagnetic spectrum is narrow, ranging between 400 and 700 nm. It is the sensitivity of the eyes to this visible radiation that enables us to see. In terms of occupational hygiene we are concerned with the subjective feeling of visual comfort, and good illumination which is described in terms of the quantity and quality of the lighting.

Quantity - this is the amount of illumination on the task. It is measured in lux and must be sufficient for the worker to undertake the task.

Quality - is the suitability of the illumination, for example the distribution of brightness in a visual environment, the colour of light, its direction, diffusion and the degree of glare.

The least desirable type of lighting is that from a single bulb in the middle of the room. Decreased contrast and improved visibility will result from increasing the number of lighting sources across a ceiling.

In general, for each visual task performed, a certain minimum quantity of light arriving on each unit area of the object in view is required, dependent primarily upon the nature of the work that is being undertaken. Too little light can lead to eyestrain and headaches, too much light can result in glare. Guidance on the recommended service values of illumination are given in the Code of the Institution of Building Services Engineers (CIBSE Code) in the UK, and by the American Society of Heating and Ventilation Engineers (ASHRAE) in the US.

Lighting in the various areas of factories and offices can be classified according to three categories:

Local lighting
Localised lighting
General lighting.

Research has shown that favourable lighting conditions exist when the illumination of the task is about three times greater that of its immediate surroundings, and when the immediate surroundings have about three times the illumination of the general workroom. Good lighting has a beneficial psychological effect on a workforce and its productivity.

16.4.2 Evaluation of illumination

The instrument most commonly used for the measurement of illumination is a photoelectric light meter (often termed a 'Lux' meter). When light is incident upon the photoelectric cell, the energy in the radiation is converted into

electrical energy and the current produced recorded on a meter calibrated in lux. It has a built-in filter which automatically applies the necessary correction factor when daylight, mercury lamp light or fluorescent light is to be measured, and is 'colour corrected' to respond to the human eye. The quantitative results obtained are assessed in terms of appropriate guidance criteria such as those recommended by CIBSE or ASHRAE.

16.4.3 Glare

Glare may be defined as any brightness within the field of vision where such character would cause discomfort, annoyance, interference with vision, or eye fatigue. Three different types of glare may be present separately or in combination.

Disability glare this will affect the capacity to see clearly, e.g. the undipped headlamp on a car or sunshine reflecting from a wet surface.

Discomfort glare this effect increases with time, e.g. a part of a visual scene (windows by day, lighting by night) may be too bright compared to the background.

Reflected glare this is seen in shining or polished surfaces which reflect a more or less distorted image of a bright light, fitting or window. This can be annoying or disabling, for it may be difficult or impossible to see whatever is beneath.

16.4.4 Good illumination

General guidelines for designing illumination of sufficient quantity and suitable quality are:

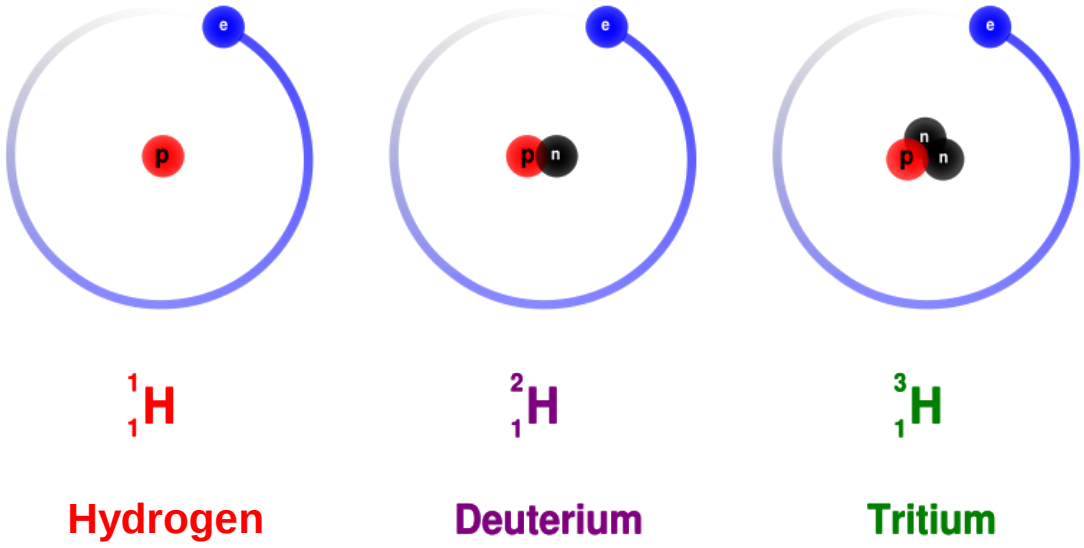
- Consider lighting at the design stage of any building or workplace
- Design for sufficient lighting levels in line with established guidance such as the CIBSE code
- Integrate daylight and artificial light
- Avoid glare
- Minimise flicker
- Ensure adequate maintenance of glazing surfaces and light fittings.

17 IONISING RADIATION

17.1 Nature

It is possible to explain many atomic scale phenomena by assuming that all atoms are made up of three fundamental particles. These are called electrons, protons and neutrons. The simplest atomic combination is formed by one electron and one proton - the hydrogen atom. In general, however, a number of negatively charged electrons rotate in certain allowed orbits around a central nucleus which is composed of an equal number of positively charged protons and some neutrons. The neutrons carry no charge and the equal number of electrons and protons ensure the charge neutrality of the complete atom, as their charge is equal in magnitude but opposite in sign.

The diagram below illustrates this for three variants of the hydrogen atom, which have different numbers of neutrons. Such variants are called isotopes.



Source: Modified from Dirk Hünniger, licensed under Creative Commons Attribution ShareAlike 3.0

Figure 17.1 - Hydrogen Isotopes

Ionising radiation refers to particles or electromagnetic radiation which have sufficient energy to affect atoms directly i.e. 'ionise' them, namely to create charged particles, or "ions", when they interact with matter. There are five different types of ionising radiation, namely alpha (α), beta (β), neutrons (n), gamma (γ), X-ray (χ). The first three of these are particles and the latter are

examples of electromagnetic radiation. Details are given in the Table set out below.

Type	Symbol	Nature	Charge	Relative Mass	Range in Air	Penetration
alpha	α	particulate (helium nucleus)	+ +	4	0.4 - 2 cm	None
beta	β	particulate (electron)	-	1/1800	5-20 cm	Slight
neutron	n	particulate (neutron)	0	1	long	High
gamma	γ	electro-magnetic	0	0	Very long	High
x-ray	χ	electro-magnetic	0	0	Very long	High

17.2 Radionuclides

Ionising radiation is emitted from unstable nuclei which are decaying, with the emission of energy. These are known as radioactive nuclei (radionuclides).

A radionuclide loses its radioactivity by decay. The decay is statistical in nature, i.e. it is impossible to predict when a particular atom will disintegrate but it is known with certainty that a proportion of the radioactivity will disappear in a given time. This rate of decay is characterised by a specific half life which is unique for each radionuclide and is unalterable. The half life is the period over which half the radioactivity of the radionuclide disappears and is constant. It is often written as $t_{1/2}$.

17.2.1 Units of ionising radiation

Units for measuring radiation are relatively complex. Most countries now use the International System of Units (abbreviated SI from the French le Système International d'Unités) which is the modern form of the metric system. However, the US continues to use an older system for some regulatory purposes. Both methods are summarised below for reference:

Activity (Becquerel)

The SI unit of for the activity of a radioactive material is the becquerel (Bq), where one Becquerel = 1 disintegration per second.

The traditional unit of activity has been the Curie (Ci), where one Curie = 3.7 x 10^{10} disintegrations per second.

Absorbed Dose (Gray)

This is a measurement of the energy imparted to matter by ionising radiation per unit mass of the material. The SI unit of absorbed dose is the gray (Gy), which is equal to an energy absorption of 1 joule/Kg.

The traditional unit of absorbed dose is the rad, where 1 Gray = 100 rads.

Dose Equivalent (Sievert)

Equal absorbed doses may not always give rise to equal risks of any biological effect. The relative biological effectiveness of a particular absorbed dose may be affected by the type of radiation or the radiation conditions. Accordingly the dose equivalent can be expressed as:

Dose equivalent (Sievert) = Absorbed dose (Gray) x Modifying Factor.

The modifying factor depends on both the 'quality' of the radiation (which is 1.0 for the lower energy radiations but rises to 20 for high energy fission fragments) and the part of the body affected.

The traditional unit is the rem where 1 sievert = 100 rem.

17.3 External and Internal Radiation

When discussing the health aspects of exposure to ionising radiation and the control of any hazard, it is important to distinguish between external radiation and internal radiation.

An external radiation hazard is one from radiation sources outside the body of sufficient energy to penetrate the outer layers of the skin. A summary of the effects of exposure, principles of control and types of monitoring are set out below:

The effects of external exposure can be summarised as:

α Minimal hazard

β Skin and eyes at risk

$\gamma\chi$ Whole body at risk (penetrating radiation)

An **internal radiation hazard** arises when the body is contaminated with a radioactive isotope. The presence of radioactive material in the body is often a more serious problem than exposure to external radiation because the radioactive material:

- is in intimate contact with the body tissues and organs (remember inverse square law).
- cannot be removed or shielded (irradiates the body 168 hr/week).

Entry to the body can occur through inhalation, ingestion, or skin absorption.

In this situation, the effects of exposure are:

α Very serious hazard

β Serious hazard

$\chi\gamma$ not normally applicable

17.4 Levels of Radiation

We are all exposed to radiation from natural sources as well as those encountered during work. This takes into account:

- Cosmic radiation which increases with height above sea level
- The material which your home is made from.
- Time spent on aircraft
- Smoking
- Medical x–rays
- Other lifestyle factors.

17.5 Biological Effects of Ionising Radiation

Exposure of living tissue to ionising radiation results in damage to the component cells. Such radiation damage can be useful to mankind (as in the treatment of cancer under carefully controlled conditions), but under most conditions it should be avoided as far as possible. Possible effects are summarised in the table below.

Acute Effects	Chronic Effects
Erythema Blood change Sterility Death	Cancer Hereditary defects

All forms of ionising radiation produce the same type of injury in irradiated tissues. However, the efficiency with which the tissue reactions are produced varies with the density of the ionisation in the path of the radiation. Particulate radiations such as alpha particles or neutrons which produce closely packed tracks of ions are more damaging per unit of energy absorbed than is electromagnetic radiation such as gamma rays or X-rays, which cause more diffuse ionisation.

Since cosmic rays bombard all of the earth's surface and naturally occurring radioactive elements exist everywhere, a certain minimal exposure to so-called "background" radiation is inevitable. In some regions, radioactive radon gas occurs naturally in bedrock such as granite. It can expose miners working underground and can accumulate in the basements of buildings, which may need special ventilation.

Owing to the use of radioactive materials in industry and the use of ionising radiations in medicine and industry, some groups of people are exposed to increased levels of radiation.

17.6 Uses of Radiation

Industrial

- Gauges - radiation (α, β, χ, neutrons) can be used to measure thickness, density and moisture level.
- Industrial Radiography - checking the integrity of welds (γ, χ).
- Laboratory analytical techniques - X-ray diffraction and fluorescence
- Tracers - Radionuclides are used in yield determination, wear tests, water and oil reservoir investigations.

Medical

- Diagnostic X-rays
- Medical imaging - radionuclides are sometimes used as markers.
- Cancer treatment - using radionuclides to destroy tumours.

17.7 Measurement of Radiation

Measurements of radiation can be undertaken in a number of different ways to measure different things.

Emitted radiation: Geiger counters and scintillation counters can be used to measure the levels of radiation from particular sources. The devices are often specific to the type of radiation being measured.

Radiation dose: Various devices can be used to measure personal dose. It is important to differentiate between internal dose (that which a person takes into their body by routes such as breathing) and external dose (received simply by virtue of being in an environment where radiation is present).

The external dose can be measured using a range of dosimeters. Ion-chamber dosimeters resemble pens, and can be clipped to one's clothing. Film-badge dosimeters enclose a piece of photographic film which will become exposed as radiation passes through it.

Measurement of internal dose involves the use of sampling pumps which collect the radioactive material to be analysed for radiation.

17.8 Radiological Protection

Control of exposure to radiation can be divided into four main approaches. In practice a combination of all of these control approaches is often applied.

1 Time: Limiting or minimizing the amount of time to which people are exposed to radiation will reduce the dose which they receive.

2 Distance: Radiation intensity decreases sharply with distance, according to an inverse square law. In addition even air attenuates alpha and beta radiation.

3 Shielding: Alpha particles may be completely stopped by a sheet of paper, beta particles by aluminum shielding. Gamma rays can only be reduced by much more substantial barriers. Barriers composed of lead, concrete or water give effective protection from energetic particles such as gamma rays and neutrons. Some radioactive materials are stored or handled underwater or by remote control in rooms constructed of thick concrete or lined with lead.

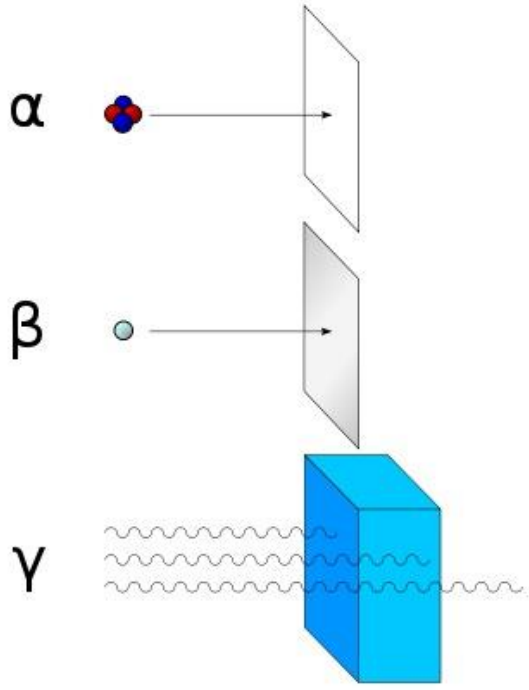


Figure 17.2 - Effectiveness of Shielding

4 Containment: Radioactive materials may be used in "sealed sources" to prevent them spreading. The use of small working spaces, segregated areas and controlled ventilation are also used to contain the release of radioactive materials

In many countries the role of radiological protection is carried out by a specialist who has recognised skills and qualifications. For example, in the UK the Health and Safety Executive specifies the level of qualification required to become a “Radiological Protection Adviser”.

17.9 Health Surveillance

The nature of radiation is such that employees who work with radiation are normally subject to some form of health surveillance, including biological monitoring. Employees working in controlled areas may be subjected to:

- Completion of a questionnaire
- A blood test
- Urine test
- Blood pressure check
- Height and weight check
- General discussion about health.

18 INTRODUCTION TO ERGONOMICS

18.1 Introduction

Ergonomics is about the interactions of people with the equipment they operate and their working environment. It aims to maximise human performance and to minimise discomfort, dissatisfaction and the risk of musculoskeletal injury.

Simply put, ergonomics is all about fitting the task to the worker. If the match is poor, the best solution is to redesign the work tasks to make them more compatible with human characteristics. It is less effective to try to change employee characteristics, for example by improving selection and training;

A good fit between technological, organisational and human factors is clearly a goal if good business performance is to be delivered. If these factors can be balanced productivity will improve, resulting in a competitive advantage together with health and safety benefits.

The scope of ergonomics is therefore very wide. Some common activities where ergonomics are important are:

- manual handling of loads
- tasks involving repetitive actions;
- the use of display screen equipment, such as when working with computers.

These applications of ergonomics are discussed below in more detail. In addition, ergonomics is closely associated with the study of human errors. Errors tend to happen when the capacity of an individual to cope with the demands of a task or situation is exceeded. This can be caused by a poorly defined man-machine interface, by lack of training or competence, or by psychological factors such as stress or fatigue. Errors can result in accidents, illness or lost productivity. For that reason, in the US, ergonomics is often called "human factors" and the term is interpreted more broadly than in this section. We will discuss human error, behaviour and work organisation further in later sections.

Ergonomics is a multi-disciplinary field of study, which draws upon, biomechanics, physiology, anatomy, psychology, physics, safety and engineering. It is fact based, solution orientated and should be fully integrated into an organisation's management processes.

18.2 Workplace Risk Assessment

The starting point for an evaluation of ergonomic factors is an assessment of the workplace. It should address:

- **Hardware**, e.g. design and layout of controls, ease of maintenance etc.
- **Software**, e.g. standard operating procedures and instructions, manuals, and computer programs
- **Visual workspace**, e.g. task / display design, display layout, information load, use of symbols.
- **Organisation**, e.g. working method, job content (degree of task variety and personal control), rate of work, satisfaction, communication, reporting, surveillance systems, management of conflict, etc.
- **Physical workspace**, e.g. access, clearance, seating, work position, reach, storage arrangements, housekeeping etc.
- **Physical environment**, e.g. temperature, noise, lighting, vibration, substances hazardous to health, etc.
- **Individual characteristics**, e.g. body size (anthropometry), strength, endurance, skill, training, motivation, attitude, etc.

For detailed assessments it may be necessary to involve an ergonomist. Ergonomists have developed ways of measuring ergonomic strain and have predictive models for dealing with physical tasks. It is often useful to video the task being performed so that it can be played back for analysis.

18.3 Manual Handling

Manual handling means the transporting or supporting of a load (including the lifting, putting down, pushing, pulling, carrying or moving) by hand or bodily force.

In some jurisdictions, for example Australia (SafeWork Australia 2011), the terminology “hazardous manual task” is used. This is defined as a task that requires a person to lift, lower, push, pull, carry or otherwise move, hold or restrain any person, animal or thing involving :

- repetitive or sustained force
- high or sudden force
- repetitive movement
- sustained or awkward posture
- exposure to vibration.

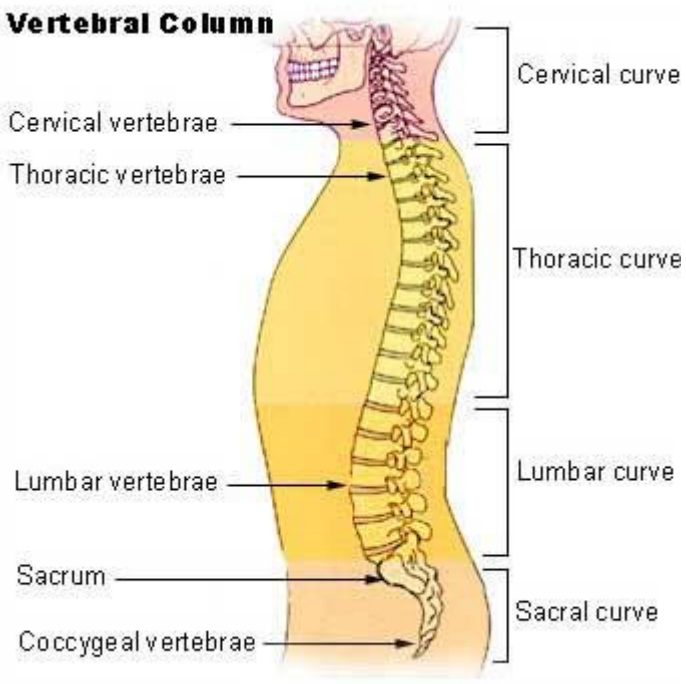
A high proportion of accidents and a significant amount of ill health are associated with manual handling operations. Most manual handling accidents reported are sprains or strains, very commonly of the back. These musculoskeletal disorders arise from the incorrect application and or prolongation of bodily force. Poor posture and extensive repetition of movement can be important factors in their onset. Other types of injury associated with manual handling operations include fractures, cuts, bruises, amputations and thermal injury.

Many manual handling injuries tend to be cumulative in origin rather than attributable to any single handling incident. A full recovery is not always made and the outcome can be physical impairment or even permanent disabilities. The costs to an individual and the employer are therefore far reaching. So our strategy for preventing injury must be preventative and not reactive.

18.3.1 The back

The spine is a superb and intricate example of engineering excellence, not just the central support system for the body and protection for the spinal cord, but essential to walking and many other body movements. However, like any other engineering structure it does not respond well to overloading or maltreatment, either in the form of sudden dynamic overload, repetitive overloads or performing outside its design parameters.

The spine comprises twenty-four bony segments (vertebrae) with five fused segments forming the sacrum and three to five fused or partially mobile segments forming a vestigial tail. Between the moveable segments are interposed twenty-three cartilaginous discs which function as excellent shock absorbers. The curved sequences of the spine allow it to absorb shocks 100 times more efficiently than if it was a straight stack.



Source: US Federal Government via Wikimedia commons

Figure 18.1 – The Back

The discs contain fluid, excellent for shock absorption, but constant compression squeezes the fluid content making the discs flatter, less flexible and less elastic. A healthy young disc has a breaking strain of 800 kg, stronger than the vertebrae, reducing to 450 kg in the elderly.

As a result of repetitive stresses or sudden traumatic stress the central fluid cell may creep through fissures in the fibrous cartilage and eventually prolapse, emerging from the disc to press excruciatingly on adjoining nerves. Contrary to common belief, discs do not slip! Once this occurs, treatment may be limited to rest, analgesics and physiotherapy. Surgery has a restricted role; it is not

practicable to approach the spine from the front and the structure is so complex and sensitive that any repairs from the rear are limited.

Back injuries often result in people taking weeks or months off work, and can easily recur. It is important that workers are supported by a "return to work" programme that encourages rapid rehabilitation and keeps them from them slipping into a state of permanent disability.

18.3.2 Conducting a manual handling assessment

Depending on the complexity of the activity, an assessment may be best carried out by those most familiar with the operations, e.g. supervisors and operators, or it may be conducted by professionals in health and safety, occupational hygiene or ergonomics, or by a team.

An assessment should consider the entirety of an operation. It should address four critical factors:

- the task;
- the load;
- the working environment;
- the capabilities of the individual.

Source: Steve Bailey

Figure 18.2 - Manual Handling Hazards from Lifting and Twisting

A simple assessment might proceed as follows:

- What parts of the body are being used?
- What actions are being performed?
- What are the risk factors?
    - How much force is the person using?
    - How awkward is the person's posture? (Repetitive bending, twisting movements increase the risk, as does lifting with extended reach)
    - How long is the action performed for?
    - How often are similar actions done?
    - How large or bulky is the item? (Consider the shape, size, weight and special difficulties of a load.)
    - Are the task and the workplace adapted to the individual? (This may involve considering working heights of benches, tables, stillage sizes.)
    - Does the working environment add to the risk of injury?
- How can this task be done differently? (Consider possible remedial measures, e.g. it may be possible to use mechanical aids or breakdown the load, or the task may be re-arranged.)

18.3.3 Methods of reducing risk

As with any occupational hygiene risk, there is a hierarchy of control.

The preferred approach is to eliminate the handling operation altogether if possible. For example, it might be possible to buy materials in pre-weighed amounts so that the need for a weighing operation is eliminated. Or, co-locating two operations might avoid the need to transfer materials between them.

Solutions may involve changing the position or height of the task, e.g. by providing adjustable tables or seating to improve posture. Often solutions involve the use of handling aids: whilst an element of manual handling is retained, bodily forces are applied more efficiently, thereby reducing the risk of injury. For example:

- A hoist can support the weight of a load, thereby leaving the handler free to control its positioning;
- A sack truck or roller conveyor can reduce the force required to move a load horizontally;

- ♦ Chutes are an efficient method of using gravity to move loads from one location to another,
- ♦ Suction pads and hand-held hooks can simplify the problem of handling a load that is difficult to grasp.

Remember that introducing new working practices can create new risks that need to be managed, for example by proper maintenance of the new equipment.

When everything possible has been done to adapt the task to the worker, there remains the need to provide information, instruction and training about the residual risks.

18.3.4 Information, instruction and training

Information - Where it is reasonably practicable to do so, employees involved in manual handling operations should be provided with precise information about the weight of each load, and about the heaviest side of any load whose centre of gravity is not positioned centrally. Where this is not reasonably practicable, general advice should be given about the range of loads to be handled, and about how to handle a load whose weight is not evenly distributed.

Training - Knowledge and training alone will not ensure safe manual handling but are an important aspect of a safe system of work. A suitable training programme should address:

- how potentially hazardous loads may be recognised;
- how to deal with unfamiliar loads;
- good handling techniques, including the proper use of handling aids;
- the proper use of personal protective equipment;
- features of the working environment that contribute to safety;
- the importance of good housekeeping;
- factors affecting individual capability, including fitness and health.

Employees should also be trained to recognise loads whose weight, in conjunction with their shape and other features, and the circumstances in which they are handled, might cause injury.

18.4 Repetitive Tasks

Tasks that involve repeated movements can lead to disorders of the muscles, joints and tendons, even when the individual actions do not involve excessive load or force.

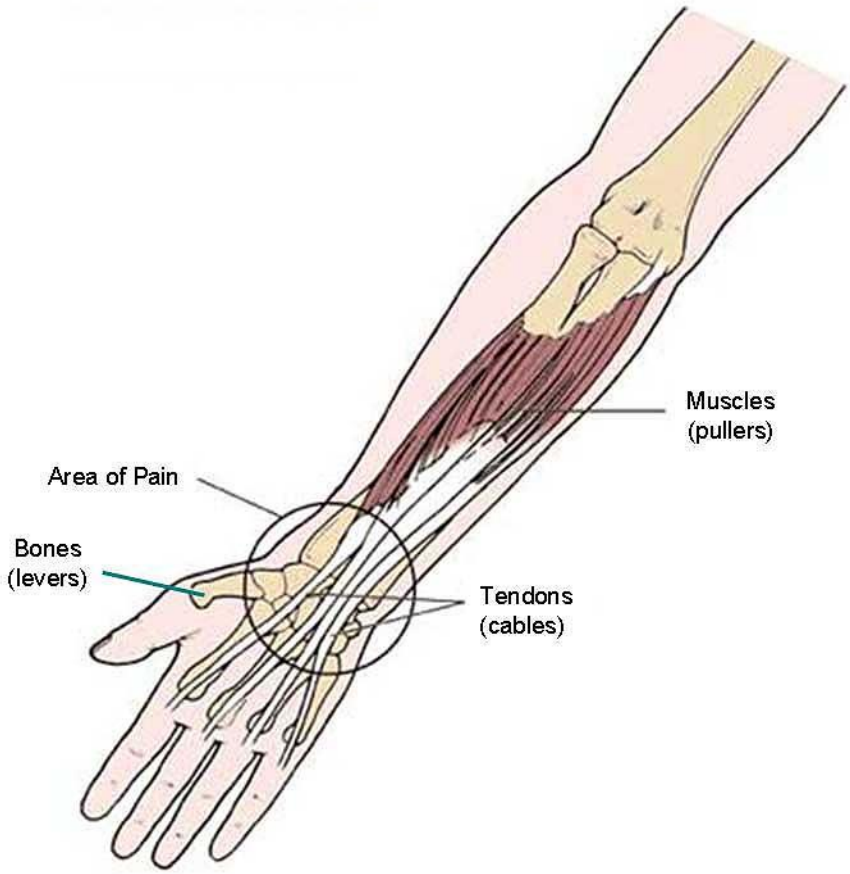


Figure 18.3 - Puller-Cable-Lever Structure of Arm showing Location of Wrist Tendonitis

These painful conditions are commonly known as Repetitive Strain Injuries (RSI) or (especially in the US) as Cumulative Trauma Disorders (CTD). Occupational conditions of the arms and hands are also known as Work Related Upper Limb Disorders (WRULD).

Well known examples of RSI include *tennis elbow*, *gamer's thumb* from excessive use of computer game controls, and *stylus finger* from overuse of mobile phone keypads. Wrist pain (tendonitis) is often associated with overuse of keyboards.

Symptoms can include pain and weakness in the affected area, made worse by use. However, diagnosis of RSI can be difficult as often there is no evident pathology. Doctors believe there is often a psychological component to RSI, and there is evidence that sufferers' experience can be aggravated by stress. Treatment is difficult and often unsuccessful, hence prevention is paramount.

Assessment of risk first requires identification of tasks that that are performed frequently or intensively. Occupational risks classically arise in repetitive assembly line work such as screwing tops on bottles, screwing together components or inserting components into awkward positions. The risk is increased if a strong pinch grip is required or if impact is involved. Undue pressure to meet production targets, especially when linked to piecework or bonus payments, can exacerbate the problem.

Risks may also arise when an automated process breaks down or a batch of product is rejected and workers are required to carry out remedial operations manually.

In complex cases, ergonomists can measure the frequency and force required by an operation and estimate the level of risk entailed.

Intervention follows the usual hierarchy:

- avoid exposure to ergonomic hazards risk factors where possible.
- reduce the risk by automating routine tasks or providing tools such as powered screwdrivers.
- introduce safe working procedures such as regular recovery breaks and limiting the time on a job. Provide information on the risks and instruction and training in safe working procedures.

18.5 Display Screen Equipment (DSE)

Many types of computerised equipment used in laboratories, factories, offices and home working incorporate a display screen and some kind of data entry device such as a keyboard or mouse. These arrangements can create several

categories of ergonomic risks and provide a good illustration of the need to tackle ergonomic issues in a holistic manner.

18.5.1 Possible effects from using DSE

- **Postural Problems (Upper limb pains and discomfort)**

These range from fatigue or soreness in the arm, hand and shoulder areas to chronic soft tissue disorders like *carpal tunnel syndrome* - inflammation of the sheath surrounding the tendons that flex the fingers.

The contribution of individual risk factors (e.g. keying rates) to the onset of any disorder is not clear. It is likely that a combination of factors is involved. Prolonged static posture of the back, neck and head are known to cause musculoskeletal problems. Awkward positioning of the hands and wrists, for example as a result of poor work technique or inappropriate work height, are other likely factors. Outbreaks of soft tissue disorders among keyboard operators have often been associated with high workloads, combined with tight deadlines. This variety of factors contributing to display screen work risk requires a risk reduction strategy that embraces proper equipment, furniture, training, job design and work planning.

- **Visual Problems (Eye and eyesight effects)**

Like other visually demanding tasks, DSE work does not cause eye damage, nor does it make existing defects worse. It may, however, make users with pre-existing vision defects more aware of them and some users may experience temporary visual fatigue, leading to a range of symptoms, such as impaired visual performance, red or sore eyes, headaches, or behavioural changes (for example, postural change). These symptoms may be caused by staying in the same position and concentrating for a long time, by poor positioning of the display screen equipment, by poor legibility of the screen or source documents, by poor lighting conditions, including the presence of glare and reflections, and or by a drifting, flickering or jittering image on the screen.

Uncorrected vision defects can make work with a display screen more tiring or stressful than would otherwise be the case.

- **Fatigue and Stress**

Many symptoms described by display screen users reflect stressors arising from the user's task. They may be secondary to upper limb or visual problems but they are more likely to be caused by poor job design or work organisation, lack of control of the work by the user, under-utilisation of skills, high-speed repetitive working or social isolation.

18.6 Conducting an Assessment

- **Identification of DSE users**

The first step is to identify employees who work with DSE, together with information on the tasks they perform and the amount of time they spend using DSE each day. Those employees who habitually use DSE for a significant part of their normal work should be classified as 'users'.

- **Assessment**

The second step is to assess users' workstations, considering the hardware, the environment, and the factors specific to the individual's use of the equipment should all be considered. The users should be consulted as part of the assessment.

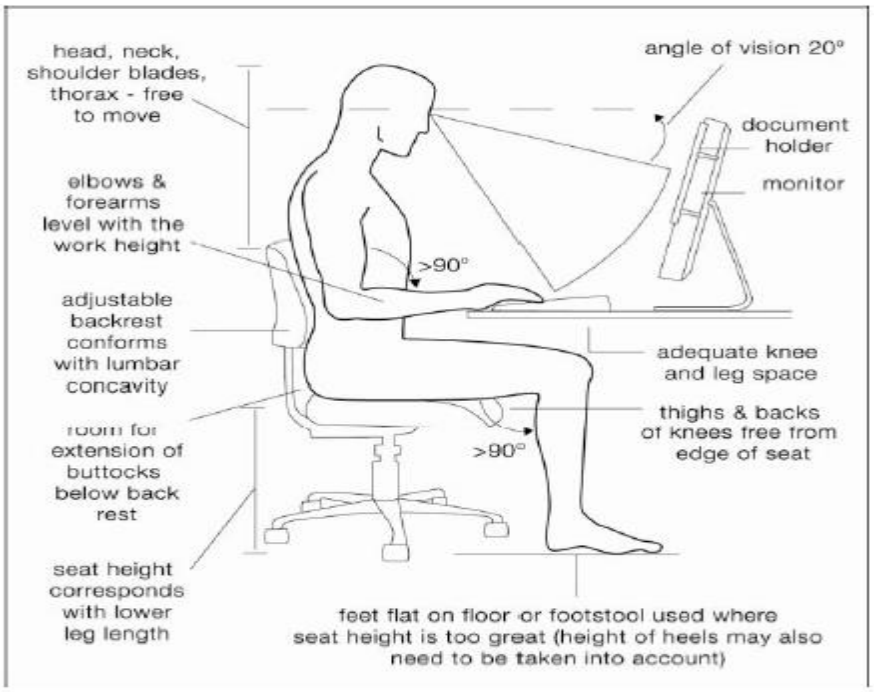
Simple checklists or proformas can be used to facilitate the assessment process, assist in the identification of remedial measures and also serve as a written record once completed.

18.7 Minimum Requirements for Workstations

The following represent good features that should be found in a typical office workstation (see figure 18.4).

- The screen should normally have adjustments for brightness and contrast. This allows individuals to find a comfortable level for their eyes, helping to avoid the problems of tired eyes and eyestrain.
- The seat should be stable and adjustable in height and the seat back should be adjustable in height and tilt. A well-designed and correctly adjusted chair encourages good posture, helping to avoid postural fatigue.

- The keyboard should normally be tiltable and separate from the screen. This allows users to adopt a comfortable typing position avoiding fatigue in the arms and hands.
- The work surface should be spacious allowing flexible arrangement of equipment. This enables the employee to adopt a number of suitable working positions which assist in the prevention of both postural and visual fatigue.
- The document holder should be stable and adjustable. A stable, well positioned document holder will minimise the need for uncomfortable head and eye movements.



(Source: McPhee, 2005 – *reproduced with the permission*)

Figure 18.4 - Suggested Arrangement of an Office Workstation

Note: *This position indicates a starting point to enable the optimum - but not perfect - work posture. No one posture is suitable for all people all the time. Comfortable work postures will vary and they need to change regularly. People doing sedentary work should get out of the chair or seat at least once an hour and move around - more if possible.*

18.8 Administrative Controls

- **Breaks or Changes in Activity**

The daily work routine of users should be broken up by changes in task or by breaks. In most tasks, natural breaks or pauses occur as a consequence of the inherent organisation of the work. Whenever possible, jobs at display screens should be designed to consist of a mix of screen-based and non screen-based work to prevent fatigue and to vary visual and mental demands.

Breaks should be short and frequent, rather than occasional and longer, e.g. a 5 minute break every hour. Several researchers also advocate the adoption of a 'micro-pause' technique, that is, short breaks of 10 – 20 seconds taken every 5 – 10 minutes - this time can be used to quickly stretch and look into the distance.

- **Eye and Eyesight Testing**

In some countries DSE users, or employees who are about to become users, can ask their employer to provide and pay for an eye and eyesight test. This test needs to be performed by a doctor or an optometrist.

- **Information and Training**

Users can often adapt their own workstations to their needs once they are aware of the risks and trained in ways to prevent them.

19 BEHAVIOUR AND CULTURE

19.1 Impacts of Behaviour in Occupational Hygiene

Worker behaviour has an important influence on exposure to hazardous agents in the workplace. For example, contact with hazardous materials can occur by:

- using contaminated tools (e.g. a paint brush with a contaminated handle) or by spreading out a chemical paste with the hands;
- using soiled personal protective equipment (PPE), leading to transfer of contaminant when donning, wearing or removing the equipment;
- poor housekeeping, working untidily or not cleaning up after work.
- failing to use PPE properly when needed, e.g. taking it off halfway through the task, or wearing it ineffectively;
- unhygienic behaviour such as failing to remove protective clothing and wash hands before a meal break.

These kinds of examples are commonly observed in workplaces. A so called “dirty worker” is often encountered who has a much higher level of exposure despite working in what appears to be the same conditions as other workers.

Other examples of behavioural issues might include:

- failing to switch on a ventilation system, or to position a mobile hood correctly;
- handling a material vigorously instead of carefully, generating more airborne vapour or dust;
- standing downwind of an exposure source rather than on the opposite side.

The impact of behaviour on exposure can be minimised by providing good engineering controls, by having good operating procedures in which workers have been well trained, have appropriate supervision and educating the workforce on the contaminants present within their workplace. However, poor behaviour can still lead to elevated exposures. A useful analogy can be drawn with accident prevention. The "Swiss Cheese" model (Reason 1997), suggests that there are multiple, but imperfect, layers of defence against accidents, as

shown below. Accidents occur when failures occur simultaneously in all the defensive barriers.

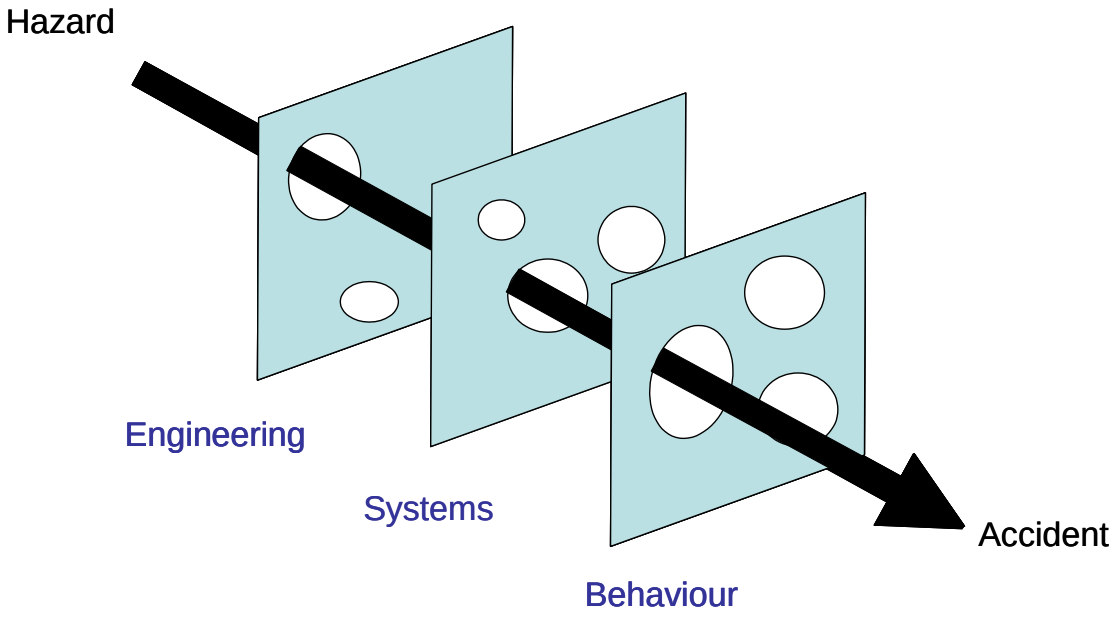


Figure 19.1 - "Swiss Cheese" model of accident prevention

Putting this into hygiene terms, we might have:

- an extraction system that is not operating at full capacity because of lack of maintenance;
- a non-standard task that isn't fully covered by the normal safe working procedure; and
- a worker who is inclined not to wear his PPE.

Any one or two of these measures might be sufficient to control exposure, but if all fail at once, over-exposure is likely.

19.2 Motivation and Behaviour Modification

In order to change behaviours it is necessary to understand and then address the factors which influence our behaviour. In recent years there has been an increase in the use of behaviour modification approaches to safety and the lessons are equally relevant to occupational hygiene. Analysis and modification of the behaviour of the worker involved in an activity has been shown to be an effective way of reducing both accidents and reducing occupational exposures.

Behaviour can be simply understood in terms of the *Antecedents - Behaviour - Consequences (A - B - C)* model (see for example, Daniels A C, Bringing out the Best in People, 2nd ed. 1999, McGraw-Hill).

- **Antecedents** create the initial motivation to act. They can include instructions from the manager, and publicity or awareness campaigns from the occupational health and safety department. How such messages are received will depend on the workers background, including the worker's experience of similar messages in the past, established ways of working and other events taking place around the same time. Antecedents set the stage for what happens next.
- **Behaviour** is the observable act. Unlike attitudes or intentions, behaviour can be observed and quantified. It is objective.
- **Consequences** are what happen after the behaviour. The worker may notice the consequences for themselves. For example, they may find it easier to do the job when their workplace is clean and tidy. Or they may find that the PPE they had to wear made them uncomfortable. They may also get verbal feedback, positive or negative, from their manager or colleagues. It is these consequences that determine whether the worker is inclined to repeat the behaviour.

Antecedents are valuable for initiating change, but only reinforcing consequences will guarantee repetition of the desired behaviour.

Often there are multiple and conflicting consequences which have to be weighed against each other. For instance, the individual may be aware that by using a respirator he has reduced his exposure to airborne asbestos and so has reduced the risk of developing cancer at some point in the future. However, he may have experienced difficulty breathing through the respirator or restricted vision that made the job harder. The general rule is that consequences that are *Soon, Certain and Positive* outweigh those that are *Late, Uncertain and Negative*. So it is easy to see why many workers might choose to discard the respirator, choosing the immediate benefits and believing that the future negative consequences may never happen.

Effective behavioural modification requires managers and health professionals to find ways to minimise the negative consequences and reinforce the positive consequences of the desired behaviours. A common mistake is to revert to the antecedents and to tell people again what they should be doing.

A behavioural intervention can be planned in three distinct stages as follows:

1. Motivation: Firstly it is necessary to motivate individuals in order to get them to want to change their behaviour. This is influenced by previous experience such as:

- Their skills in the activity which they are undertaking and knowledge of the hazards associated with it.
- Their beliefs about consequences of exposure to a particular hazard.
- Their beliefs about the performance and capabilities of control measures.
- The established ways of working (health and safety culture).

2. Instigation: Once people are motivated they need to be supported to enable them to change behaviour. This support needs to be both physical (having time, training, equipment etc) and social (from colleagues and managers).

3. Maintenance: When a behaviour has been changed, efforts need to be made to ensure that it doesn't revert back. Typically health and safety professionals focus on antecedents such as maintaining high levels of awareness and refreshing knowledge and skills. However, the most important factor is reinforcing the positive consequences of the change.

Each of these stages of motivation, instigation and maintenance is in turn influenced by the circumstances within the job (immediate work environment), the organisation and outside organisations society.

19.3 Health and Safety Culture

When a pattern of behaviour becomes widespread in an organisation it can be described as the *organisational culture.* Culture can mean many things – a simple definition is "how we do things around here". This simple definition

illustrates how culture and behaviour are linked and provides an objective way to assess culture by collecting information on observed behaviours.

Culture defines the unwritten rules of an organisation - how things really work, in contrast to what is supposed to happen. Culture reflects the underlying attitudes and values of the organisation.

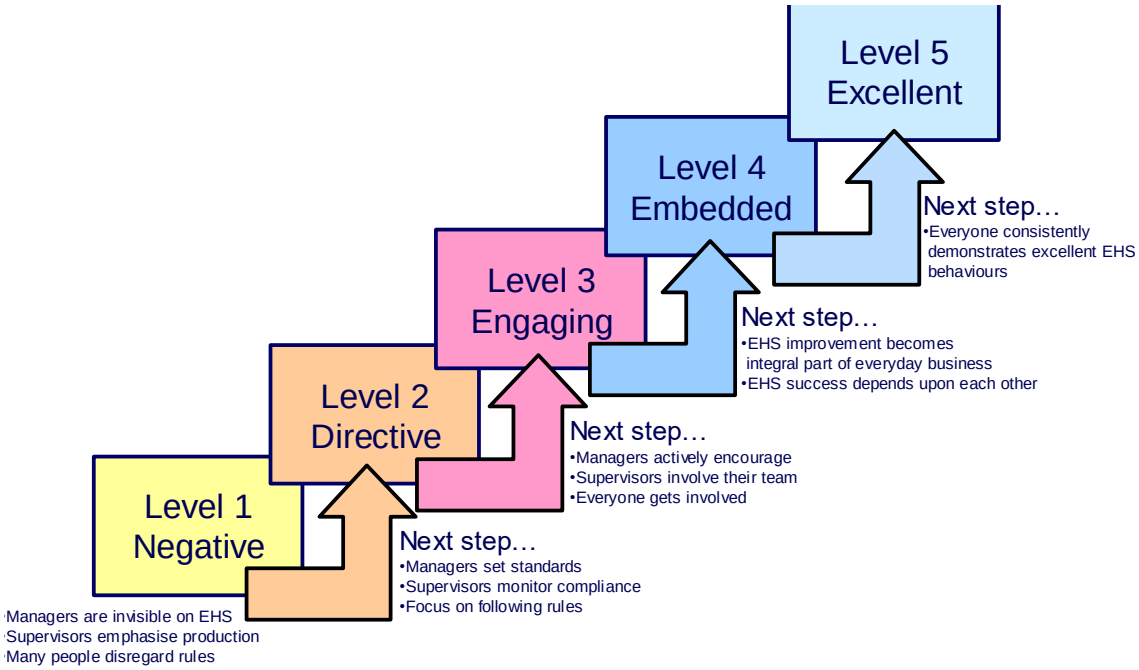
Once a behaviour becomes embedded in the organisation's culture it can be hard to change. It would be pointless encouraging an individual to change his or her behaviour if everyone else continued to behave differently. Peer pressure would ensure that the worker reverted to the cultural norm as soon as possible. In such a situation, the only way to change behaviour is to address the culture. Culture change is a major long term project and requires extensive preparatory work.

An organisation's culture can be said to be positive for health and safety if it encourages behaviours that minimise incidents and exposure to risk. For example, in a positive culture it would be normal for workers to report promptly any defects in control measures; to wear protective equipment correctly; to follow safe working procedures. Similarly, managers would be expected to visit the workplace regularly to check on health and safety; to discuss health and safety with their employees; to act promptly on reports of deficiencies

Negative cultures are often characterised by fear and blame, which inhibit reporting of dangerous conditions and inhibit improvement. Employees flout the rules and managers turn a blind eye.

It has been observed that when identical behavioural safety initiatives are implemented in different organisations, the success of the initiatives varies significantly. In some places an initiative might bring positive change, whereas elsewhere it will fail. How could this be so? Initial research in the oil and gas industry revealed that the success of such safety initiatives was dependent on pre-existing levels of safety culture development. Different sites even within the same organisation, although apparently similar, differed in the how well-developed their safety culture was, and some were not “ready”.

To help ensure the success of a safety culture improvement initiative, this initiative needs to be “matched” to the site’s existing safety culture level. This also means that the most appropriate type of safety culture improvement initiative will change as its level of safety culture improves. What might have helped the company’s safety culture progress from the lower levels of development will not be the same type of initiative that will help it obtain excellence.



Source: GlaxoSmithKline

Figure 19.2 - An example of a culture maturity ladder

The example of a health and safety culture maturity ladder displayed above describes 5 levels of culture. Each level reflects the behaviours and involvement in health and safety of everyone on site. Starting at Level 1 where production is emphasised, people disregard the rules and managers are not visible, up to Level 5 where all levels consistently demonstrate the right behaviours. There are a number of steps that need to be taken in order to move up each level of the ladder. If an organisation tried to move from Level 1 to Level 4 or 5 in one leap the initiative would be likely to fail.

Similarly, it must be recognised that to stay at any level will require work to maintain the situation or the culture can suffer.

20 WORK-RELATED STRESS

Psychosocial aspects of the work environment have been increasingly recognised in recent years. Problems associated with “work-related stress” are now considered a central issue in the management of health and safety. In many developed countries cases of “mental ill health” represent the single most common cause of work-related illness.

Well-designed, organised and managed work helps to maintain and promote individual health and well-being. But where there has been insufficient attention to job design, work organisation and management the benefits associated with work can be lost. One common result is work-related stress.

By the term work-related stress we mean the effects arising where work demands of various types and combinations exceed the person’s capacity and capability to cope. It is a significant cause of illness and disease and is known to be linked with high levels of sickness absence, staff turnover and other indicators of organisational underperformance - including human error.

The design and management of work is important in anticipating, recognising and preventing stressful situations. Of course, many of the greatest stressors in life occur outside the workplace and it is often not possible to avert stress simply by focussing on workplace issues. Many large organisations now offer *resilience* training to their employees to help them manage work-life balance and avoid stress for themselves. For people experiencing stress, though, it needs to be diagnosed and treated in a timely fashion so that the worker can be rehabilitated.

20.1 Symptoms of Stress

Stress produces a range of signs and symptoms, these can include;

Changes in behaviour: finding it hard to sleep, changed eating habits, increased smoking or drinking, avoidance of friends and family or sexual problems.

Physical symptoms: tiredness, indigestion and nausea, headaches, aching muscles or palpitations.

Mental changes: becoming less decisive, finding it hard to concentrate, suffering from loss of memory, feelings of inadequacy or low self esteem.

Emotional changes: getting irritable or angry; feeling anxious or numb, being hypersensitive, or feeling drained and listless.

20.2 Assessment of Stress

The use of a survey is the most common method for gathering information on whether work-related stress appears to be a potential problem in a workforce. It can also give an indication as to who is likely to be affected and how. Surveys typically involve asking all employees a series of questions where they rank their individual perceptions of the kinds of factors likely to contribute to stress or job satisfaction. These might include:

- Task variety.
- Work demands in balance with ability.
- Continuous development of skills.
- Responsibility and authority.
- Participation in work progress and development.
- Involvement in planning and problem solving.
- Deadlines (time pressure).
- Social support and interaction with colleagues.
- Visibility of the entirety of the process.
- Positive work management climate.
- Freedom to move around physically.
- Control over schedule (pace).
- Choice of working methods
- Influence on production quantity and quality.
- Length of cycle time.
- Degree of freedom of action.
- Workgroup organisation.

The UK Health and Safety Executive produce an example of such a survey tool as well as providing a useful spreadsheet tool for analysing the results. See:

http://www.hse.gov.uk/stress/standards/step2/surveys.htm (accessed May 2016).

20.3 Management of Stress

Good management of psychosocial factors in an organisation can help promote the health benefits of work as well as avoiding work-related stress. It involves introducing work practices and a culture through the whole organisation which covers the following aspects of the work:

Demands – including workload, work patterns and the work environment.

- Demands should be adequate and achievable in relation to the agreed hours of work.
- Jobs need to be designed to be within the capabilities of employees.
- People's skills and abilities need to be matched to the job demands.
- Employee concerns about their work environment should be addressed.

Control – how much say the person has about the way they do their work.

- Where possible, employees should have some control over their pace of work.
- Employees should have a say over when breaks can be taken.
- Employees should be consulted over their work patterns.
- Employees should be encouraged to use their skills and initiative to do their work;
- Employees should be encouraged to develop new skills to help them undertake new and challenging pieces of work.

Support – including the encouragement, sponsorship and resources provided by the organisation, line management and colleagues.

- The organisation should have policies and procedures to support employees.
- Systems should be in place to enable and encourage managers to support their staff.
- Systems should be in place to enable and encourage employees to support their colleagues.

- Employees should know what support is available and how and when to access it.
- Employees should know how to access the required resources to do their job.
- Employees should receive regular and constructive feedback on their work.
- Confidential health advice and counselling should be available to employees who need it.

Relationships – including promoting positive working to avoid conflict and dealing with unacceptable behaviour.

- The organisation should promote positive behaviours at work to avoid conflict and ensure fairness.
- Employees should share information relevant to their work.
- The organisation should have agreed policies and procedures to prevent or resolve unacceptable behaviour.
- Systems should be in place to enable and encourage managers to deal with unacceptable behaviour.
- Systems should be in place to enable and encourage employees to report unacceptable behaviour.

Role – whether people understand their role within the organisation and whether the organisation ensures that they do not have conflicting roles.

- The organisation should ensure that, as far as possible, the different requirements it places upon employees are compatible.
- The organisation should provide information to enable employees to understand their role and responsibilities.
- Systems should be in place to enable employees to raise concerns about any uncertainties or conflicts they have in their role and responsibilities.

Change - how organisational change (large or small) is managed and communicated in the organisation.

- The organisation should provide employees with timely information to enable them to understand the reasons for proposed changes.

- The organisation should ensure adequate employee consultation on changes and provides opportunities for employees to influence proposals.
- Employees should be made aware of timetables for changes and have access to relevant support during changes.

21 CAREERS IN OCCUPATIONAL HYGIENE

21.1 Occupational Hygiene Practice

Occupational hygiene services are organised in a variety of different ways depending on:

- the size and resources of the employing organisation.
- the need for specialist expertise.
- the availability of outside help.

A large company working with toxic materials will probably employ one or more occupational hygienists in-house. Small companies, or those with few occupational health risks, will buy in services from a consultant as required.

Some countries provide state occupational hygiene services, through central institutes of occupational health. Others place statutory requirements on employers to use qualified hygienists or occupational health services. Yet others have no regulatory requirements.

In this section we will examine the roles and characteristics of the various types of service, and of the hygiene staff within them.

21.1.1 In-house services

Generally speaking, organisations with less than 1,000 people cannot justify employing a full-time occupational hygienist. Basic hygiene services are likely to be provided through a safety officer or occupational health nurse with a consultant being called in when needed. Exceptions to this rule tend to occur when the company has a specific large scale occupational hygiene problem, for example in the lead industry. Generally large, often multinational organisations, in areas such as chemicals, pharmaceuticals, metal extraction and refining, oil and gas, electronics have in-house occupational hygienists. There are also in-house services in some health authorities and in the civil service.

Such a "service" may comprise a single hygienist, or a number with different levels of experience and seniority. They tend to develop deep expertise in those areas of occupational hygiene of particular interest to the organisation,

and individuals may well have the opportunity to publish research papers. Conversely, the breadth of expertise will only be as wide as the company's operation.

Typical jobs in an in-house function include:

***Assistant hygienist or hygiene technician*.** They will have academic qualifications ranging from GCSE in the UK [or a high school diploma in the USA] to a degree, plus specific (often on-the-job) training in occupational hygiene measurement techniques. Technicians or chemists from a site' laboratory may transfer into such a role.

Their duties could include:

- measurement of worker exposure using standard techniques.
- calibration and maintenance of sampling equipment.
- laboratory analysis of collected samples.
- testing of control measures such as ventilation systems.

Usually these duties will be carried out under the supervision of a more senior hygienist. Even so, the person will need to be resourceful, observant, able to communicate clearly and to adapt to changing technology.

Occupational hygienist, is likely to have had experience as a technician or assistant and may have a higher degree. They will demonstrate a high degree of commitment to the profession. They would be expected to:

- know the workplaces, plant, processes, materials, sources of exposure and people involved.
- know the legal requirements which may apply.
- be well versed in the recognition of potential health hazards and their association with disease or discomfort.
- understand the derivation of the accepted hygiene standards.
- design appropriate workplace or biological sampling programmes.
- select, purchase, calibrate and maintain appropriate field equipment.
- carry out surveys of the workplace and be aware of the limitations of such surveys.

- evaluate the risk to health by using his professional judgement and with reference to reliable hygiene standards.
- apply statistical treatment to the data obtained.
- store and retrieve data as necessary.
- assess control methods by observation and measurement.
- recommend new or improved control measures to management.

In the course of the work there will be contact with management, workforce, unions, medical, safety and engineering personnel. Service on committees, presentations and participation in training sessions may be involved. The hygienist may also represent the company externally, to the enforcing authorities, planning authorities etc.

***Senior occupational hygienist**,* a hygienist with who has proven professional competence and experience.

The senior hygienist uses past experience to introduce appropriate occupational hygiene programmes into the organisation, monitor progress and take action as necessary. Duties may include:

- formulating occupational hygiene policies and standards.
- auditing and monitoring the effectiveness of the policies.
- risk assessment of new processes, by scrutinising materials, plant designs etc and anticipating problems.
- educating and training management and workforce in occupational hygiene.
- supervision and professional development of hygiene staff.
- management of an occupational hygiene laboratory.
- quality assurance of hygiene measurements and programmes.

At this level, excellent communication skills are essential. The senior hygienist must be able to interpret the incoming data and persuade managers, workers or authorities accordingly. Both written and oral skills are crucial.

Other managerial skills are also expected, like the ability to develop subordinates and to control a budget. An appreciation of cost effectiveness is essential to the task, as is an up-to-date awareness of legislation, litigation, toxicology and epidemiology.

It is likely that the senior hygienist will be very active professionally, both learning from his peers and contributing to knowledge. Committee work, publications and presentations are a necessary part of keeping up to date and communicating your own discoveries.

The hygienist may be part of the decision making team at senior management level. In a multi-national company, the hygienist may have corporate responsibilities with an international remit and sound judgement based on years of experience is necessary. Such a hygienist becomes the primary source of information and advice needed by senior management while retaining functional control over occupational hygiene policy and professional practice in the organisation.

21.1.2 Consultancy

Most commonly, consultancy is provided by commercial services. They may be independent companies, or linked to an insurer or equipment manufacturer. In any case, they are normally run for profit and are funded by the fees received. Fees are charged either on a daily rate basis or are quoted for a complete job.

There are exceptions: some trade associations and group services, for example, offer consultancy on a not-for-profit basis. Usually they are funded (at least partly) by a subscription or levy on the members. This may be supplemented by charging a reduced (subsidised) daily rate.

Consultancy is also provided by some universities, who may see it as a way of keeping academic staff in touch with the real world, or simply as another source of income. And there are some independent foundations who may have grant subsidies enabling them to charge reduced fees.

Hygienists in consultancy need the same technical skills as those in industry, but rarely have chance to develop such deep specialisations. Rather they

acquire an incredibly broad experience of different types of problems. This demands an ability to assimilate new situations very quickly and an unusually high degree of self-reliance. On the whole, they tend to be more qualified and experienced than hygienists in industry.

Job levels in consultancies parallel those in industry.

21.1.3 State agencies

Services provided by the state may have enforcement or advisory roles or both. Sometimes the two functions sit a little uncomfortably together, as when an inspector offers advice but threatens to prosecute if the advice is not taken. State services are usually seen as authoritative but may also be viewed with suspicion if they have a role in enforcement.

Enforcing inspectors in the field are usually health and safety generalists, who call in specialist occupational hygiene help when required to carry out surveys and provide advice.

Hygienists may also be involved in:

- Coordinating data for standard setting.
- Serving on national and international committees.
- Liaison with many national scientific, industrial and academic bodies.
- Commissioning or conducting research.
- Producing guidance on the whole spectrum of prevention and control issues.
- Drafting and reviewing legislation.

In some countries the state agencies are funded through general taxation. In others, companies pay a compulsory levy to fund state occupational health services. The levies may be supplemented by discounted consultancy fees for specific projects. In these countries, private commercial consultancies tend to be uncommon.

21.1.4 Research and teaching

The universities, colleges and research organizations provide another employment area for hygienists. They may:

- carry out research into health hazards, measurement techniques or control methods
- teach undergraduate and postgraduate courses, and lecture to doctors, nurses, safety officers, engineers etc, as a subsidiary subject.
- conduct occupational hygiene investigations within the organisation and sometimes externally as consultants.

The career structure of lecturer, senior lecturer and professor is common to other university functions and does not necessarily relate to occupational hygiene qualifications.

21.2 Implications for Hygienists

These differing characteristics of the various types of occupational hygiene services have a profound effect on what they are like to work in. The objectives, management and funding of the organisations all impose constraints on how they operate, with areas to consider including service provision of the business, facilities available to provide services, opportunities for development and advancement and quality assurance within the organisation. .

21.3 The Hygienist as a Manager

The concept of the hygienist as a manager can mean different things to different people. It might imply:

- managing occupational hygiene programmes - designing programmes, planning their implementation, conducting and monitoring them;
- managing a hygiene service - either in-house or as a consultancy, with responsibility for staff, budgeting etc.;
- being part of a company's management team, advising line managers on specialised hygiene matters to meet the needs of the business.
- changing careers - moving into an area such as marketing or line management on the strength of the abilities acquired through practising as a hygienist.

All of these are possible interpretations, but a broader concept of the management role of the hygienist is also possible.

The effectiveness of a hygienist can be judged by the success achieved in improving the working environment. The hygienist must strive to enlist the cooperation of the workers in the occupational hygiene programme, with the full support of management and utilising to capacity any other hygiene staff. Effectiveness depends partly on technical knowledge, but mostly on an ability to get results. It may involve:

- influencing employees to use the control measures provided properly;
- supervising other hygiene staff to perform optimally; or
- influencing managers to make or support decisions.

Getting results in this way, through people, is the science of management. It requires attitudes, knowledge and skills which traditionally are not taught to hygienists.

An occupational hygiene manager has a major influence on company policies, direction and performance. Management ability is therefore a core requirement for all senior hygienists. Key skills which must be mastered include:

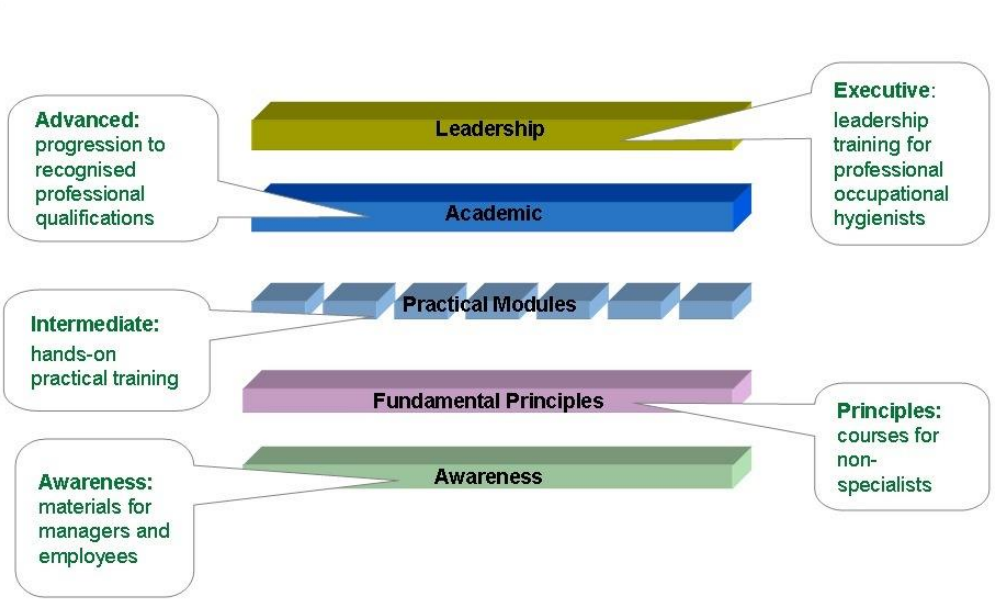
- Executive & administrative skills such as setting objectives, planning, supervision, problem solving, decision making, time management, delegation, budgeting and auditing;
- People management skills including recruitment interviewing, training and development of staff, counselling, disciplinary interviewing, team building, leadership and motivation;
- Communication skills like report writing, making presentations and public speaking, handling meetings, persuasion (or selling) and negotiation.

These skills must be used against a background of the organisation's culture, procedures, current status and plans. Hygienists should plan to gain experience of management situations as part of their career development and or attend management skills training. A more difficult adjustment is the necessary shift in attitudes. Traditionally hygienists are impartial advisers, who present the facts for others to make decisions. Becoming a manager implies

being willing to take ownership of issues. The manager must remain objective, but be results oriented rather than impartial. Managers must also be willing sometimes to take decisions on the basis of incomplete data rather than deferring action until the scientific proof is complete.

21.4 Personal Development

Occupational hygiene is a subject that offers opportunities for lifelong learning and development. Not only is it broad and technically challenging, but it evolves over time creating new fields of knowledge. Taught courses are available at five different levels (see figure 21.1).



Source: Steve Bailey

Figure 21.1 – Education and Training Needs

Many hygienists are the sole hygienist in their organisation and may feel unsure what training they need or how to develop themselves. There are many ways for hygienists to keep in touch with their professional peers so that they can share information and learn from each other.

21.4.1 Join a society

There are established occupational hygiene societies in nearly 30 countries. Details can be found on the website of the International Occupational Hygiene Association (IOHA) - see http://ioha.net/ (accessed February 2016).

Many societies offer conferences and meetings for hygienists to come together, with Newsletters and websites to help people stay in touch. Some also offer professional qualifications. There are 15 countries with IOHA recognised certification schemes covering 9 different languages. The countries with IOHA National Accreditation Recognition certification schemes are:

- Australia
- Canada
- France
- Germany
- Hong Kong
- Italy
- Japan
- Malaysia
- Netherlands
- Norway
- South Africa
- Sweden
- Switzerland
- United Kingdom
- United States

A global system of training and qualifications to facilitate transferability of qualifications between countries has been established through OHTA (Occupational Hygiene Training Association) www.ohtatraining.org accessed February 2016.

21.4.2 Get involved

- Join an internet forum. Most large associations or institutes have them, as do large manufacturing companies.
- Go to conferences and give presentations.
- Attend or arrange a local meeting.
- Keep up to date by reading occupational hygiene journals such as Annals of Work Exposures and Health - see https://academic.oup.com/annweh (accessed July 2019) and the

Journal of Occupational and Environmental Hygiene – see http://www.aiha.org/news-pubs/Pages/JOEH.aspx (accessed February 2016).

21.4.3 Build your network

- Find an individual that you can maintain contact with, either as a buddy or as a mentor.
- Partner with a university, consultancy or training organisation in your area.

21.5 Ethics

The primary duty of a hygienist must always be to safeguard the health and well-being of the workforce. But the hygienist also has responsibilities towards his employer, clients (if the hygienist is a consultant) and the general public. Inevitably, then, ethical questions will arise. For instance:

- confidentiality of personal occupational health data must be protected, yet employers must be told which employees are at risk.
- there may be conflicts of loyalty between the duties of hygienists to employers, workers, clients and the law.
- there may be constraints on the freedom of the hygienist to carry out his duties e.g. access to sites, equipment available, time allowed, level of supporting staff.
- the use of junior staff for fieldwork can raise questions about the adequacy of supervision.
- advertising and sales practices of consultancies may need to be subject to ethical constraints.

Professional bodies will have a written Code of Ethics to ensure these matters are dealt with responsibly and consistently by the profession. Standards of conduct are as rigorous as those required by other professional disciplines such as medicine and the law. Members are obliged to comply with the Code and may be subject to disciplinary action and possibly expulsion if they do not.

Under a Code of Ethics, the principal duty to employees may be supplemented by a number of subservient duties, for example:

To employers / clients

- Keep confidential all information about their operations or processes.
- Advise honestly, responsibly and competently.

To the workforce

- Maintain an objective attitude towards risks to health.
- Use information gained solely for occupational hygiene purposes and for the benefit of the workforce.

To the general public

- Maintain an objective attitude towards matters of public concern.
- Confine themselves to matters on which they can speak with authority, distinguishing between accepted fact and informed opinion.

To other professionals

- Maintain the highest levels of integrity and professional competence.
- Respect other professionals and avoid conflict situations where possible.

In addition, consultant hygienists have some special responsibilities:

- To inform their client of any interest or employment that might compromise their independence.
- Not to work for more than one client simultaneously on the same matter.
- Not to accept payment or gratuities from any third party.
- Not to improperly solicit for work, e.g. by offering financial inducements or by calling into question the ability of another consultant.

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