

# Chemical hazards

Allan R. Mbewe

# Classification of Hazardous chemical substances

## 1. Solid

- Grinding, abrasion or disintegration of a large piece of material may produce dust.
- A dust is defined as a group of airborne solid particles ranging from 0.1 to 100 micrometers in diameter (1 micron = 0.001mm or  $\mu\text{m}$ ).

## 2. Liquids

- Liquids, like solids, can cause physical damage as well as poisoning.
- Fluidity gives liquids mobility and leads to problems containment as they are readily converted to aerosols and vapours.
- Liquids can dissolve and react with other substances – which may have profound effects and harm to living organisms

# Classification of Hazardous chemical substances Cont'd.

## 3. Gases

- Gases can cause either physical or chemical damage e.g. an inert gas could kill simply by displacing air.
- Chemicals in gas phase are most hazardous from point of acute toxicity since the lungs have evolved to facilitate uptake of oxygen and readily absorb most gases.
- Absolved gases enter the general blood circulation directly, unlike substances absorbed from the intestine, which are often transformed by the liver.

# Classification of Hazardous chemical substances Cont.

## 4. Vapour

- Vapours are the gaseous form of substances which are normally in solid or liquid form at the existing temperature and pressure.
- Vapours are in equilibrium with the solids or liquids from which they originate.
- The equilibrium changes with changes in temperature and pressure.
- Vaporization increases with increase in temperature or with decrease in pressure.
- Substances with high vapour pressure and liquids with low boiling points vaporise readily

# Classification of Hazardous chemical substances Cont'd.

## 5. Aerosols

- An aerosol is a suspension in a gas of liquid droplets or solid particles, ranging from 0.001 to 100  $\mu\text{m}$  effective aerodynamic diameter.
- Mass concentration may range from  $10^{-9}$  to 10 gm per cubic meter gas.
- Amongst aerosols, a distinction should be made between dusts, fumes, smoke, mist and fog (smog).

# Classification of Hazardous chemical substances Cont'd.

## 6. Fumes

- These are solid particles formed by condensation from gaseous or vapour phase.
- Fumes usually result from chemical reactions such as oxidation or from sublimations or distillation process followed by condensation e.g.
  - oxides of iron and copper.
- Fumes may flocculate and coalesce.
- Fume particles are usually less than  $1\mu\text{m}$  in diameter and can be breathed into the alveoli but are usually breathed out again and so may be less of a hazard than larger particles in the  $0.5$  to  $10\mu\text{m}$  range.

# Classification of Hazardous chemical substances Cont.

## 7. Smoke

- Smoke results from combustion of fossil or biofuels, asphaltic materials and wood.
- Smoke consists of soot, liquid droplets and, in the case of wood and coal, ash.
- Smoke contains polycyclic aromatic hydrocarbons which are identified as carcinogens and is associated with increased risk of lung cancer and should be kept to a minimum

# Classification of Hazardous chemical substances Cont.

## 8. Mist, fogs and smog

- Mist and fogs consist of suspended droplets formed by condensation of gas or vapour or by dispersal of liquid by splashing or foaming or by deliberate atomization e.g.
  - oil mist from cutting and grinding operations and pesticide mists from spraying operations.
- Mists and fogs may carry harmful micro-organisms in suspension.
- Smog is a term coined in 1905 to describe the mixture of smoke and fog that plagued industrial England.
- The air pollutants (sulphur oxides and particulates) combine with atmospheric moisture to form the greyish haze called smog, especially in winter.

# Points to note in physical forms of chemicals

- Chemical substances can change from one physical form to another depending upon the environmental conditions, especially temperature and pressure
- Sunlight can cause photochemical processes to occur and large changes in the chemistry of exposed systems such as, ultraviolet radiation and X-rays
- Most work environmental samples will contain chemicals in a variety of states and these will determine the exposure conditions for people or other organisms at risk.
  - It is important that environmental conditions are known before any hazard characterization or risk assessment is made.

# Points to note in physical forms of chemicals cont'd

- Electromagnetic and electrostatic fields may affect the distribution of particulates and consequently both exposures and related chemical processes
- Radon is a naturally occurring radioactive gas which may complicate interpretation of epidemiological data relating to mutagenic chemicals

# Adverse effects of chemical hazards based on toxicological effects

## 1. Irritants

- Irritants can affect various parts of the respiratory tract. The following distinctions can be made:
  - Chemical irritants which only affect the upper respiratory tract e.g.
    - ✓ aldehydes (acetaldehyde, acrolein, formaldehyde, paraformaldehyde)
    - ✓ alkaline dusts and mists
    - ✓ ammonia, chromic acid, ethylene oxide, hydrochloric acid fumes, hydrofluoric acid fumes, sulphur dioxide and sulphur trioxide.

# Irritants cont'd

- Irritants which affect the upper respiratory tract and the lung tissue e.g.
  - ✓ halogens (bromide, chlorine, fluorine and iodine),
  - ✓ chlorine oxides, cyanogen bromide, cyanogen chloride,
  - ✓ dimethyl sulphate, ozone, sulphuric chloride, phosphorus trichloride  
phosphorus pentoxide.
- Irritants which affect mainly the terminal respiratory passages and air sacs e.g.
  - ✓ arsenic trichloride
  - ✓ nitrogen dioxide
  - ✓ phosgene.
- The nature of the effect and region affected are determined mainly by the irritant's water solubility or its solubility in pulmonary fluids.

## 2. Asphyxiants

- These agents interfere with the oxidation of the cells of the tissues.
- They are usually physiological inert gases which exert their influence by diluting atmospheric oxygen to partial pressure below that required to maintain an oxygen saturation of the blood which is sufficient for normal tissue respiration.
- When the concentration of oxygen in the inhaled air falls below the normal level of 20.9% adverse effects occur e.g.
  - distress occurs below 16%, unconsciousness below 11% and breathing soon stops at a concentration of 6% and lower.
- This will of course result in death e.g.
  - acetylene, argon, CO<sub>2</sub>, ethane, helium, hydrogen, neon, nitrogen and nitrous oxide.

# Asphyxiants cont'd

- Chemical asphyxiation also occurs by means of a chemical reaction which either prevents blood from transporting oxygen from the lungs or prevents normal oxygenation of the tissues, even if the blood is saturated with oxygen e.g.
  - CO (combines with haemoglobin)
  - cyanogens, hydrogen cyanide, nitrites (inhibits oxidation enzymes)
  - aniline
  - methyl and dimethyl aniline
  - toluidine (forms inactive methaemoglobin)
  - nitrobenzene (not only forms methaemoglobin but also lowers blood pressure and disturbs and finally halts breathing)
  - hydrogen sulphide (causes respiratory paralysis)

### 3) Anaesthetics and narcotics

- These substances act primarily by inducing simple anaesthesia without serious system effects.
- They have a depressant action on the central nervous system through their partial pressure in the blood supply to the brain e.g. in the descending order of their action:
  - acetylene hydrocarbons (acetylene, allylene, crotonylene)
  - olefin hydrocarbons (ethylene to heptalene)
  - ethers (ethyl and isopropyl ether)
  - paraffin hydrocarbons (propane to decane)
  - aliphatic alcohols (ethyl, propyl, butyl, and amyl)
  - esters (these substances are not particularly anaesthetic are hydrolyzed in the body organic acids and alcohols)

## 4) Systemic effects

- Systemic effects usually occur from substances which are not highly reactive but are absorbed and distributed around the body causing systemic injury at target organ or tissue distinct from the absorption site.
- Target is not necessarily the organ of great accumulation e.g.
  - organochlorine pesticides accumulate to very high levels in adipose (fatty) tissue but do not appear to be harmed by them.
- Some substances cause both local and systemic effects e.g.
  - tetraethyl lead which damages the skin on contact is absorbed and transported to the central nervous system where it causes further damage.

## 4) Systemic effects cont'd

- Effects of the chemical can accumulate even if the chemical itself does not e.g.
  - this true of organophosphate pesticides on the nervous system
  - the death of nerve cells accumulate because they cannot be replaced though damaged nerve fibres can be regenerated.

# 5) Allergy – Allergic Hypersensitivity

- Allergic hypersensitivity is the name given to disease systems following exposure to a previously encountered substance (**allergen**) which would otherwise be classified as harmless.
- Essentially, an allergy is an adverse reaction of the altered immune system.
- The allergic response and subsequent exposure to an allergen is called sensitization or hypersensitivity.
- Allergic reactions may be very severe and even fatal.
- To produce an allergic reaction, most chemical must act as **haptens**, that is, combine with protein to form **antigens**.

## 5) Allergy cont'd

- These antigens cause production of **antibodies** and further exposure to the allergen (previously encountered substance) can cause the allergy or disease symptoms.
- The most common allergies or symptoms are:
  - Skin ailments such as dermatitis and urticaria (an allergic reaction of the skin which induces sensation of burning and itching)
  - Eye problems such as conjunctivitis or worse
  - Death resulting from anaphylactic shock (hypersensitiveness or susceptibility produced by the allergen) e.g. Idiosyncratic reaction.

## 6. Idiosyncratic reaction

This is another form of extreme sensitivity or reaction.

- An idiosyncratic reaction is an excessive reactivity of an individual to a chemical e.g.
  - an extreme sensitivity to low doses as compared with the average member of the population.
- The other form of an idiosyncratic reaction relates to an abnormally low reactivity to high doses e.g.
  - a group of people which has a deficiency of an enzyme required to convert methaemoglobin (which cannot carry oxygen) back to haemoglobin.
- This group is exceptionally “sensitive” to chemicals like nitrites which produce methaemoglobin condition (blue-baby syndrome).

## 6) Acute and chronic effects

- This factor considers whether adverse effects produced by a potentially toxic chemical are likely to be:
  - Acute or immediate reaction or
  - Chronic or delayed reaction.

## 6 (a) Acute effects

- Acute effects are those symptoms that appear right or soon after exposure e.g in Bhopal disaster;
  - many people complained of chest pains and severe eye irritations and many children died soon after being exposed.
- Acute effects often disappear shortly after exposure ends and are generally caused by fairly high concentrations of chemicals during the short term of exposure.
- Most effects classified under local effects are acute in nature
- Chronic effects are delayed and long lasting responses to toxic agents.
- They may occur months or years after exposure and usually persist for years as in the case emphysema caused by cigarette smoke or air pollution.

## 6(a) Chronic effects Cont'd

- Chronic effects are generally the result of low level exposure over long periods, though short term exposures may also have delayed effects e.g. in Bhopal disaster;
  - methyl isocyanate effects are still being felt today.

## 6(a) Chronic effects Cont'd

- Chronic effects are difficult to control because of their long latency period which provides a false assurance of safety from chronic effects, such as cancer, during periods of exposure.
- In most cases, by the time symptoms of cancer are detected it is too late to save the worker by removing him from further exposure at a workplace.
- Most hazardous compounds known to day have been identified by ‘body count’ or epidemiology.
- The hidden chronic long term effect is called latency and may result in development of cancer, mutations, birth defects and reproductive impairment

# Outcomes of chronic long term effects

## a) Cancer

- Cancer is uncontrolled proliferation of cells that form the **primary tumour** and travel in the blood and other body fluids.
- The spread of cancerous cells is called **metastasis**.
- In distant sites the cancerous cells may form **secondary tumours**.
- Remember that every cancer starts when there is disorder in a single cell growth.
- The process occurs most often in tissues undergoing rapid cellular division, for example, the bone marrow, lungs, linings of intestines, ovaries, testes and skin.

# Cancer cont'd

- None dividing cells, such as nerve cells and muscle cells rarely become cancerous.
- Many cancers begin after **mutations** or changes in the genetic material, **DNA (deoxyribonucleic acid)**, a chemical blue print which carries coded genetic information).
- Ninety percent of all chemicals known to cause cancer also cause mutations in bacterial test systems.
- The causative agents include a variety of chemical substances, viruses, physical agents such as x-rays and ultraviolet light, emotions, smoking, etc.

# Cancer cont'd

- Research has shown that 20 to 40% of all cancers are caused by workplace and environmental pollution (Daniel D. Chiras 1991).
- The majorities of people are exposed to or work with more than one chemical at the same time.
- Other problems associated with cancer causation and control is the discovery that it involves at least two stages:
  - Initiation – the first stage and
  - Promotion – the subsequent stage

# Initiation and promotion process

- The initiating chemical or compound transforms a normal cell into a potential tumour cell, by mutating the cell's genetic material.
- The promoting chemical stimulates the division and replication of this cell, creating a tumour.
- An example of this type of effect is one demonstrated by polycyclic aromatic hydrocarbon, benzo(e)pyrene.
- This compound is not carcinogenic following repeated administration to experimental animals.
- However if exposure to this compound is combined with exposure to minute iron particles (also inactive as a carcinogen), tumours are produced in the animals.

# Initiation and promotion cont'd

- Compounds and materials that can promote carcinogenesis tend to have the ability to irritate cells and increase the tendency of cells to multiply.
- Some compounds are complete carcinogens, that is, they have both effects of initiation and promotion e.g. asbestos, aflotoxins, benzene etc.

# Examples of complete carcinogens

- Examples of carcinogens:
  - aromatic amines (naphthylamine, 4-aminodiphenyl, auramine, benzidine)
  - nitro-and azo-derivatives of aromatic amines, arsenic, asbestos, benzene, beryllium
  - chromate (hexa-valent compounds)
  - coal tar products (anthracene oil, asphalt, coke, creosote oil, carbon black, lignite pitch, soot and tar oil)
  - power paraffin, grease, paraffin oil, and wax
  - radiation (radioactive substances, ultraviolet rays, and x-rays).
- Even cobalt and nickel compounds are suspect.

## b) Mutations

- Agents that cause changes (mutations) in the genetic material are called **mutagens**.
- In other words, they alter the genes and thus the chromosomes of the cell.
- In general three types of genetic alteration are seen:
  - changes in the DNA itself
  - alterations of chromosomal structure i.e. deletion or rearrangement of parts of the chromosomes
  - missing or developing extra chromosomes
- For our purposes the term mutations includes all three above.

# Mutations cont'd

- Mutations can be caused by chemical substances such as caffeine (stimulant found in coffee and tea) or physical agents such as ultraviolet light and other high energy radiation.
- Mutations may also occur in reproductive cells or germ cells found in the male and female gonads (testes and ovary).
- Unrepaired germ-cell mutations may be passed on to offspring.
- If a genetically damaged ovum, for example, is fertilized by a normal sperm, the mutation is passed on to every cell in the offspring.

# Mutations cont'd

- This delayed effect makes it difficult to pinpoint the causes of mutations e.g. mutagens include:
  - Ionising radiation, radio-active isotopes ( $C^{14}$ ,  $Na^{24}$ ,  $P^{32}$ ,  $Ca^{45}$ ,  $Fe^{55}$ ,  $Zn^{65}$ )
  - certain chemicals (alkylating agents such as ethylenelmine, anticarcinogenic drugs such as 6-mercaptopurine, antidepressant drugs, fungicides such as captan, pesticides, solvents)

## c) Birth defects

- Birth defects are physical, biochemical, or functional abnormalities manifest in newly born children.
- The most obvious defects are the physical abnormalities e.g.
  - cleft palate
  - lack of limbs, or
  - spinal bifida (a disease characterized by an imperfect closure of the spinal cord, often resulting in paralysis).

## Birth defects cont'd

- The incidence of birth defects is usually higher than anticipated because minor defects escape detection at birth.
- For example, mental retardation and certain enzyme deficiencies are commonly missed by physicians.
- Agents that cause birth defects are called **teratogens**.
- Unlike mutagens, however, teratogens do not have an effect on the body's genetic material but on embryonic development.
- Embryonic development can be divided into three parts:
  - A period of early development right after fertilization (1 to 2 weeks)
  - A period when organs are developing (organogenesis) or embryonic period
  - A period during which the organs have formed and the foetus mainly increases in size

# Effects on embryonic development cont'd

- Teratogenic agents have a pronounced effect on embryonic development during organogenesis
- The effects of a teratogenic agent are related to both time and exposure and the type of chemical.
- Certain chemicals affect only certain organs e.g. Methyl mercury damages the development of brains of embryos.
- Ethyl alcohol can affect several systems; for instance, children born to alcoholic mothers exhibit numerous defects including growth failure, facial disfigurement, heart defects and skeletal defects

## d) Reproductive impairment

- Reproductive toxicity is the field of study that examines the effects of chemical and physical agents to reproductive systems of males and females.
- Reproduction is a complex process involving many steps as follows:
  - An ovum and sperm meet and successfully unite
  - The zygote, the product of this union, must divide by mitosis and become implanted in the wall of the uterus, where it acquires nutrients from the mother's blood
  - Tissues develop from the ball of cells, and then organs develop from these tissues.

# Reproduction process cont'd

- Meanwhile, the mother is undergoing metabolic and hormonal changes and at the end of the development period (about 9 months) birth takes place
- This requires hormones that contract the uterus and expand the cervix (the opening between the vagina and uterus)
- Next, the breasts begin to produce the milk, a hormonally regulated process called **lactation**

# Reproductive impairment cont'd

- The chemical and physical agents may interrupt any of the above complex processes thus interfering with reproduction.
- The field of study that examines these effects is called **Reproductive Toxicology**.
- Studies have shown that factory workers temporarily become sterile when exposed on the job to DBCP (1, 2-dibromo-3-chloropropane).
- Also men who routinely handle various organic solvents e.g. Carbon tetrachloride, chloroform, trichloroethylene, 1,4-dioxane) often have abnormal sperms, unusually low sperm counts and varying levels of infertility.

# Chemicals associated with reproductive impairment

- A wide number of chemicals such as:
  - diethylstilbestrol (DES)
  - borax (used in the manufacture of enamels and glazes, or soldering flux, tanning and as antiseptic)
  - cadmium (for electroplating other metals or component of many alloys, alkaline batteries, fluorescent lamps, etc)
  - methyl mercury and many cancer drugs are toxic to reproductive systems of males and females.

# Reproductive impairment cont'd

- Studies in Quebec, Canada, showed that of the 386 children who had died of cancer before the age of 5, their fathers had been working at the time they were conceived, in occupations that exposed them to high levels of hydrocarbons.
  - Some were painters exposed to paint thinners.
- This suggested that hydrocarbons had entered the blood stream
  - travelled to the testis and there damaged the germ cells resulting in genetic defect (mutation passed to the offspring)

# Interactions that may influence development of adverse effects upon exposure to a chemical (toxin)

## 1. Reversible or irreversible adverse effect

- It is important to consider whether the adverse effect is reversible or irreversible.
- For liver, which has a great capacity for regeneration, many adverse effects are reversible and complete recovery can occur.
- For the central nervous system in which regeneration of tissue is severely limited, most adverse effects leading to morphological changes are irreversible and recovery is, at best, limited.
- Carcinogenic and teratogenic effects are also irreversible, but suitable treatment may reduce the severity of effects.

# Interactions that may influence development of adverse effects upon exposure to a chemical Cont'd

## 2. Additive effect

- This is an effect which is the result of two or more chemicals acting together and which is the simple sum of their effects when acting independently.
- In mathematical terms:  $1+1 = 2$  or  $1+5 = 6$ .
- Effects of organophosphates are usually additive.

# Interactions that may influence development of adverse effects upon exposure to a chemical Cont'd

## 3. Synergistic or multiplicative effects

- This is an effect of two chemicals acting together which is greater than the simple sum of their effects when acting alone.
- This is called synergism. In mathematical terms:  $1+1 = 4$  or  $1+5 = 10$  etc.
- The best example of this is “asbestos fibres and cigarette smoking).

# Interactions that may influence development of adverse effects upon exposure to a chemical Cont'd

## 4. Potentiation interaction

- In potentiation, a substance while on its own causes no harm makes the effects of another chemical much worse
  - This may be considered to a form of synergism. In mathematical terms:  
 $0+1 = 5$ ;  $0+5 = 20$  etc.
- Example of this is;
  - Isopropanol, at concentrations which are not harmful to the liver, increases (potentiates) liver damage caused by a given concentration of carbon tetrachloride.

# Interactions that may influence development of adverse effects upon exposure to a chemical Cont'd

## 5. Antagonism

- An antagonism effect is the result of a chemical counteracting the adverse effects of another
- It is a situation where exposure to two chemicals together has less effect than the simple sum of their independent effects.
- Such chemicals are said to show antagonism. In mathematical terms:  $1+1 = 0$ ;  $1+5 = 2$  etc.

# Interactions that may influence development of adverse effects upon exposure to a chemical Cont'd

## 6. Tolerance interaction

- Tolerance is a decrease in sensitivity to a chemical following exposure to it
- Tolerance may result in almost complete insensitivity to a chemical.
- It usually reflects metabolic capacity to inactivate and eliminate the chemical and its metabolites e.g.
  - cadmium causes tolerance to itself in some tissues by inducing the synthesis of the metal-binding protein, metallothionein.
- However it should be noted that cadmium-metallothionein sticks in the kidney causing nephrotoxicity.

# Interactions that may influence development of adverse effects upon exposure to a chemical Cont'd

## **7. Other predisposing factors**

- Racial characteristics
- Age and experience
- Skin type
- Perspiration
- Sex
- Season and humidity
- Personal hygiene
- Pre-existing skin diseases or health conditions

# Some important adverse effects of chemical hazards

<i>Pollutant</i>	<i>Major Sources</i>	<i>Typical Effects</i>
Carbon monoxide (CO)	Incomplete combustion of fuels, automobile exhausts, jet engine emissions, blast furnaces, mines and tobacco smoking.	Toxicity, blood poisoning, increased proneness to accidents, CNS impairment. CO combines with haemoglobin, forming carboxy haemoglobin, which interferes with respiration and hence leads to death.
Hydrogen sulphide (H <sub>2</sub> S)	Coke ovens, paper mills, petroleum industry, oil refining, viscose rayon manufacturing plants, manufacture of dyes, tanning industry and sewage treatment plants.	Headaches, conjunctivitis, sleeplessness, pain in the eyes, respiratory paralysis, and asphyxiation, malodorous. In high concentrations, it may lead to blockage of oxygen transfer, poisoning cell enzymes and damaging nerve tissues.

# Some important adverse effects of chemical hazards Cont.

<i>Pollutant</i>	<i>Major Sources</i>	<i>Typical Effects</i>
Sulphur Dioxide (SO <sub>2</sub> )	Combustion of coal, combustion of petroleum products, burning of refuse, petroleum industry, oil refining, power houses, sulphuric acid plants, metallurgical operations and from domestic burning of fuels.	Increased breathing rate and feeling of air-starvation, suffocation, aggravation of asthma and chronic bronchitis, impairment of pulmonary functions, respiratory irritation, sensory irritation, irritation of throat and eyes.
Oxides of Nitrogen (NO <sub>2</sub> )	Automobile exhausts, coal-fired and gas-fired furnaces, boilers, power stations, explosives industry, fertilizer industry, manufacture of HNO <sub>3</sub> , combustion of wood and refuse	Respiratory irritation, headache, bronchitis, pulmonary emphysema, impairment of lung defenses, edema of lungs, lachrymatory effect, loss of appetite, corrosion of teeth.

## Some important adverse effects of chemical hazards Cont.

<i>Pollutant</i>	<i>Major Sources</i>	<i>Typical Effects</i>
Dusts	Asbestos factories, mining activities, power stations, metallurgical industries, ceramic industry, factory stacks, glass industry, cement industry, foundries.	Respiratory diseases, toxicity from metallic dusts, silicosis and asbestosis from the specific dusts. Asbestos dust causes pulmonary fibrosis, pleural calcification and lung cancer.
Ammonia (NH <sub>3</sub> )	Chemical industries, coke oven refineries, stocks yards, fuel incineration. Refrigerant	Damage to respiratory tracts and eyes, corrosive to mucous membranes.
Formaldehyde (HCHO)	Waste incineration, automobile exhausts, combustion of fuels, photochemical reactions.	Irritation to eyes, skin and respiratory tract.

## Some important adverse effects of chemical hazards Cont.

<i>Pollutant</i>	<i>Major Sources</i>	<i>Typical Effects</i>
Lead (Pb)	Automobile emissions, lead smelters, burning of coal or oil, lead arsenate pesticides, smoking mining and plumbing.	Absorption through gastrointestinal and respiratory tract and deposition in mucous membranes, cause liver and kidney damage, gastro-intestinal damage, mental retardation in children, abnormalities in fertility and pregnancy.
Zinc (Zn)	Zinc refineries, galvanizing processes, brass manufacture, metal plating, and plumbing.	Zinc fumes have corrosive effect on skin and can cause irritation and damage mucous membranes.

# General preventive and control measures of chemical hazards

- Elimination of a specific chemical hazard or process
  - This involves banning importation and usage of the chemical
- Substitution of process, equipment or materials
- Isolation of process, material or worker
- Enclosure of process or machinery
- Ventilation through general ventilation and local exhaust ventilation
- Personal and general hygiene

# Preventive and control measures Cont'd

- Personal protection (use of PPE)
- Occupational hygiene:
  - Identification, assessment and control of hazards
- Provision of supplementary environmental health facilities and services
- Have occupational health policy and safety programmes
- Enforcement of occupational health safety laws

THE END

THANKS