GUIDELINES ON

prevention and control of chemical hazard

MINISTRY OF
MANPOWER

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INTRODUCTION

Chemicals are used extensively in industry. Many useful products are derived from chemicals. Examples are pesticides, fertilizers, paints, plastics and fibre glass.

However, it is important to exercise caution in the usage of chemicals. Some chemicals are inherently so dangerous that they have to be stored in special containers to avoid contact with air. Others may appear harmless, but can cause injury almost immediately upon contact. For many toxic chemicals, the health effects may take a long period of time to develop.

Basically, chemicals may pose one or more of the following hazards: toxic, flammable, explosive, reactive and radioactive. To assess the hazard potential of a chemical, one should look not just at the inherent properties such as flammability, toxicity, reactivity or radioactivity of the chemical but also, the degree of exposure to the users. The latter would depend on many factors such as the chemical and physical properties, frequency of usage, amount of materials being used and manner in which such chemicals are handled.

These guidelines serve to enable readers to understand the hazards that chemicals can pose, to identify such hazards and take the necessary measures to prevent or control such hazards.

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CLASSIFICATION OF CHEMICALS

CLASSIFICATION ACCORDING TO THE PHYSICAL STATE

There are various ways of classifying chemicals. One way to classify chemicals is according to their physical states at room temperature.

Any matter can be classified as solid, liquid or gas. Sometimes, knowing the physical state of a substance, one can expect the main pathway of entry into the human body. For example, carbon monoxide being a gas at room temperature, enters the body by inhalation.

Sometimes, it may not be so obvious. Solids can be suspended in the air in the form of fine dust or fumes which may enter the body by inhalation. Tiny liquid droplets suspended in the air such as acid mists may cause irritation to the respiratory tract and the skin.

CLASSIFICATION ACCORDING TO CHEMISTRY

Basically, any chemical can be classified as inorganic or organic.

Inorganic Chemicals

Metals, non-metals and their compounds are generally regarded as inorganic chemicals. They include:

- metals and their compounds such as mercury, copper, iron oxide, lead sulphate, zinc phosphate;
- inorganic acids such as sulphuric acid, hydrochloric acid, nitric acid;
- inorganic alkalis such as sodium hydroxide, potassium hydroxide;
- non-metals such as carbon, sulphur, nitrogen, chlorine, bromine, hydrogen;
- inorganic gases such as carbon monoxide, carbon dioxide, ammonia, hydrogen sulphide.

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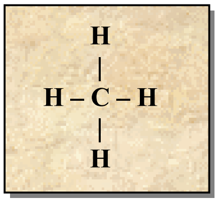
Organic Chemicals

Generally, organic chemicals are compounds with one or more carbon atoms. Organic chemicals that contain only carbon and hydrogen atoms are called hydrocarbons. Organic compounds can be grouped according to the functional groups attached to the carbon skeleton. Some of the major classes of organic chemicals and their effects are as follows.

Alkanes

Alkanes are paraffinic (saturated) hydrocarbons having a general structural formula C_nH_{2n+2} where n is the number of carbon atoms.

Examples: methane (CH_4), butane (C_4H_{10}), hexane (C_6H_{14}).



$$\begin{array}{c} H \\ | \\ H-C-H \\ | \\ H \end{array}$$

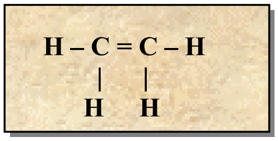
Methane

Alkanes are flammable but relatively non-toxic, except n-hexane which is known to be neurotoxic.

Alkenes

Alkenes are olefinic (unsaturated) hydrocarbons having a general formula $C_nH_{2n.}$

Examples: ethylene (C_2H_4), propylene (C_3H_6).



$$\begin{array}{c} H-\underset{\displaystyle H}{\underset{|}{C}}=\underset{\displaystyle H}{\underset{|}{C}}-H \end{array}$$

ethylene

Alkenes are flammable but relatively non-toxic.

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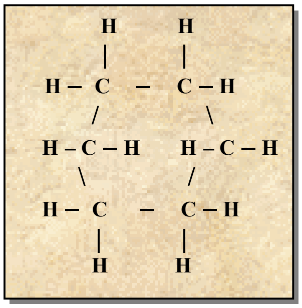
Cyclic hydrocarbons

These are hydrocarbons having a ring structure, saturated or unsaturated with hydrogen.

Example: cyclohexane (C_6H_{12}).



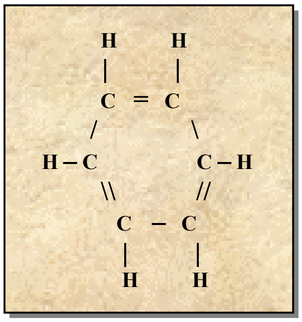
cyclohexane

Cyclic hydrocarbons are of low toxicity. The un-saturated cyclic hydrocarbons generally are more irritating than the saturated forms.

Aromatics

Aromatic hydrocarbons contain a 6-carbon ring structure. Aromatic compounds are unsaturated.

Examples: benzene [C_6H_6], toluene [$C_6H_5CH_3$], xylene [$C_6H_4(CH_3)_2$]



benzene

The aromatic hydrocarbons, in general, are irritants and potent narcotics. The main health effects of the common aromatic solvents other than benzene are dermatitis and effects on the central nervous system. Benzene is notorious for its effects on the blood forming tissues of the bone marrow. It is a leukemogenic agent.

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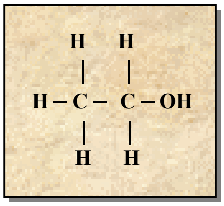
Alcohols

Alcohols are characterized by the presence of a hydroxyl group (-OH).

Examples: methanol (CH_3OH), ethanol (C_2H_5OH), propanol (C_3H_7OH).



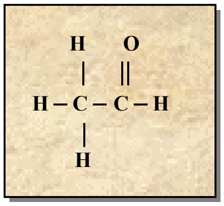
ethanol

Alcohols can depress the central nervous system. Exposure to high air levels may lead to unconsciousness and even death. Methanol is especially noted for being able to cause impairment of vision due to injury to the optic nerve.

Aldehydes

Aldehydes contain the double bonded carbonyl group, C=O with only one hydrocarbon group on the carbon.

Examples: formaldehyde (HCHO), acetyaldehyde (CH_3CHO).



acetyaldehyde

The aldehydes are well known for skin and mucosal irritation and their action on the central nervous system. Dermatitis from aldehydes is common. Aldehydes are also characterised by their sensitizing properties. Allergic responses are common.

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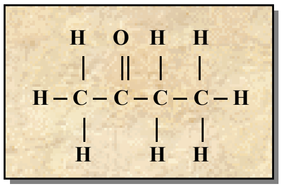
Ketones

Ketones contain the double bonded carbonyl group, C=O with two hydrocarbon groups on the carbon.

Examples: acetone (CH_3COCH_3), methyl ethyl ketone ($CH_3COC_2H_5$).



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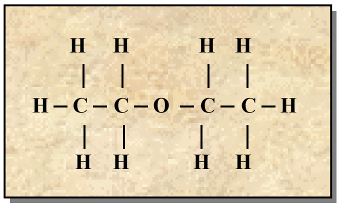
methyl ethyl ketone (MEK)

The common ketones generally exert a narcotic effect. All are irritating to the eyes, nose and throat. Methyl n-butyl ketone is especially noted for its effects on peripheral nerves.

Ethers

Ethers contain the C-O-C linkage.

Example: ethyl ether ($C_2H_5OC_2H_5$).



$$\begin{array}{ccccccccccccc} & & \mathrm{H} & & \mathrm{H} & & & & \mathrm{H} & & \mathrm{H} \\ & & | & & | & & & & | & & | \\ \mathrm{H} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{O} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{H} \\ & & | & & | & & & & | & & | \\ & & \mathrm{H} & & \mathrm{H} & & & & \mathrm{H} & & \mathrm{H} \end{array}$$

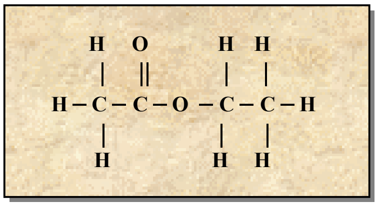
ethyl ether

Ethers are volatile hydrocarbons. Their primary effect is anaesthetic and irritating.

Esters

Esters are formed by the reaction of an organic acid with an alcohol.

Example: ethyl acetate ($CH_3COOC_2H_5$).



$$\begin{array}{ccccccccccccc} & & \mathrm{H} & & \mathrm{O} & & & & \mathrm{H} & & \mathrm{H} \\ & & | & & \| & & & & | & & | \\ \mathrm{H} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{O} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{H} \\ & & | & & & & & & | & & | \\ & & \mathrm{H} & & & & & & \mathrm{H} & & \mathrm{H} \end{array}$$

ethyl acetate

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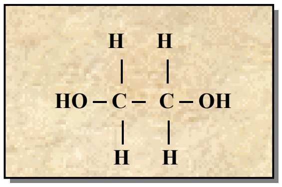
Esters are noted for their irritating effects on the exposed skin and to the respiratory tract. They are also potent anaesthetics.

Glycols

Glycols contain double hydroxyl (-OH) groups.

Example: ethylene glycol [$C_2H_4(OH)_2$].



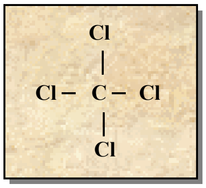
ethylene glycol

Glycols are non-volatile due to their low vapour pressures. Inhalation exposures are not likely unless they are heated or sprayed. The mists and vapours are irritating.

Halogenated Hydrocarbons

Halogenated hydrocarbons are compounds with one or more hydrogen atoms replaced by halogen atom(s) – fluorine (F), chlorine (Cl), bromine (Br) or iodine (I).

Examples: carbon tetrachloride (CCl_4), trichloroethylene ($CHCl{=}CCl_2$), methylene chloride (CH_2Cl_2), bromochloromethane ($BrCH_2Cl$).



carbon tetrachloride

Halogenated hydrocarbons are stable and non-flammable. The chlorinated hydrocarbons, in general, are more toxic than the common fluorinated hydrocarbons. Specific effects and toxicities vary widely, but the most common effects from the chlorinated hydrocarbons are depression of the central nervous system, dermatitis and injury to the liver.

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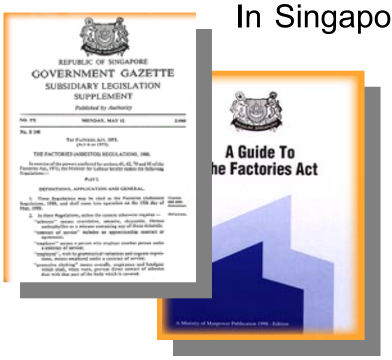
LEGISLATION ON HAZARDOUS SUBSTANCES IN FACTORIES



REPUBLIC OF SINGAPORE
GOVERNMENT GAZETTE
SUBSIDIARY LEGISLATION
SUPPLEMENT
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A Guide To
he Factories Act

In Singapore, the law relating to the health, safety and welfare of persons employed in factories is the Factories Act. It is administered by the Ministry of Manpower.

The Factories Act has a number of sections dealing with the control and prevention of chemical hazards. Summarized below are the important provisions relating to the control of flammable, explosive and toxic substances in factories.

Flammable Substances

Section 35 of the Factories Act requires precautions to be taken against explosion from any flammable dust, gas, vapour or substance that may escape into any workplace. The precautions include removal or prevention of accumulation of flammable substances and exclusion of possible sources of ignition.

This section also requires that flammable or explosive substances in any plant, tank or vessel must be removed or rendered non-flammable or non-explosive before carrying out any hot work on such plant, tank or vessel.

Section 46(1) stipulates that practical steps must be taken to keep sources of heat or ignition separate from flammable substances or any process which may give rise to any flammable gas or vapour.

Airborne Contaminants

Inhalation of airborne contaminants eg toxic gases, vapours, dusts and fumes is the most common path of exposure to chemicals in workplaces. Control of such contaminants is required under section 59 of the Factories Act.

This section requires that all practicable measures must be taken to protect employed persons against inhalation of toxic airborne contaminants and to prevent their accumulation in any workplace. The measures to be taken include one or more of the following where appropriate:-

- carrying out the process or work in isolated areas;

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- carrying out the process or work in closed systems;
- providing adequate dilution ventilation to dilute the contaminants;
- providing local exhaust ventilation to remove the contaminants; or
- carrying out the process or work wet.

Local exhaust ventilation system is widely used for airborne contaminants control; the law stipulates that the local exhaust ventilation system must be so designed, constructed, operated and maintained to effectively remove the airborne contaminants at the source of generation.

The Act requires that the atmosphere of any workplace in which toxic substances are used, handled or given off must be tested by a competent person at regular intervals to ensure that airborne contaminants are not present in quantities liable to injure the health of persons employed. Results from such testing must be recorded and kept for at least 5 years.

Occupiers must take all necessary measures to ensure that no person is exposed to toxic substances in excess of the permissible exposure levels specified in the Factories (Permissible Exposure Levels) Order.

Toxic Substances

Section 60 of the Factories Act deals with the control of toxic substances. The requirements are as follows.

- Toxic substances must be placed under the control of a competent person who has adequate knowledge of the properties of the substances and their dangers.
- Labels must be affixed to containers of toxic substances indicating the hazards involved and the precautionary measures to be taken.
- Persons who are liable to be exposed to toxic substances must be warned of the hazards involved and of the precautionary measures to be observed.
- Warning notices specifying the nature of the danger of the toxic substances must be placed at all entrances to any workroom and at appropriate locations where the toxic substances are used or present.

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Material Safety Data Sheets

Material safety data sheets (MSDS) provide an important hazard communication link between chemical suppliers and end users. The requirements on MSDS are stipulated under section 60A of the Factories Act.

This section requires a factory occupier to:-

- obtain the MSDS of any toxic, corrosive or flammable substance used, handled or stored in the factory;
- assess the information in the MSDS and take precautionary measures to ensure the safe use of the substance; and
- make available the MSDS to all persons who are liable to be exposed to the substance.

It also requires the chemical supplier to provide the MSDS for the substance, giving an accurate and adequate description of the identity, properties of the substance, safety and health hazard information, precautions to be taken and safe handling information.

Harmful Substances / Processes

Under section 65 of the Factories Act, a factory occupier is required to:-

- substitute harmful substances or processes with less harmful or harmless substances or processes wherever possible;
- take effective measures to prevent the liberation of harmful substances and for the protection of workers against inhalation, skin absorption or ingestion of the substances; and
- take preventive measures for the protection of workers from harmful radiations.

Meals in Certain Dangerous Trades

Section 61 states that there should be no taking of food or drinks in any room where toxic or injurious dust or fume is liberated. Suitable facilities must be made available to enable workers to take their meals elsewhere in the factory.

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Protective Clothing and Appliances

Section 62(1) of the Factories Act stipulates that suitable protective clothing and appliances including where necessary, suitable gloves and respirators must be provided and maintained for the use of workers who are exposed to any toxic or offensive substance.

Separate Changing and Washing Facilities

Under section 66 of the Factories Act, the Chief Inspector may direct the factory occupier to provide separate changing and washing facilities for persons employed in any process involving the manufacture, handling or use of toxic, injurious or offensive substances.

Permissible Exposure Levels

The permissible exposure levels (PEL) of some 600 toxic substances are specified in the Factories (Permissible Exposure Levels of Toxic Substances) Order. This Order was operative from 1 Jan 97.

PEL is the maximum time weighted average concentration in the air of a toxic substance to which persons may be exposed without suffering from any adverse health effects. Two types of PEL are prescribed:-

- PEL (Long Term) means the permissible exposure level over an 8-hour working day and a 40-hour working week.

- PEL (Short Term) means the permissible exposure level over a 15-minute period during any working day.

The Order also addresses the excursion limits for substances that do not have a PEL (Short Term) and the combined effects from exposure to more than one substance.

Statutory Medical Examinations

Under the Factories (Medical Examinations) Regulations, workers must undergo pre-employment and regular medical examinations if they are employed in any occupation involving exposure to benzene, vinyl chloride, organophosphates, tar, pitch, bitumen, creosote, silica, asbestos, trichloroethylene, perchloroethylene,

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raw cotton, lead, mercury, manganese, cadmium and arsenic or their compounds.

The objective of these examinations is to detect work related illness early and to ensure workers are fit for such work.

The examinations are specific to the type of hazards involved. The employer must arrange and pay for these examinations which must be carried out by a designated factory doctor registered with the Chief Inspector of Factories.

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FLAMMABLE SUBSTANCES

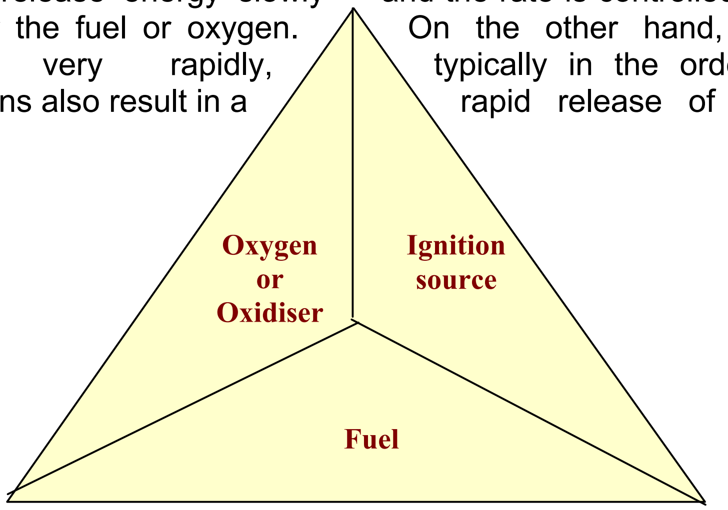
Fires and explosions can cause loss in human lives or property and may have serious impact on the environment. It is thus important that flammable and explosive chemicals be handled with care and effective measures be taken to prevent their occurrence.

Fire or burning is an exothermic oxidation of an ignited fuel. The fuel can be in solid, liquid or vapour form, but vapour and liquid fuels are generally easier to ignite. A fire will only occur if the fuel, oxidizer (generally oxygen in air) and an ignition source are present. If any of these components is removed or not present in the right proportions, a fire will not occur. Altering only one of these components sufficiently will stop the process of burning.

Most explosions in chemical plants are derived from chemical reactions. This type of explosion is called chemical explosion and can be uniform or propagating in nature. An explosion in a vessel tends to be an uniform explosion, while one that occurs in a long pipe tend to be a propagating explosion.

Detonation and deflagration are the two kinds of chemical explosions which are propagating in nature. In a detonation, the shock wave travels at supersonic velocity, i.e. a speed greater than sound. For deflagration, this velocity is significantly lower. Pressures in a detonation wave are much higher than deflagrations. Thus detonations are more destructive than deflagrations. A deflagration may turn into a detonation, particularly when travelling down a long pipe.

The distinction between fires and explosions is the rate of energy release. Fires tend to release energy slowly and the rate is controlled by the diffusion rate of either the fuel or oxygen. On the other hand, explosions release energy very rapidly, typically in the order of microseconds. Explosions also result in a rapid release of pressure or shock waves.



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Some common fuels, oxidizers and ignition sources are as follows:

Components of fire triangle	**Common sources**
Fuels *Solids*	Wood, paper, plastic, fibres, polymer dust, flour, metal particles.
Liquids	Acetone, isopropyl alcohol, hexane, gasoline.
Gases	Acetylene, propane, butane, hydrogen.
Oxidizers	Oxygen, hydrogen peroxide, metal peroxide, organic peroxide, sodium chlorate, ammonium nitrate.
Ignition sources	Burning match, cigarettes, sparks, flames, friction, static electricity, heat from a light bulb, hot surfaces, internal combustion engines, ovens, heating equipment.

Flash Point

The flash point of a liquid is the lowest temperature at which it gives off enough vapour to form an ignitable mixture with air. Liquids with low flash point are more flammable than liquids with higher flash point.

Flammable liquids have flash points below 38 ^{o}C. They can cause fire and explosion in the presence of an ignition source, even at room temperature.

Substances with flash points above 38 ^{o}C are classified as combustible materials. Though they do not burn at room temperature, they can be ignited when heated up to their flash points.

Explosive Range / Flammability Limits

Vapour-air mixtures will only ignite and burn over a well-specified range of compositions. The mixture will not burn when the composition is lower than the lower explosive limit (LEL); the mixture is too lean for combustion. Conversely, the mixture is also not combustible when the composition is above the upper explosive limit (UEL); the mixture is said to be too rich. If a mixture within its explosive range of concentration is ignited, flame propagation will occur.

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Most petroleum vapours have a flammable range of approximately 1 to 10% by volume. Some flammable gases have a wide range of flammability and must be handled with extreme care. Examples are hydrogen (4 – 76%), acetylene (2.5 – 82%) and ethylene oxide (3 – 100%).

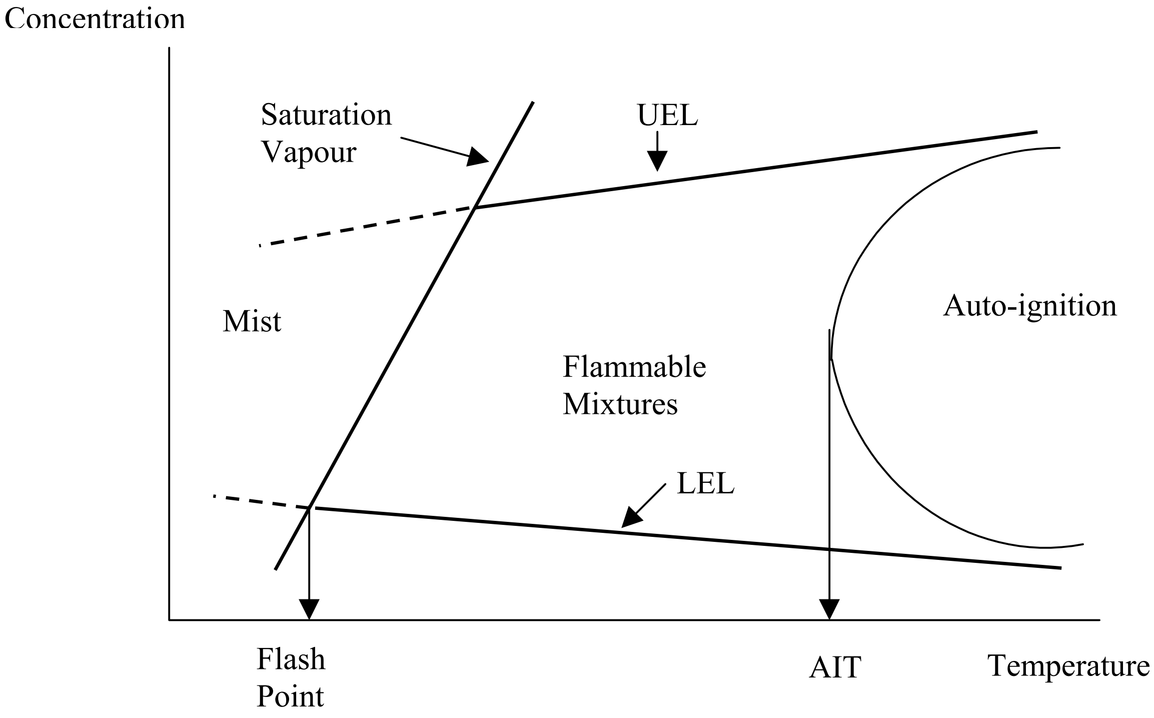
To prevent fire and explosion, it is often necessary to maintain the product's concentration in the air below its LEL, for example by means of adequate ventilation.

Under Singapore Standard Code of Practice 40:1987 on storage of flammable and combustible liquids, the flammable liquids are divided into different classes.

Class		**Flashpoint (closed cup)**	**Initial boiling point**
I	Extremely flammable	<23°C	≤35°C
II	Highly flammable, F	≥23° and ≤ 61°C	>35°C
III	Flammable, F	>61°C	>35°C

Autoignition Temperature / Ignition Temperature

This is the temperature at which a substance (solid, liquid or gas) will self-ignite and sustain combustion in the absence of a spark or flame. The closer the autoignition temperature, AIT is to room temperature, the higher the fire risk.



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The following page lists the flash points, the flammability limits and the autoignition temperatures of some common industrial chemicals.

Chemical	Flash Point (°C)	Flammable Limits in Air (%)		Autoignition Temperature (°C)
		Lower (LEL/LFL)	Upper (UEL/UFL)	
Acetaldehyde	-37.8	4.0	60.0	175
Acetone	-17.8	2.6	12.8	465
Acetylene	-18.0	2.5	82.0	306
Ammonia	NA	16.0	25.0	651
Benzene	-11.1	1.2	7.1	498
Butane	-60.0	1.8	8.4	287
Butyl Acetate	15.5	1.4	7.5	425
Carbon Disulphide	-30.0	1.3	50.0	90
Carbon Monoxide	NA	12.5	74.0	607
Cyclohexane	-20.0	1.3	8.3	245
1,1-Dichloroethylene	-18.0	7.3	16.0	570
Diethyl Ether	-45.0	1.7	36.0	170
Ethane	NA	3.2	12.5	472
Ethyl Acetate	-4.4	2.0	11.5	427
Ethyl Alcohol	13.0	3.5	19.0	365
Ethyl Ether	12.8	1.85	36.5	160
Ethylene	NA	2.7	36.0	490
Ethylene Dichloride	13.0	6.2	16.0	413
Ethylene Oxide	-20.0	3.0	100.0	429
Heptane	-4.0	1.1	6.7	204
Hexane	-21.7	1.1	7.5	225
Hydrogen	NA	4.0	76.0	400
Hydrogen Sulphide	NA	4.3	44.0	260
Isobutane	-82.7	1.8	8.4	462
Isopropyl Alcohol	11.7	2.0	12.0	399
Methane	NA	5.0	15.4	537
Methyl Alcohol	-46.7	5.5	36.5	385
Methyl Chloride	-45.6	8.1	17.4	632
Methyl Cyclohexane	-4.0	1.2	6.7	250
Methyl Ethyl Ketone	-6.0	1.8	10.0	515
Octane	13.3	1.0	6.5	206
Pentane	-49.4	1.4	7.8	260
Propane	-104.4	2.2	9.5	450
Propyl Acetate	13.0	1.7	8.0	450
Propylene	NA	2.0	11.1	455
Propylene Oxide	-37.2	2.1	37.0	465
Styrene	31.0	1.1	6.1	490
Toluene	4.4	1.2	7.0	480

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Vinyl Chloride	-78.0	3.6	33.0	472
Xylene (o/m/p)	17.0 / 25.0 / 25.0	0.9/ 1.1 / 1.1	6.7 / 7.0 / 7.0	463 / 527 / 528

EFFECTS OF FIRES & EXPLOSIONS

Fires generate heat which can cause injury to persons. Fires can also cause explosions and generate smoke and toxic gases. Excessive smoke can hinder the escape of persons during a fire.

Toxic gases, such as carbon monoxide is most frequently produced by carboneous materials. Carbon monoxide is odourless and is a chemical asphyxiant. It can overcome people during the first stage of fire.

Burning of combustible materials containing elements, such as chlorine, sulphur and nitrogen, can result in the formation of irritating and toxic gases. For example, polyvinylchloride (PVC) and nitrogen containing polymers such as polyurethane foam, may release hazardous concentrations of irritating hydrogen chloride and extremely toxic hydrogen cyanide upon combustion.

An explosion may give rise to blast waves which can cause damage to humans and buildings. Furthermore, if the explosion occurs in a confined space such as inside a vessel, the force of the explosion can rupture the vessel and project debris (missiles) to its surroundings, creating what is often called a missile effect. Hot, toxic gases or dust may be produced by an explosion. These hazardous products can also cause serious injury to humans.

Types of Fire

A *pool fire* is the combustion of flammable vapour evaporating from a layer of liquid at the base of the fire. A common source is a spill of liquid or a liquid in an open container.

A *flash fire* is the combustion of a flammable vapour and air mixtures at less than sonic velocity, such that negligible damaging overpressure is generated.

A *jet flame* is the combustion of substance emerging with sufficient momentum from an orifice, as when ignition occurs on substance releasing from a flammable source under pressure.

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A *fireball* is a fire burning sufficiently fast for the burning mass to rise into the air as a cloud or ball. It is particularly associated with a *boiling liquid expanding vapour explosion* (BLEVE).

Types of Explosion

A *confined explosion* is an explosion of a fuel-oxidant mixture inside a closed system such as a tank or vessel.

A *vapour cloud explosion* is a partially confined explosion in an open air of a cloud made up of a mixture of a flammable vapour or gas with air.

A *boiling liquid expanding vapour explosion* (BLEVE) is the sudden rupture of a vessel or system containing liquified flammable gas under pressure as a result of fire impingement. The pressure burst and the flashing of the liquid to vapour creates a blast wave and potential missile damage, and immediate ignition of the expanding fuel-air mixture leads to intense combustion creating a *fireball*.

A *pressure burst* is the rupture of a vessel or system under pressure which results in the formation of a blast wave and missiles.

A *rapid phase transition* is the rapid change of state of a substance which may produce a blast wave and missiles as in the instantaneous vaporisation of water on contact with molten metal.

FIRE PROTECTION

The main aspects of fire protection are prevention and loss limitation.

PREVENTION

Effective fire prevention simply means the manipulation of the three constituents (fuel, oxidizer or oxygen, heat) so that a fire cannot start.

Oxygen

Nearly all combustion processes require the presence of oxygen. Furthermore, the higher the oxygen concentration, the more rapidly will the burning process be. Inerting is often used to reduce the concentration of oxygen to a safe concentration. This process involves the addition of an inert gas, usually nitrogen or carbon dioxide. Sometimes, steam is also used.

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Vacuum purging is the most common inerting procedure for vessels. This purging method comprises three basic steps:
(1) drawing a vacuum on a vessel until the desired vacuum is achieved;
(2) relieving the vacuum with an inert gas to atmospheric pressure; and
(3) repeating steps (1) and (2) until the desired oxidant concentration is reached.

Heat

Burning is an exothermic process. The very small fire started by a tiny heat source supplies to its surroundings more heat than it absorbs, thus enabling it to ignite more fuel and oxygen mixture. The combustion started will then propagate to initiate more fires. The various sources of ignition are open flames, electric sources, hot surfaces, spontaneous ignition, sparks, static electricity and friction. Ensuring that there is no contact of the heat source to possible flammable fuel-oxygen mixture can prevent the occurrence of a fire.

Fuel

Combustion takes place most readily between oxygen and a fuel in its vapour or other finely divided state. Solids are most easily ignited when reduced to powder or vaporised by the application of heat. For liquids, some will give off dangerous quantities of flammable vapours at below room temperature. Preventing the vaporisation of a flammable chemical and its accumulation to form dangerous concentration are the two basic principles of fire prevention.

Preventive Measures

The following are some common measures to prevent fire and explosion.

- A flammable liquid with a low flash point should as far as possible be substituted with a non-flammable liquid having a higher flash point.

- The use of flammable liquids having a flash point of less than 32°C should be restricted to situations in which they are absolutely necessary.

- Flammable liquids should be handled in well-ventilated areas.

- Effective ventilation should be applied to prevent accumulation of flammable aerosols or vapours.

- The quantities of all flammable substances should be kept to the absolute minimum.

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- Flammable liquids should be stored in safety containers. The safety containers should be properly labelled and kept in a properly constructed fireproof store when not in use.

- Grounding wires should be used when transferring a flammable solvent from one container to another. This would prevent generation of static electricity, which could ignite the vapours.

- Fire resistant partitions can be used to isolate open flames and heated sources from flammable materials.

- A closed system transfer of flammable or/and toxic chemicals should be used to prevent emission of flammable aerosols or vapours

- Safety devices such as automatic temperature control sensors could be used to warn operators of overheating in process vessels so that appropriate measures can be promptly applied.

- Sparkproof or non-sparking tools and materials should be used in areas where flammable materials are likely to be present.

- Regular and thorough housekeeping should be practiced to minimise flammable dust accumulation.

- Smoking, welding, flame cutting and other hot work should be prohibited where flammable materials are stored or handled.

- All used flammable liquid soiled materials including oily rags should be disposed of in a container placed at a designated area. Smoking should also not be allowed in this area.

LOSS LIMITATION

Loss limitation aims to discover fires and extinguish fires.

Some examples of the loss limitation aspect of fire protection are as follows.

- Hazardous processes and storage should be segregated into separate buildings spaced adequately apart.

- Fire walls can be used to subdivide one large risk into smaller risk areas to stop the spread of the fire.

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- Proper maintenance of plants including regular inspection, physical guarding to prevent damage and demarcating "keep clear" lines on the floor.
- Automatic fire alarms or warning and sprinkler systems should be installed for prompt discovery and extinguishing of fires.
- Proper enclosure of vertical openings such as stairways and elevators to prevent fire spreading from one floor to another.
- In areas where flammable substances are used or stored, suitable fire fighting equipment should be readily available and adequate means of escape provided.
- All personnel should be familiar with and trained in the use of the fire fighting equipment so that a small fire can be quickly put out.
- In the event of the fire getting out of hand, everyone should know how to escape safely.

CLASSIFICATION OF FIRES AND FIRE EXTINGUISHERS

Fires are classified into four categories which take into account the type of substance that forms the fuel and the means of extinction.

Class A:Fires involve combustion of solid materials which are usually of an organic nature such as wood, paper, plastic, and natural fibres. The most effective extinguishing agent is water either as a spray or jet. The mode of extinguishing is by cooling of the glowing embers which propagate the fire.

Class B:Fires involve combustion of flammable liquid and gas, such as oil, gasoline, paint, acetone, and grease, where oxygen exclusion or a flame-interrupting effect of the extinguishing agent is required.

Class C:Fire involving electrical wiring and electrical equipment where dielectric nonconductivity of the extinguishing agent is required.

Class D:Fires consisting of combustible metals, such as magnesium, potassium, powdered aluminum, titanium, zinc, sodium, zirconium, and lithium, where a material specific extinguishing agent is required. Special dry powder e.g. graphite, talc, soda ash, limestone and dry sand must be used. The extinguishers act by smothering the fire. Normal extinguishing agents should not be used for Class D fires.

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TYPES OF FIRE EXTINGUISHER

Types of fire extinguisher	**Suitable classes of fire**	**Remarks**	**Examples**
Dry Chemical, Standard Type	Class B and C fires	Leaves a mildly corrosive residue that must be cleaned up immediately to prevent damage to electrical equipment. Best uses for automotive, grease fires and flammable liquids.	
Dry Chemical, Multipurpose Type	Class A, B and C fires	Effective on most common types of fires. Highly corrosive and leaves a sticky residue. Not for use around delicate electrical appliances or computers.	
Halogenated Agents	Class A, B and C fires (depending on agent used, label must be checked)	Expensive but very versatile and clean. Leaves no residue. Mildly toxic. Excellent for computers and electrical equipment and good for flammable liquids and automotive use. This is one of the best choice for office use, however, environmental restrictions and rising costs limit availability.	
Carbon Dioxide	Class B and C fires	Very clean, no residue. Spraying range is short, therefore extinguishing agent must be applied close to fire.	
Water Based Agent	Class A fires only	Inexpensive to refill and maintain. These are the most common extinguishers in use	

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INCOMPATIBLE & PYROPHORIC CHEMICALS

INCOMPATIBLE CHEMICALS

Incompatible chemicals are chemicals that can react with each other violently, with evolution of heat, or the production of flammable or toxic products. The following is a list of chemicals and their incompatible chemical(s).

Chemical	Incompatible Chemical
Acetic acid	Chromic acid, nitric acid, hydroxyl-containing compounds, ethylene, glycol, perchloric acid, peroxides and permanganates.
Acetone	Concentrated nitric and sulphuric acid mixtures.
Acetylene	Chlorine, bromine, copper, silver, fluorine and mercury.
Alkali and alkaline earth metals, such as sodium, potassium, lithium, magnesium, calcium, powdered aluminium	Carbon dioxide, carbon tetrachloride, and other chlorinated hydrocarbons. (Also prohibit water, foam, and dry chemical on fires involving these metals – dry sand should be used).
Ammonia (anhydrous)	Mercury, chlorine, calcium hypochlorite, iodine, bromine and hydrogen fluoride.
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulphur, finely divided organics or combustibles.
Aniline	Nitric acid, hydrogen peroxide.
Arsenic materials	Any reducing agent
Azides	Acids

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Bromine	Ammonia, acetylene, butadiene, butane and other petroleum gases, sodium carbide, turpentine, benzene, and finely divided metals.
Calcium oxide	Water
Carbon, activated	Calcium hypochlorite
Chlorates	Ammonium salts, acids, metal powders, sulphur.
Chromic acid and chromium trioxide	Acetic acid, naphthalene, camphor, glycerol, turpentine, alcohol, and other flammable liquids.
Chlorine	Ammonia, acetylene, butadiene, butane and other petroleum gases, hydrogen, sodium carbide, turpentine, benzene, and finely divided metals.
Chlorine dioxide	Ammonia, methane, phosphine, and hydrogen sulphide.
Copper	Acetylene, hydrogen peroxide.
Cyanides	Acids
Fluorine	Everything (isolate)
Hydrazine	Hydrogen peroxide, nitric acid, any other oxidant.
Hydrocarbons (benzene, butane, propane, gasoline, turpentine)	Fluorine, chlorine, bromine, chromic acid, peroxide.
Hydrocyanic acid	Nitric acid, alkalis
Hydrofluoric acid, anhydrous (hydrogen fluoride)	Ammonia, aqueous or anhydrous
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, any flammable liquid, combustible materials, aniline,

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	nitromethane.
Hydrogen sulphide	Fuming nitric acid, oxidising gases
Hypochlorites	Acids, water
Iodine	Acetylene, ammonia (anhydrous or aqueous)
Mercury	Acetylene, fulminic acid.
Nitrates	Sulphuric acid.
Nitric acid (concentrated)	Acetic acid, acetone, alcohol, aniline, chromic acid, hydrocyanic acid, hydrogen sulphide, flammable liquids, flammable gases and nitratable substances.
Nitroparaffins	Inorganic bases, amines.
Oxalic acid	Silver, mercury
Oxygen	Oils, grease, hydrogen, flammable liquids, solids or gases
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, oils.
Peroxides, organic	Acids (organic or mineral), avoid friction, store cold.
Phosphorus	Caustic alkalies or reducing agents
Phosphorus (white)	Air, oxygen
Potassium chlorate	Acids (see also chlorates)
Potassium perchlorate	Acids (see also perchloric acid)
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulphuric acid
Selenides	Reducing agents

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Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds
Sodium	See alkali metals (above)
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium peroxide	Any oxidisable substance, such as ethanol, methanol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerol, ethylene glycol, ethyl acetate, methyl acetate, and fufural.
Sulphides	Acids
Sulphuric acid	Chlorates, perchlorates, permanganates
Tellurides	Reducing agents

As far as is practicable, incompatible chemicals must be stored away from each other. They should always be handled such that they must not accidentally come into contact with each other.

PYROPHORIC CHEMICALS

Pyrophoric chemicals are substances that ignite spontaneously when in contact with air or its moisture, either by oxidation or hydrolysis. Some of these reactions liberate flammable gases. The following are examples of pyrophoric chemicals.

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Pyrophoric alkyl metals and derivatives

Butyllithium
Diethylberyllium
Diethylcadmium
Diethylmagnesium
Diisopropylberyllium
Dimethylberyllium
Dimethylbismuth chloride
Dimethylcadmium
Dimethylmagnesium
Dimethylmercury
Methylbismuth oxide
Methyllithium
Methylpotassium
Methylsodium
Methylsilver
Propyl copper
Tetramethyllead
Tetravinyllead
Triethyl bismuth
Vinyllithium

Pyrophoric carbonyl metals

Carbonyllithium
Carbonylpotassium
Carbonylsodium
Hexacarbonylchromium
Hexacarbonyltungsten
Tetracarbonylnickel

Pyrophoric metals (in finely divided state)

Caesium
Potassium
Sodium
Copper-Zirconium alloy
Nickel-Titanium alloy

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Pyrophoric metal sulphides

Barium sulphide
Diantimony trisulphide
Dibismuth trisulphide
Iron sulphide
Potassium sulphide
Sodium disulphide

Pyrophoric alkyl non-metals

Bis-(dibutylborino) acetylene
Tetramethylsilane
Triethylborane
Trimethylphosphine

Pyrophoric alkyl non-metal halides

Butyldichloroborane
Dichloroethylsilane
Dichloromethylsilane
Trichloro(ethyl)silane
Dichloro(vinyl)silane

Pyrophoric alkyl non-metal hydrides

Diethylarsine
Diethylphosphine
Ethylphosphine
Methylphosphine
Methylsilane

Because of their reactivity, pyrophoric chemicals should be stored in tightly closed containers under an inert atmosphere, or for some, an inert liquid. All transfers and manipulations of pyrophoric chemicals must also be carried out under an inert atmosphere or liquid.

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TOXIC CHEMICALS

The potential that a chemical can cause harmful health effects depends on two factors: the toxicity of the chemical and the degree of exposure. The toxicity of a chemical is an inherent property. However, a chemical will produce injury or disease only if a worker is actually exposed to it. The degree of exposure of workers to a chemical will depend on how it is used and the availability and effectiveness of the control measures in the workplace.

ROUTES OF ENTRY INTO THE BODY

A chemical may enter into the body through three routes: inhalation, skin absorption and ingestion.

Inhalation

The main route of entry of chemicals into the body is by inhalation. The total amount of a toxic compound absorbed depends mainly on the concentration of airborne chemicals and the duration of exposure. Excessive exposure by inhalation may cause direct irritation or local damage to the respiratory system or injury to tissues within the body as a result of absorption from the lungs into the circulatory system.

Skin absorption

Direct contact of the skin with certain chemicals may result in primarily irritation or a sensitization reaction similar to an allergic type of response. Some chemicals can penetrate through the skin, and enter the bloodstream and exert their toxic effects in various sites of the body. Examples are cyanide, phenol, aniline, carbon disulfide, nitrobenzene and acrylonitrile

Ingestion

Ingestion of toxic materials may occur as a result of poor personal hygiene Examples are eating with hands that are contaminated with toxic substances or taking meals in a contaminated atmosphere in the work areas. Ingested materials may be absorbed into the blood from the intestine. The blood may then transport these materials to various parts of the body where injury is effected.

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TOXIC EFFECTS OF CHEMICALS

The effects of exposure to chemicals may be classified in the following ways:

- Acute effect – A short-term exposure to usually very high concentration of toxic chemicals resulting in immediate illness, irritation and even, death.
- Chronic effect – Prolonged or repeated exposure to low concentrations of noxious substances resulting in certain diseases which may take some time to develop.
- Reversible (temporary) effect – An effect that disappears if exposure to the chemical ceases.
- Irreversible (permanent) effect – An effect that has a lasting, damaging effect on the body, even if exposure to the chemical ceases.
- Local effect – The chemical causes harm at the point of contact or entry.
- Systemic effect – The chemical enters the body, is absorbed and transported to the various organs of the body where harm is effected.

In some cases, a chemical may have more than one effect, depending on the mode of entry, transport and the concentration absorbed. For example, a single exposure to high level of benzene can result in unconsciousness – an acute effect, whilst repeated exposure to low concentrations of benzene can result in damage to the blood system e.g. anaemia or leukemia, which takes a fairly long period of time to develop, i.e. a chronic effect.

A chemical product is considered to be a toxic or harmful chemical product if it falls within any one of the categories listed in the table below.

Classes of toxicity

Class	LD_{50} absorbed orally in rat mg/kg body weight	LD_{50} dermal absorption in rat or rabbit mg/kg body weight	LC_{50} absorbed by inhalation in rat, mg/litre per 4 h Gases and Vapors	LC_{50} absorbed by inhalation In rat, mg/litre per 4 h Aerosols and particulates
Very toxic	≤ 25	≤ 50	≤ 0.5	≤ 0.25
Toxic	> 25 to ≤ 200	> 50 to ≤ 400	> 0.5 to ≤ 2.0	> 0.25 to ≤ 1
Harmful	> 200 to ≤ 2000	> 400 to ≤ 2000	> 2.0 to ≤ 20	> 1 to ≤ 5

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Toxic or hazardous chemicals can be classified in the following ways:

Class of Toxic Chemicals	**Description**	**Example**
Asphyxiant	A chemical that interferes with the ability of living tissue to absorb oxygen.	
	- Simple asphyxiant – the presence of a gas reduces the oxygen to very low levels.	Nitrogen, acetylene, carbon dioxide, methane.
	- Chemical asphyxiant – interferes with the body's ability to transport and utilise oxygen.	Carbon monoxide, hydrogen cyanide, hydrogen sulphide.
Carcinogen	A chemical that causes cancer.	Acrylonitrile, asbestos, arsenic, benzopyrene, vinyl chloride, benzidine, naphthylamine.
Corrosive	A chemical that destroys or damages living tissue on contact.	Strong acids and alkalis such as phenol, sulphuric acid, sodium hydroxide.
Hepatoxic	A chemical that causes damage to the liver.	Carbon tetrachloride, chloroform, trichloroethylene, perchloroethylene, vinyl chloride, nitrosamines.
Irritant	A chemical that produces local irritation or inflammation of the skin, eyes, nose or tissues of the respiratory system.	Nitrogen oxides, sulphur dioxide, chlorine, ammonia, formaldehyde.
Mutagen	A chemical that causes permanent damage to DNA in a cell. DNA is deoxyribonucleic acid, a molecule that carries genetic information to control the proper growth and function of cells.	Chloroprene.

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Narcotic	A chemical that depresses the central nervous system which may lead to coma and death.	Acetone, xylene, chloroform, isopropyl alcohol, ethyl ether.
Nephrotoxic	A chemical that causes damage to the kidneys.	Mercury, cadimum, lead, halogenated hydrocarbons.
Neurotoxic	A chemical that produces toxic effects on the nervous system.	Manganese, tetraethyl lead, hexane, mercury, carbon disulphide, methyl alcohol.
Sensitizer	A chemical that causes or induces an allergic reaction. Effects will depend on individual susceptibility to the chemical itself.	Toluene di-isocyanate, maleic anhydride, nickel or chromium compounds.
Teratogen	A chemical that, if present in the blood stream of a woman and transported to the developing fetus will result in structural or congenital abnormalities in the child.	Lead, methyl mercury, formamides.

Chemicals may also have toxic effects on other organs and body systems such as lungs, blood, bone marrow and skin.

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CORROSIVE CHEMICALS

These are substances which, by chemical action, will cause severe damage when in contact with living tissue or in case of leakage, will materially damage or even destroy other goods or the means of transport; they may also cause other hazards.

Corrosive chemicals can be solids e.g. sodium hydroxide, liquids e.g. hypochlorite solution or gases e.g. chlorine and ammonia. Some chemicals become corrosive when they come into contact with water or moisture e.g. benzyl chloride and chlorosilanes on contact with sweat on the skin.

Classification

Corrosive chemicals commonly used in industry may be grouped into the following classes.

Group of Corrosive Chemicals	Examples
Acids and anhydrides	Sulphuric acid, hydrochloric acid, nitric acid, acetic acid, acetic anhydride, phosphoric acid, phosphorous trioxide
Alkalis or bases	Potassium hydroxide, sodium hydroxide, organic amines such as ethanolamine
Halogens, halogen salts, organic halides	Chlorine gas, ferric chloride, chlorite solutions, acetyl iodide
Other corrosive substances	Ammonium polysulphide, peroxides, hydrazine

Acids can be classified as inorganic or mineral acids and organic acids. Examples of mineral acids are sulphuric acid, hydrochloric acid and nitric and examples of organic acids are acetic acid, ascorbic acid and salicylic acid.

Anhydrides are substances which have properties similar to those of acids. They react with water forming the corresponding acids e.g. acetic anhydride reacts with water to form acetic acid.

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Properties of Acids and Alkalis

Acids and alkalis (bases) have a common property; they are corrosive. Besides attacking living tissue, they also attack many other materials. They react with metals to produce hydrogen which is highly flammable.

Acids and bases may have toxic properties and some are also flammable. Some acids like nitric acid and hydrochloric acid, release highly corrosive vapours at room temperature when in concentrated form.

When an acid and a base are mixed, they neutralise each other producing a salt and water which also produces heat.

Mixing an acid or a base with water also produces heat. This may create hazards, such as splashes and formation of dangerous mists when water is added to a concentrated acid.

Acidity and Alkalinity

The pH is the scale used to compare the strength or level of acidity and alkalinity of acids and bases and their diluted solutions.

The pH is related to the amount of hydrogen ions present in the solution. It is expressed on a scale from 0 to 14. The pH of a neutral solution is 7. Acids have a pH of <7 and bases of >7.

The limits of acidity and alkalinity may be classified as follows:

pH	**0 to 2**	**strongly acidic**
pH	**3 to 5**	**weakly acidic**
pH	**6 to 8**	**neutral**
pH	**9 to 11**	**weakly basic**
pH	**12 to 14**	**strongly basic**

Acids with pH values 0 to 2 and bases with pH values 11.5 to 14 may be classified as corrosive.

Health Effects

The health effects of direct contact with acids or alkalis vary from irritation causing inflammation to a corrosive effect causing ulceration and in severe cases, chemical burns. The effects depend on the properties of the acids and alkalis, the concentration and time of contact with these substances.

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Some acids and alkalis produce heat when they come into contact with water or moisture. These chemicals may cause both corrosive injuries and burns due to the heat produced.

Occupational hazards due to contact with acids or alkalis mostly affect the skin, eyes and respiratory tract. The eyes are most susceptible to rapid, severe and often irreversible damage.

Acid fumes may also corrode the teeth e.g. long-term exposure to low levels of hydrochloric acid fumes can result in erosion of the incisor teeth.

The effect of strong acids and alkalis is experienced within moments of exposure. The effect may also be delayed, depending on the substance and the concentration. For example, the effect of diluted hydrofluoric acid may vary from irritation to severe burns of the skin depending on the concentration and duration of exposure.

Direct contact of organic anhydrides with the eyes, skin, mucous membranes, or the respiratory system causes irritation and sensitization.

Storage Containers

The construction materials for tanks and containers for storage of acids and alkalis must be able to resist corrosion from inside and outside. These materials must not react with the contents and impurities.

Steel is the most common construction material for corrosion-resistant tanks and containers. Carbon steel is not resistant to strong acids and elevated temperatures. Aluminium tank containers should not be used for acids or alkalis.

Reinforced plastic is light and chemically resistant to mineral acids. This material may be used at temperatures up to 80 °C. The corrosive effect of an organic acid should be checked before putting it into a reinforced plastic tank.

Thermoplastic materials such as polyvinyl chloride (PVC), polyethylene (PE), polypropylene (PP) and polytetrafluorine ethylene (PTFE) are usually chemically resistant to acids and alkalis.

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ANTICIPATION & IDENTIFICATION OF CHEMICAL HAZARDS

HAZARD ANTICIPATION

The management should anticipate or predict the real and potential hazards before a chemical or process involving the use of chemicals is introduced into the plant. Hazard analysis at the design stage will ensure that appropriate measures are implemented before the start of the operation.

In general, the following points should be taken note of:

- All new chemical products and processes involving the use of chemicals should be investigated for potential hazards prior to implementation or purchase. A proper procedure for acquisition of chemicals should also be set up.

- Information on the hazards of the chemicals and the requirements for protection against such hazards must be sought from suppliers and this should be supplemented from other sources, if necessary. Chemical products should not be purchased unless such information is available.

- Toxic or hazardous chemicals should only be used after taking into consideration the degree of risk involved and the operational and economic effects of substitution with less toxic or less hazardous chemicals.

In terms of health and safety hazards; the following are the rules of thumb for hazard anticipation:

- An open process is more hazardous than a closed process.

- A manual operation is more hazardous than an automatic operation.

- A high temperature process is more hazardous than a low temperature process.

- A high-pressure system is more hazardous than a low-pressure system.

- A gas is usually more hazardous than a liquid.

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- A liquid is usually more hazardous than a solid.
- Organic solvents are usually more hazardous than aqueous systems.
- A finely divided or pulverised solid is more hazardous than a pelletized solid.
- A liquid with high vapour pressure is more hazardous than a liquid with low vapour pressure.
- A flammable liquid with a low flash point is more hazardous than a liquid with a high flash point.
- A flammable liquid with a low autoignition temperature is more hazardous than a liquid with a high autoignition temperature.
- A flammable gas or vapour with a wide range of flammability is more hazardous than one with a narrow range of flammability.
- A compressed gas or a gas used in a pressurized environment is usually more hazardous than a gas used in atmospheric or normal pressure.
- A substance with a low boiling point is usually more hazardous than one with a high boiling point.

HAZARD IDENTIFICATION

Identification or recognition of chemical hazards requires knowledge of the process, operation or work activities, information on the chemicals used, manner and conditions of usage, frequency and duration of exposure and control measures employed. Sensory perception plays an important role in this activity. The sense of vision can be used to establish sources of particulates generation. Many gases and vapours can also be detected by odour.

Though our senses can be useful in identifying the presence or extent of airborne contaminants, it is important to note the limitation of such ways of identifying hazards. For example, hydrogen sulphide has a distinctive “rotten egg” odour at low concentrations, however, at high concentrations, it causes nasal fatigue and the distinctive “rotten egg” odour cannot be sensed.

An inventory of all toxic and hazardous chemicals used or handled or produced in the plant should be kept. In addition, all processes and locations involving the use of chemicals should be identified. Besides raw materials, intermediates,

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products and by-products associated with the manufacturing processes should be considered.

Every process involving chemicals should be examined to identify hazards associated with normal activity, abnormal operating conditions and possible emergency situations. Any process or operation involving chemicals that may cause bodily injury or pose a health risk by inhalation, ingestion or skin contact should be classified as a potential hazard.

Hazards of Organic Solvents

For toxic organic solvents, knowledge of the toxicological effects alone is not adequate to assess the hazard potential of the solvents. The vapour pressure, ventilation conditions and manner of usage will determine the concentration in air. Where two or more chemicals having similar toxicological effects are liberated into the workplace, the combined health effects of these chemicals should be considered.

For flammable liquids, the flash point, range of flammability, ignition temperature and other factors will determine the potential of fire and explosions.

Identifying Chemical Hazards In Industrial Processes

In the industry, there are many processes which should arouse immediate suspicion of significant exposure to chemicals unless specific information that the process in question is properly controlled. Some of these are:

- Any process involving combustion should be looked at to determine what by-products of the combustion may be released to the work environment.
- Any process involving the melting of metal should be studied for toxicity of the metal fumes or dust produced.
- Any process involving an electric discharge in air should be examined for the possibility of production of ozone and oxides of nitrogen.
- Grinding (especially dry grinding operations such as milling and blasting) or crushing of any material involves the hazard of dust of the material being treated and the grinding materials.
- Wet grinding of any material presents possible hazards of mist.
- Conveying, sieving or screening of any dry material presents a dust hazard.

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- Mixing of dry material presents a dust hazard.

- Mixing of wet material presents possible hazards of solvent vapours and mists.

- Cold bending, forming, or cutting of metals or non-metals should be examined for hazards of contact with lubricant and inhalation of lubricant mist.

- Hot bending, forming, or cutting of metals or non-metals may have the hazards of lubricant mist, decomposition products of the lubricant, contact with the lubricant and dust.

- Painting and coating processes should be examined for the possibility of hazards from inhalation and contact with toxic and irritating solvents and inhalation of toxic pigments.

- Explosive processing will involve gases from the explosive, largely carbon monoxide and oxides of nitrogen, and dust from the material being processed.

MATERIAL SAFETY DATA SHEETS

A material safety data sheet (MSDS) provides the following information about a chemical.

1 Identification
  - Product name
  - Chemical name
  - Chemical formula
  - Manufacturer's name and address
  - Contact number

2 Composition and information on ingredient
  - Hazardous ingredients
  - % by volume or weight of hazardous ingredients

3 Physical and chemical properties
  - Appearance
  - Odour
  - Boiling and melting points
  - Vapour pressure
  - Specific gravity
  - Solubility in water

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- Fire and explosion data (i.e. flash point, flammability limits, autoignition temperature)
- Other properties (e.g. viscosity, vapour density, pH)

4 Hazards identification
  - Types of hazards including corrosive, flammable, reactive, toxic, harmful, explosive
  - Adverse health effects and symptoms of overexposure

5 Stability and reactivity
  - Decomposition conditions and products
  - Polymerisation
  - Incompatible materials

6 Toxicological information
  - Routes of entry
  - Acute effects
  - Chronic effects
  - Toxicity ratings (e.g. LD_{50} , LC_{50})
  - Permissible exposure levels (e.g. PEL, TLV)

7 Handling and storage
  - Storage container
  - Storage conditions
  - Safe handling procedures

8 Exposure control and personal protection
  - Engineering controls (e.g. enclosure, isolation, local exhaust ventilation)
  - Personal protective equipment (e.g. gloves, respirators, face shield)
  - Specific hygiene measures if indicated

9 Transport information
  - Types of packaging
  - Labelling
  - Placarding
  - Special transport requirements (e.g. shock sensitivity)

10 Spillage, accidental release measures
  - Steps to be taken including decontamination procedures
  - Personal protective equipment

11 Fire-fighting measures
  - Types of fire-fighting agents
  - Precautions to be observed
  - Protective clothing and breathing apparatus

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12 First-aid measures
- First-aid treatments for the three possible routes of exposure (i.e. inhalation, ingestion, skin or eye contact)

13 Disposal considerations
- Disposal containers and methods
- Precautions during waste handling

14 Ecological information
- Mobility
- Persistence and biodegradability
- Bioaccumulative potential
- Aquatic toxicity and data relating to ecotoxicity

15 Other information
- National regulations and references
- Training advice
- Recommended uses and restrictions
- Sources of key data used to compile the MSDS

- Each hazardous chemical used should have a material safety data sheet (MSDS) containing the above information.

- Chemical manufacturers or suppliers should prepare or provide MSDS for all hazardous chemicals they produce or supply. They should ensure that the information contained in the MSDS is adequate, accurate and up-to-date.

- Chemical suppliers should provide factory occupiers and employers with MSDS on the first occasion that the hazardous chemical is supplied to the factories and on request.

- Factory occupiers and employers should obtain a MSDS for each toxic or hazardous chemical they use. They should assess all relevant information provided on the MSDS and take necessary measures to ensure the safe use of chemicals.

- Factory occupiers and employers should not purchase any proprietary chemicals, which are sold under a commercial name without a MSDS.

- Factory occupiers and employers should not accept incomplete MSDS but instead should demand full information from the suppliers. If necessary, they should switch orders to other suppliers who are able to provide MSDS with complete information.

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- Factory occupiers and employers should maintain a collection of the MSDS of all hazardous chemicals used in the factories. They should not withhold any information or alter the MSDS except where an overseas MSDS in a foreign language is to be translated to English or languages understood by their workers.

- Factory occupiers and employers should ensure that MSDS are readily accessible or available to persons who are exposed or likely to be exposed to the toxic or hazardous chemicals.

- Persons who handle any hazardous chemicals, or may be exposed or affected by these chemicals, should be informed of the hazards or potential hazards of these chemicals and the procedures for safe handling, use, storage, transport and disposal.

For more information about MSDS, please refer to the "Guidelines on the Preparation of Material Safety Data Sheets (MSDS)" published by the Ministry of Manpower.

LABELLING OF CONTAINERS

The objective of labelling is to enable users of chemicals know exactly what chemicals they are handling, the hazards involved and the precautionary measures to be taken.

- Suppliers of chemicals should ensure that all containers of toxic and hazardous chemicals that they supply are properly labelled.

- The label should indicate the name, contents, danger symbols and hazards of the chemicals (i.e. hazard or risk phrases) as well as the precautionary measures to be taken (i.e. precaution or safety phrases).

- If a toxic or hazardous chemical is decanted or transferred from its original container to a new one, the container to which the chemical is decanted should also be properly labelled.

- Always check the label before handling any chemical. If a chemical container does not have a label, do not handle it until it is properly labelled.

- All torn, damaged or misplaced labels should be replaced.

- Always check the MSDS if you have any doubts about a toxic or hazardous chemical after reading the label.

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In addition to the hazard and precautionary phrases listed below, other codes like the National Fire Protection Association (NFPA) hazard identification system and the HAZCHEM emergency action code can also be used. Please refer to the Singapore Standard 286: Part 3 and Part 5: 1984.

HAZARD PHRASES FOR LABELLING

The following are hazard phrases that can be used for labelling of containers of hazardous substances. Four hazard phrases should suffice to describe the risks.

H1	Explosive when dry
H2	Risk of explosion by shock, friction, fire or other sources of ignition
H3	Extreme risk of explosion by shock, friction, fire or other sources of ignition
H4	Forms very sensitive explosive metallic compounds
H5	Heating may cause an explosion
H6	Explosive with or without contact with air
H7	May cause fire
H8	Contact with combustible material may cause fire
H9	Explosive when mixed with combustible material
H10	Flammable
H11	Highly flammable
H12	Extremely flammable
H13	Extremely flammable liquified gas
H14	Reacts violently with water
H15	Contact with water liberates highly flammable gases
H16	Explosive when mixed with oxidising substances
H17	Spontaneously flammable in air
H18	May form flammable or explosive vapour-air mixture in use
H19	May form explosive peroxides
H20	Harmful by inhalation
H21	Harmful in contact with skin
H22	Harmful if swallowed
H23	Toxic by inhalation
H24	Toxic in contact with skin
H25	Toxic if swallowed
H26	Very toxic by inhalation
H27	Very toxic in contact with skin
H28	Very toxic if swallowed
H29	Contact with water liberates toxic gases
H30	Can become highly flammable in use
H31	Contact with acids liberates toxic gases
H32	Contact with acids liberates very toxic gases
H33	Danger of cumulative effects
H34	Causes burn

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H35	Causes severe burn
H36	Irritating to eyes
H37	Irritating to respiratory system
H38	Irritating to skin
H39	Danger of very serious irreversible effects
H40	Possible risks of irreversible effects
H41	Risk of serious damage to eyes
H42	May cause sensitization by inhalation
H43	May cause sensitization by skin contact
H44	Risk of explosion if heated under confinement
H45	May cause cancer
H46	May cause heritable genetic damage
H47	May cause birth defects
H48	Danger of serious damage to health by prolonged exposure
H49	May cause cancer by inhalation
H50	Very toxic to aquatic organisms
H51	Toxic to aquatic organisms
H52	Harmful to aquatic organisms
H53	May cause long-term adverse effects in the aquatic environment
H54	Toxic to flora
H55	Toxic to fauna
H56	Toxic to soil organisms
H57	Toxic to bees
H58	May cause long-term adverse effects in the environment
H59	Dangerous to the ozone layer
H60	May impair fertility
H61	May cause harm to the unborn child
H62	Possible risk of impaired fertility
H63	Possible risk of harm to the unborn child
H64	May cause harm to breasted babies
H65	Harmful: may cause lung damage if swallowed

PRECAUTIONARY PHRASES FOR LABELLING

The following are precaution phrases that can be used for labelling of containers of hazardous substances. Four precaution phrases should suffice to formulate the most appropriate safety advice.

P1	Keep locked up
P2	Keep out of reach of
P3	Keep in a cool place
P4	Keep away from living quarters
P5	Keep contents under … (appropriate liquid to be specified by the manufacturer)

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P6	Keep under … (inert gas to be specified by the manufacturer)
P7	Keep container tightly closed
P8	Keep container dry
P9	Keep container in a well-ventilated place
P12	Do not keep container sealed
P13	Keep away from food, drink and animal feeding stuffs
P14	Keep away from … (incompatible materials to be indicated by the manufacturer)
P15	Keep away from heat
P16	Keep away from sources of ignition – no smoking
P17	Keep away from combustible material
P18	Handle and open container with care
P20	Do not eat or drink when using
P21	Do not smoke when using
P22	Do not breathe dust
P23	Do not breathe gas/vapour/fumes/spray mist (appropriate wording to be specified by the manufacturer)
P24	Avoid contact with skin
P25	Avoid contact with eyes
P26	In case of contact with eyes, rinse immediately with plenty of water and seek medical advice
P27	Take off immediately all contaminated clothing
P28	In case of contact with skin, wash immediately with plenty of … (to be specified by the manufacturer)
P29	Do not empty into drains
P30	Never add water to this product
P33	Take precautionary measures against static discharges
P34	Avoid shock and friction
P35	Dispose this material and its container in a safe way
P36	Wear suitable protective clothing
P37	Wear suitable gloves
P38	Wear suitable respiratory protection equipment if ventilation is insufficient
P39	Wear eye/face protection equipment
P40	Use … (to be specified by the manufacturer) to clean the floor and all objects contaminated by this material
P41	In case of fire or explosion, do not breathe fumes
P42	Wear suitable respiratory protection equipment (appropriate wording to be specified by the manufacturer) during fumigation or spraying
P43	In case of fire, use … (appropriate fire-fighting equipment to be specified by the manufacturer)
P45	In case of accident or if you feel unwell, seek medical advice immediately
P46	If swallowed, seek medical advice immediately and show this container or label
P47	Keep at temperature not exceeding … °C (to be specified by the manufacturer)

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P48 Keep wetted with … (appropriate material to be specified by the manufacturer)
P49 Keep only in the original container
P50 Do not mix with … (to be specified by the manufacturer)
P51 Use only in well-ventilated areas
P52 Not recommended for interior use on large surface areas
P53 Avoid exposure – obtain special instructions before use
P56 Dispose this material and its container at special waste collection point
P57 use appropriate container to avoid environmental contamination
P58 To be disposed off as hazardous waste
P59 Refer to manufacturer or supplier for information on recovery or recycling
P60 This material and its container must be disposed off as hazardous waste
P61 Avoid release to the environment – refer to special instructions / MSDS
P62 If swallowed, do not induce vomiting: seek medical advice immediately and show this container or label

RECOGNITION OF HAZARDS BY ODOUR THRESHOLDS

There is a significant personal variation in odour thresholds of chemicals. Individuals may respond differently to the same odour. At a given concentration, a person may smell and recognise the odour, while another person may barely notice it. Thus, the sense of smell cannot be relied upon to assess the hazards of chemicals used in the workplace.

In the absence of instrumentation to measure the airborne concentration of gases and vapours, greater reliance must be placed upon the surveyor's senses, especially during a walk through inspection.

The odour thresholds of some commonly used chemicals are listed below. Included in the table are the irritating concentrations and description of odour. Great caution must be exercised in using these numbers in the recognition phase as a rough estimation of airborne concentrations.

Odour Thresholds and Irritation Concentrations of Chemicals

Chemical Compound	Low Odour mg/m3	High Odour mg/m3	Description of Odour	Irritating Concentration mg/m3
Acetaldehyde	0.0002	4	Green, sweet, fruity	90
Acetic acid	2.5	250	Sour, vinegar-like	25
Acetic anhydride	0.6	1.5	Sharp odour, sour acid	20
Acetone	48	1,614	Minty chemical, sweet	475
Acetonitrile	70	70	Ether-like	875
Acrolein	0.05	38	Burnt, sweet	1.3

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Acrylic acid	0.3	3	Rancid, sweet	-
Acrylonitrile	8	79	Onion-garlic pungency	-
Allyl alcohol	2	5	Pungent, mustard	13
Allyl chloride	1.4	75	Green, garlic, onion	75
Allyl glycidyl ether	44	44	Sweet	1,144
Ammonia	0.03	40	Pungent, irritating	72
Aniline	0.0002	350	Pungent, amine-like	-
Arsine	0.8	2	Garlic-like	-
Benzene	4.5	270	Sweet, solventy	9,000
Boron trifluoride	4.5	4.5	Pungent, irritating	-
Bromine	0.3	25	Bleachy, penetrating	2
1,3-Butadiene	0.4	3	**Mild,aromatic**	
n-Butyl acetate	33	95	Fruity	473
n-Butyl alcohol	0.4	150	Sweet	75
Butyl cellosolve	0.5	288	Sweet, ester	-
Butyl cellosolve acetate	0.7	1.3	Sweet, ester	-
Carbon disulfide	0.02	23	Disagreeable, sweet	-
Carbon tetrachloride	60	128	Sweet, pungent	-
Cellosolve	2	185	**Sweet, pleasant**	**-**
Cellosolve acetate	0.3	270	Sweet, musty	-
Chlordane	0.008	0.04	**Pungent, chlorine-like**	-
Chlorine	0.03	15	Bleachy, pungent	9
Chlorine dioxide	0.3	0.3	Sharp, pungent	15
Chlorobenzene	1	280	Sweet, almond-like	933
Chloroform	250	1,000	**Sweet,pleasant**	20,480
Cresol	0.001	22	Sweet, creosote, tar	-
Cumene	0.04	6	Sharp, aromatic	23
Cyclohexane	1.4	1.4	Sweet, aromatic	1,050
Cyclohexanol	400	400	Camphor-like	200
Cyclohexanone	0.5	400	Sweet, peppermity	100
Diborane	2	4	Repulsively sweet	-
o-Dichlorobenzene	12	300	**Pleasant,aromatic**	150
p-Dichlorobenzene	90	180	Mothballs	240
Dichloroethane	446	810	Chloroform-like	-
Diethylamine	0.06	114	Fishy, ammonical	150
Diisobutyl ketone	0.7	2	Sweet, ester	150
Dimethyl formamide	300	300	**Fishy,unpleasant**	-
1,1-Dimethylhydrazine	12	20	Ammonical, amine-like	-
1,4-Dioxane	0.01	612	Ethyl-like	792
Epichlorohydrin	50	80	Chloroform-like	325

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Ethanolamine	5	11	Ammonia	13
Ethyl acetate	0.02	665	Fruity, pleasant	350
Ethyl alcohol	0.3	9,690	Sweet, alcoholic	9,500
Ethyl amine	0.5	396	Sharp, ammonical	180
Ethyl benzene	9	870	aromatic	870
Ethyl ether	1	3	Sweet, ether-like	300
Ethyl mercaptan	3 x 10^{-5}	0.09	Garlic	-
Ethylene diamine	2.5	28	Ammonical, musty	250
Ethylene dibromide	77	77	Mild, sweet	-
Ethylene dichloride	24	440	sweet	-
Ethylene glycol	63	63	sweet	-
Ethylene oxide	520	1,400	Sweet, olefinic	-
Fluorine	6	6	**Pungent, irritating**	50
Formaldehyde	1.5	74	Pungent, hay	1.5
Formic acid	0.05	38	Pungent, penetrating	27
Furfural	0.02	20	Almonds	48
Hydrazine	3	4	Ammonical, fishy	-
Hydrochloric acid	7	49	Irritating, pungent	49
Hydrofluoric acid	0.03	0.1	Strong, irritating	4
Hydrogen bromide	7	7	Sharp, irritating	10
Hydrogen cyanide	0.9	5	Bitter almond	-
Hydrogen sulfide	0.0007	0.01	Rotten eggs	14
Iodine	9	9	**Irritating**	2
Isophorone	1	50	Sharp, objectionable	50
Isopropyl alcohol	8	490	pleasant	490
Maleic anhydride	1.8	2	Acrid	6
Methyl acetate	610	915	Fragrant, fruity	30,496
Methyl acrylate	70	70	Sharp, sweet, fruity	263
Methyl alcohol	13	26,840	Sweet	22,875
Methyl bromide	80	4,000	Sweetish	
Methyl cellosolve	0.3	288	Mild, non-residual	368
Methyl cellosolve acetate	1.6	240	Sweet, ester	-
Methyl chloroform	543	3800	Chloroform-like	5,429
Methyl ethyl ketone	0.7	148	Sweet, acetone-like	590
Methyl isobutyl ketone	0.4	193	Sweet, sharp	410
Methyl mercaptan	4 x 10^{-5}	0.08	Sulfidy	-
Methyl amine	0.03	12	Fishy, pungent	-
Methylene chloride	540	2,160	Sweet	8,280
Mineral spirits	157	787	**Kerosene-like**	-
Naphthalene	1.5	125	Mothball, tar-like	75
Nickel carbonyl	0.2	21	Musty	-
Nitric acid	0.8	2.5	**Acrid, choking**	155

Nitric oxide	0.4	1.2	-	-
Nitrobenzene	0.02	9.5	Shoe polish, pungent	230
Nitroethane	620	620	Mild, fruity	310
Nitrogen dioxide	2	10	Sweetish, acrid	20
Nitromethane	250	250	Mild, fruity	360
1-Nitropropane	1080	1,080	Mild. fruity	360
2-Nitropropane	18	1,029	**Fruity**	-
Octane	725	1,208	Gasoline-like	1,450
Ozone	0.001	1	Pleasant, clover-like	2
Pentane	7	3,000	Gasoline-like	-
Perchloroethylene	31	469	Mildy sweet	1,340
Phenol	0.2	22	Medicinal, sweet	182
Phosgene	2	4	Musty hay, green corn	8
Phosphine	0.03	3.6	Decaying fish	11
n-Propyl alcohol	0.08	150	Sweet, alcohol	-
Propyl alcohol	75	500	Sharp, musty	13,750
Propylene	40	116	Aromatic	-
Propylene oxide	25	500	Sweet, alcoholic	1,125
Pyridine	0.009	15	Burnt, sickening	90
Stoddard solvent	5	156	Kerosene-like	2,100
Styrene	0.2	860	Solvently, rubbery	430
Sulfur dioxide	1.2	12.5	Pungent, irritating	5
Sulfuric acid	1	1	-	1.1
Tetrachloroethane	21	35	Sickly sweet	1,302
Tetrahydrofuran	7	177	Ether-like	-
Toluene	8	150	Rubbery, mothballs	750
Toluene 2,4-diisocyanate	3	17	Sweet, fruity, acrid	4
Trichloroethylene	1	2,160	Etheral, chloroform like	864
Turpentine	560	1,120	**Pine-like**	560
Vinyl acetate	0.4	1.7	Sour, sharp	-
Naphtha	4	4	-	435
Xylene	0.4	174	Sweet	435

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HAZARD ASSESSMENT

Where a chemical hazard has been identified, assessment or evaluation should be made to determine the degree of exposure, the consequences of exposure and all factors contributing to the exposure.

WORKPLACE MONITORING

Workplace monitoring is carried out for a number of reasons, they are:-

- assessing possible health risks resulting from work activities,
- assessing the need for and the effectiveness of exposure control measures,
- determining compliance with permissible exposure levels of toxic substances,
- assessing the effect of changes in processes, materials or controls.
- identifying hazardous areas or work tasks that give rise to the most exposure,
- investigating complaints concerning alleged health effects,
- reassuring employees who may be exposed to toxic airborne contaminants.

Under the Factories Act section 59(6), regular workplace monitoring is required in any factory in which toxic chemicals are used or given off.

MONITORING OR SAMPLING METHODS

The method of sampling will depend on the chemical being monitored. The common air sampling methods are:-

Sample Bag Method

Air sample bags are used to collect gases and vapours when the concentration is above the detection limits of common analytical or direct reading instruments. These bags are made of inert plastic film. Air is pumped into the bag and analysed directly from the bag by detector tubes, gas chromatography or other instruments.

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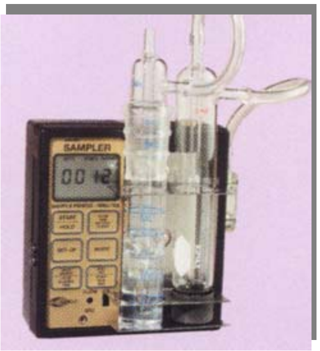
Sorbent Tube Method

Sorbent tubes are used for sampling of many gases and hydrocarbon vapours. The tube contains a bed of adsorbent such as charcoal or silica gel. When air is pulled through the tube, airborne chemicals are trapped by the adsorbent. After sampling, the sorbent is removed and the trapped chemicals are extracted, identified and quantified using gas chromatography or other analytical methods.



Impinger Method

Impingers are glass bubble tubes used to collect certain inorganic chemicals and some organic chemicals. A known volume of air is bubbled through the impinger which contains a liquid medium. The liquid will physically dissolve or chemically react with the chemical of interest. The liquid is then analysed by colorimetric, volumetric or other analytical methods to determine the airborne contaminant concentration.

Badge Method

Many gases and hydrocarbon vapours can be sampled passively without a pump, using gas monitoring badges. Badges are available with a variety of collection media including solid adsorbents and reagent-filled tubes. The air sample comes into contact with the adsorbent by diffusion. Analysis methods vary with the badge type or chemical sampled and include colour change and gas chromatography.

Filter Method

Filters are used to collect particulates matters such as dusts, fumes and mists. Air is pulled through a filter of a specific type and pore size. The collected contaminants can be analysed by gravimetric, microscopic or atomic absorption technique.

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DIRECT READING INSTRUMENTS

There are many types of direct reading instruments available for measuring gases, vapours and aerosols (particulates in air) using different detection principles. Some of the instruments are specific for a particular contaminant, others are non-specific. Most direct reading instruments allow for continuous monitoring of the contaminant level, some have data logging features and alarm settings to warn users of hazardous conditions.

Detector tubes are commonly used for detecting toxic gases and vapours. With this method, a known volume of air is drawn through a tube containing a chemical reagent. The reagent changes colour in the presence of the contaminant of interest. The length of stain indicates the airborne contaminant concentration.

Other specific direct reading instruments for measuring toxic gases include electrochemical sensors and solid state gas detectors. Photoionizers and infrared analysers are the most versatile direct reading instruments for measuring many gases and vapours. However both are non-specific and can only be used for measuring known compounds.

Direct reading instruments are also available for measuring the mass concentration of aerosols or airborne particulates. These instruments are usually based on piezobalance or optical light scattering principle.

SELECTION OF MEASUREMENT TECHNIQUES / EQUIPMENT

A number of factors need to be considered prior to selecting an air monitoring technique or equipment for any particular application are:

- Specificity – the ability to uniquely detect one compound in the presence of other contaminants.
- Accuracy – the closeness of result to the actual or true concentration present.
- Sensitivity – the amount of substance that must be present to give a response.

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- Calibration – the checks that are required to verify that an instrument is performing acceptably at the concentrations of interest.

- Interference – the reaction of other substances other than the compound of interest with the measurement techniques.

- Warning alarms – the audible or visual signals to alert personnel that higher than acceptable concentrations are present.

- Datalogging features – the ability to store the monitoring data for time-weighted average concentration determination.

- Cost – the expense associated with the purchase of equipment or supplies, as well as any associated laboratory analysis costs for indirect methods.

- Intrinsic safe – the characteristic of the equipment required so that it can be used in certain area.

Selection of instruments and equipment best capable of providing the data required in a given survey or study, is ultimately a matter of judgement on the part of the industrial hygiene professionals.

SAMPLING STRATEGIES

Air sampling strategies in terms of the locations, duration and frequency of sampling as well as the number of samples - must fulfil the requirements that the samples taken will represent workers' exposures or environmental conditions and that measurements are efficient, accurate and economical.

Location of Sampling

The choice of the monitoring locations depends on the objective of sampling or the type of information required.

If the objective of monitoring is to determine a worker's exposure level, it is necessary to conduct personal monitoring by attaching the monitoring device as close as possible to the worker's breathing zone.

If the objective is to assess the contaminant concentration at selected locations or to evaluate the adequacy or effectiveness of engineering control measures, area monitoring is required by setting the sampling equipment in a fixed position in the work area.

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Personal Sampling

To maximise the effectiveness of monitoring for assessing exposure hazard, it is necessary to group workers in a plant based on their job tasks and the similarity of the physical conditions (eg equipment, process and ventilation) of the workplace or the environment in which they work. Workers in the same group can be randomly selected for monitoring. The sample size should be at least 3 to 5 per group or from 25% to 50% of those in the group for groups of 10 or more.

Duration and Volume of Sampling

The total volume of air sampled depends on flowrate and duration of sampling. For a certain flowrate, the duration of sampling will determine the total volume of the sample. The minimum duration of sampling is directly proportional to the sensitivity of the analytical method but is inversely proportional to the expected concentration. The total volume of air sampled must yield a measurable amount of contaminant for accurate analysis.

A single sample or several consecutive samples covering the whole of the period of the shift should be taken to determine the time-weighted average concentrations of exposure.

To minimise error associated with fluctuations in exposure, full-shift sampling for air contaminants should be conducted for at least 6 hours for 8 hours shift and at least 8 hours for 12 hours shift. If the worker is exposed to contaminants for less than 6 hours, a partial period sampling could be conducted. In this case, the unsampled time should be calculated as zero exposure.

If technology has not been developed to allow full-shift sampling, a series of “grab” or “spot” samples taken randomly throughout the workshift is acceptable. The acceptable number of samples is 4 to 7.

Frequency of Sampling

The frequency of air monitoring depends on the exposure level:

- Where workers are exposed to contaminants of less than 10% of the PEL, no air monitoring is required unless there is a change in the process.

- Where workers are exposed to contaminants between 10% and 50% of the permissible exposure level (PEL), monitoring should be carried out at least once a year.

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- Where the exposure is between 50% and 100% PEL, monitoring should be conducted at least once every six months.

- Where the exposure exceeds PEL, monitoring should be done at least once every three months until the exposure is reduced to below the PEL by appropriate control measures.

What to Sample

Very often, more than one chemical is used in the workplace. Consequently, workers may be exposed to more than one hazard. For practical reasons, it may not be possible to sample the exposure of every chemical. The type of chemicals to sample will depend on basically two factors:

- The risk to the workers – depending on which chemicals are likely to be liberated into the workplace atmosphere. This will in turn depend on the kind of operations (manual or closed) and the physical properties of the chemicals (e.g. the vapour pressure of an organic solvent).

- The toxic effects of the chemicals.

Please refer the Guideline on Sampling Strategy and Submission of Air Monitoring/Sample Analysis Report for details.

PERMISSIBLE EXPOSURE LEVELS (PEL)

When assessing risks of exposure to contaminants in working environments, the results of air sampling or concentration measurements are compared with their permissible exposure levels or PELs. Two types of PELs are specified in the Factories (Permissible Exposure Levels of Toxic Substances) Order:

- PEL (Long Term) is the maximum time-weighted average (TWA) concentration of a toxic substance to which persons may be exposed over an 8-hour workday or a 40-hour workweek.

- PEL (Short Term) is the maximum TWA concentration to which persons may be exposed over a period of 15 minutes during the workday.

To determine compliance with PEL, sample(s) should be collected to cover the period for which the exposure standard is defined, ie a 15-minute sampling period to evaluate compliance with PEL (Short Term) and an 8-hour monitoring period to determine compliance with PEL (Long Term).

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For airborne contaminants having both PEL (Long Term) and PEL (Short Term), the long-term full-shift sample(s) should be supplemented by short-term grab sample(s) to catch the peaks if there are wide fluctuations in the air levels.

Appropriate statistical analysis of monitoring results should be made to determine the status of compliance or non-compliance.

To evaluate whether an overexposure occurs for cases where more than one chemical is sampled, one has to see whether these chemicals have similar or different toxicological effects.

Please refer to the Factories (Permissible Exposure Levels of Toxic Substances) Order for more information on such evaluation.

The Permissible Exposure levels of some of the common toxic substances are appended below.

Permissible Exposure Levels of Toxic Substances

Toxic Substance	Permissible Exposure Level (PEL)			
	PEL (Long Term)		PEL (Short Term)	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Acetic acid	10	25	15	37
Acetic anhydride	5	21	-	-
Acetone	750	1780	1000	2380
Acrylonitrile (Vinyl cyanide)*	2	4.3	-	-
Aluminium dust	-	10	-	-
Ammonia	25	17	35	24
Aniline*	2	7.6	-	-
Antimony and compounds, as Sb	-	0.5	-	-
Arsenic, elemental and inorganic compounds, as As	-	0.01	-	-
Arsine	0.05	0.16	-	-
Asphalt (petroleum) fumes	-	5	-	-
Barium, soluble compounds, as Ba	-	0.5	-	-

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Benzene*	5	16	-	-
Beryllium and compounds, as Be	-	0.002	-	-
Bromine	0.1	0.66	0.2	1.3
1,3-Butadiene	2	4.4	-	-
Butane	800	1900	-	-
n-Butanol*	-	-	50	152
sec-Butanol	100	303	-	-
n-Butyl acetate	150	713	200	950
Cadmium, elemental and compounds, as Cd	-	0.05	-	-
Calcium carbonate (Limestone, Marble)	-	10	-	-
Calcium hydroxide	-	5	-	-
Calcium silicate	-	10	-	-
Calcium sulfate	-	10	-	-
Carbon black	-	3.5	-	-
Carbon dioxide	5000	9000	30,000	54,000
Carbon disulfide*	10	31	-	-
Carbon monoxide	25	29	-	-
Carbon tetrachloride (Tetrachloromethane)*	5	31	10	63
Chlorine	0.5	1.5	1	2.9
Chloroform (Trichloromethane)	10	49	-	-
Coal tar pitch volatiles (Polycylic aromatic hydrocarbons), as benzene solubles	-	0.2	-	-
Cobalt, elemental and inorganic compounds, as Co	-	0.02	-	-
Copper				
Fume	-	0.2	-	-
Dusts & mists, as Cu	-	1		

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Cotton dust, raw	-	0.2	-	-
Cresol*	5	22	-	-
Cyclohexane	300	1030	-	-
Cyclohexanol	50	206	-	-
Cyclohexanone*	25	100	-	-
Cyclohexene	300	1010	-	-
Diborane	0.1	0.11	-	-
Ethanol (Ethyl alcohol)	1000	1880	-	-
Ethyl acetate	400	1440	-	-
Ethylene glycol	-	-	50	127
Ethylene oxide	1	1.8	-	-
Ethyl ether (Diethyl ether)	400	1210	500	1520
Ethyl mercaptan (Ethanethiol)	0.5	1.3	-	-
Fibrous glass dust	-	10	-	-
Fluorides, as F	-	2.5	-	-
Fluorine	1	1.6	2	3.1
Formaldehyde	-	-	0.3	0.37
Formic acid	5	9.4	10	19
Furfural*	2	7.9	-	-
Furfuryl alcohol*	10	40	15	60
Gasoline	300	890	500	1480
Grain dust (oat, wheat, barley)	-	4	-	-
Graphite, respirable dust	-	2	-	-
Heptane	400	1640	500	2050
Hexane (n-Hexane)*	50	176	-	-
Hydrazine*	0.1	0.13	-	-
Hydrogen bromide	-	-	3	9.9
Hydrogen chloride	-	-	5	7.5
Hydrogen cyanide*	-	-	4.7	5

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Hydrogen fluoride	-	-	3	2.6
Hydrogen peroxide	1	1.4	-	-
Hydrogen sulfide	10	14	15	21
Iodine	-	-	0.1	1.0
Iron oxide dust & fume, as Fe	-	5	-	-
Iron salts, soluble, as Fe	-	1	-	-
Isobutyl acetate	150	713	-	-
Isobutyl alcohol	50	152	-	-
Isophorone	-	-	5	28
Isopropyl acetate	250	1040	310	1290
Isopropyl alcohol	400	983	500	1230
Lead, inorganic dusts and fumes, as Pb	-	0.15	-	-
L.P.G. (Liquified petroleum gas)	1000	1800	-	-
Malathion*	-	10	-	-
Maleic anhydride	0.25	1.0	-	-
Manganese, as Mn				
Dust and compounds	-	5	-	-
Fume	-	1	-	3
Mercury				
Alkyl compounds*	-	0.01	-	0.03
Aryl compounds*	-	0.1	-	-
Inorganic forms* eg. metalic mercury	-	0.025	-	-
Methanol (Methyl alcohol)*	200	262	250	328
Methyl acetate	200	606	250	757
Methyl acrylate*	10	35	-	-
Methyl n-butyl ketone (2-Hexanone)*	5	20	-	-
Methylene bisphenyl isocyanate (MDI, Diphenyl methane diisocyanate)	0.005	0.051	-	-
Methylene chloride (Dichloromethane)	50	174	-	-

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Methyl ethyl ketone (MEK, 2-Butanone)	200	590	300	885
Methyl ethyl ketone peroxide	-	-	0.2	1.5
Methyl isobutyl ketone (Hexone)	50	205	75	307
Methyl mercaptan (Methanethiol)	0.5	0.98	-	-
Mineral wool fiber	-	10	-	-
Molybdenum, as Mo				
Soluble compounds	-	5	-	-
Insoluble compounds	-	10	-	-
Naphtha	300	1370	-	-
Naphthalene*	10	52	15	79
Nickel				
Metal	-	1	-	-
Insoluble compounds, as Ni	-	1	-	-
Soluble compounds, as Ni	-	0.1	-	-
Nickel carbonyl, as Ni	0.05	0.12	-	-
Nickel sulfide, as Ni	-	1	-	-
Nicotine*	-	0.5	-	-
Nitric acid	2	5.2	4	10
Nitric oxide	25	31	-	-
Nitrogen dioxide	3	5.6	5	9.4
Nitrous oxide	50	90	-	-
Nuisance particulates	-	10	-	-
Octane	300	1400	375	1750
Oil Mist, mineral	-	5	-	10
Ozone	-	-	0.1	0.20
Parathion*	-	0.1	-	-
Pentane	600	1770	750	2210
Perchloroethylene (Tetrachloroethylene)	25	170	100	685

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Phenol*	5	19	-	-
Phosgene	0.1	0.40	-	-
Phosphine	0.3	0.42	1	1.4
Phosphoric acid	-	1	-	3
Phosphorus	0.02	0.1	-	-
Phthalic anhydride	1	6.1	-	-
Platinum				
Metal	-	1	-	-
Soluble salts, as Pt	-	0.002	-	-
Portland cement	-	10	-	-
Potassium cyanide	-	-	-	5
Potassium hydroxide	-	-	-	2
n-Propyl acetate	200	835	250	1040
n-Propyl alcohol*	200	492	250	614
Propylene oxide (1,2-Epoxypropane)	20	48	-	-
Selenium and compounds, as Se	-	0.2	-	-
Silica-Amorphous				
Diatomaceous earth (uncalcined)	-	10	-	-
Precipitated silica	-	10	-	-
Silica, fume, respirable dust	-	2	-	-
Silica, fused, respirable dust	-	0.1	-	-
Silica gel	-	10	-	-
Silica-Crystalline				
Cristobalite, respirable dust	-	0.05	-	-
Quartz, respirable dust	-	0.1	-	-
Tridymite, respirable dust	-	0.05	-	-
Tripoli, respirable dust	-	0.1	-	-

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Silicon	-	10	-	-
Silver				
Metal	-	0.1	-	-
Soluble compounds, as Ag	-	0.01	-	-
Sodium cyanide	-	-	-	5
Sodium hydroxide	-	-	-	2
Stoddard solvent	100	525	-	-
Styrene, monomer (Phenylethylene, Vinyl benzene)	50	213	100	426
Sulfur dioxide	2	5.2	5	13
Sulfuric acid	-	1	-	3
Talc	-	2	-	-
Tantalum, metal and oxide, as Ta	-	5	-	-
Tetraethyl lead, as Pb*	-	0.1	-	-
Tetrahydrofuran	200	590	250	737
Tetramethyl lead, as Pb*	-	0.15	-	-
Tin				
Metal	-	2	-	-
Oxide inorganic compounds, as Sn	-	2	-	-
Organic compounds, as Sn*	-	0.1	-	0.2
Titanium dioxide	-	10	-	-
Toluene (Toluol)*	50	188	-	-
Toluene-2,4-diisocyanate (TDI)	0.005	0.036	0.02	0.14
1,1,1-Trichloroethane (Methyl chloroform)	350	1910	450	2460
1,1,2-Trichloroethane*	10	55	-	-
Trichloroethylene	50	269	100	537
2,4,6-Trinitrotoluene (TNT)*	-	0.5	-	-
Tungsten, as W				
Insoluble compounds	-	5	-	10

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Soluble compounds	-	1	-	3
Turpentine	100	566	-	-
Vegetable oil mists	-	10	-	-
Vinyl chloride (Chloroethylene)	5	13	-	-
Welding fumes	-	5	-	-
Wood dust				
Hard wood	-	1	-	-
Soft wood	-	5	-	10
Xylene	100	434	150	651
Zinc oxide				
Fume	-	5	-	10
Dust	-	10	-	-
Zirconium and compounds, as Zr	-	5	-	10

Note:
[a] ppm means parts of the substance per million parts of contaminated air by volume;
[b] mg/m^3 means milligrammes of the substance per cubic metre of contaminated air;
* means the chemicals can contribute to significant exposure through skin adsorption.
The following formula can be used to convert mg/m^3 to ppm at standard temperature (25°C) and pressure (760mmHg)

$$(\text{ppm}) = (\text{mg/m}^3) \times 24.5 / \text{molecular weight of the chemical}$$

For work shift more than 8 hrs, some steps need to be done to adjust the PEL such that it can be compared against the concentration of the contaminant. The user can choose either of the following methods:

- OSHA model
  Adjustments of Permissible Exposure Limits:
  Daily Reduction Factor = 8/h
  where h = hours worked per day
  Adjusted PEL = 8hr PEL x Daily Reduction Factor

- Brief & Scala model (a more conservative model)
  Adjustments of Permissible Exposure Limits:
  Daily Reduction Factor = {8/h x (24-h/16)
  where h = hours worked per day
  Adjusted PEL = 8hr PEL x Daily Reduction Factor

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BIOLOGICAL MONITORING

The primary objective of biological monitoring is to ensure that the current or past exposure of the worker is not harmful to his health by detecting excessive exposure before obvious health effects occur.

Biological monitoring is useful in assessing the overall exposure a worker to a chemical. This can be done by monitoring :

- the amount of a chemical that has been absorbed by the worker and/or
- the health effects of the absorbed chemical on the worker.

Biological monitoring involves measuring the level of an appropriate determinant in biological samples usually blood or urine collected from the worker at the specified time. The determinant can be the chemical of interest or its metabolite. It can also be a characteristic reversible biochemical change induced by the chemical.

Interpretation of Results

The BTLV (biological threshold limit value) represents the maximum concentrations of the toxic substance or its metabolites in the biological sample which would not be associated with significant risk to the worker's health. These limits generally represent the biological equivalent of the established permissible exposure levels for air contaminants.

All results exceeding the BTLV must be verified by a repeat test as soon as possible. If the repeat test is higher than the recommended BTLV, he should be removed from further exposure to the hazard until subsequent follow up results fall below the BTLV and there are no other abnormalities. Meanwhile, appropriate corrective action should be taken to improve the industrial hygiene conditions at the workplace. All such cases should be notified to the Chief Inspector of Factories using the Tenth or Eleventh Schedule of the Factories Act.

Please refer to table below for the frequency and type of tests done for the various hazards.

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Hazards, types of examinations and frequency of examinations

Chemical	Pre-employment examination	Frequency of examination	Periodic examination	Biological TLV for toxicological result
Arsenic (As)	a)Urine As b) Liver function test: Bil, AST, ALT, SAP, GGT c) Full-sized CXR	Every 12 months	a)Urine As	U-As: 300 mcg/L
Asbestos	a) Full-sized CXR	Every 36 months	a) Full-sized CXR	
Benzene	a)Urine phenol b)FBC & peripheral blood film	Every 12 months	a)Urine phenol b)FBC & peripheral blood film	U-phenol: 50 mg/L
Cadmium (Cd)	a)Blood Cd b)Urine β_2 microglobulin	Every 12 months	a)Blood Cd b)Urine β_2 microglobulin	B-Cd: 10 mcg/L
Cobalt (non-statutory)	a) Urine cobalt	Every 12 months	a) Urine cobalt (end-of-shift)	U-Co: 15 mcg/L
Cotton	a) Lung function test: FEV1 and FVC	Every 12 months	a)Lung function test: FEV1 & FVC	
Inorganic Fluoride (non-statutory)	a) random Urine Fluoride b) Skeletal X-ray (i.e. X-ray of pelvis, lateral views of thoracic and lumbar spine)	Every 12 months	a) Urine Fluoride	U-Fl: 5 mg/L
Hexane (non-statutory)	a) Urine 2,5-hexanedione (end-of-shift sample)	Every 12 months	a) Urine 2,5-hexanedione	5 mg/g creat
Organic Lead (Pb)	a)Urine Pb	Every 6 months	a)Urine Pb	U-Pb: 150 mcg/L

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Chemical	Pre-employment examination	Frequency of examination	Periodic examination	Biological TLV for toxicological result
Inorganic Lead	a)Blood Pb b)Hb	Every 6 months	a)Blood Pb b)Hb	B-Pb: 50 mcg/dL for males 30 mcg/dL for females
Manganese (Mn)	a)Urine Mn	Every 12 months	a)Urine Mn	U-Mn: 50 mcg/L
Inorganic Mercury (Hg)	a)Urine Hg	Every 12 months	a)Urine Hg	U-Hg: 50 mcg/L
Organophosphates	a)rbc cholines-terase b) Plasma cholines-terase	Every 6months	a)rbc cholines-terase	
Perchloroethlyene(PCE)	a) Urinary trichloroacetic acid (U-TCA) b) Liver function test: Bil, AST, ALT, SAP, GGT	Every 12 months	a) Urinary trichloroacetic acid	U-TCA: 7 mg/L
Silica	a) Full-sized CXR	Every 36 months	a) Full-sized CXR	
Tar, Pitch, Bitumen and Creosote	Clinical examination only	Every 12 months	Clinical examination only	
Toluene (non-statutory)	a)Urine Hippuric acid	Every 12 months	a)Urine Hippuric acid	U-hippuric acid: 1.6 g/g creat or mg/ml
Trichloro – ethylene (TCE)	a)Urine trichloroacetic acid (U-TCA) b) Liver function test: Bil, AST, ALT, SAP, GGT	Every 12 months	a)Urine trichloroacetic acid (U-TCA)	U-TCA: 100 mg/L

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Chemical	Pre-employment examination	Frequency of examination	Periodic examination	Biological TLV for toxicological result
Trinitro-toluene (TNT) (non-statutory)	a)Urine DNAT b) Liver function test: ALT, AST, SAP, Bil,GGT, SGPT	Every 12 months	a)Urine DNAT b) Liver function test: Bil, ALT, AST, SAP, GGT	U-DNAT: 10 mg/L
Xylene (non-statutory)	a)Urine methyl hippuric acid	Every 12 months	a)Urine methyl hippuric acid	U-methyl hippuric acid: 1.5 g/g creat
Vinyl Chloride Monomer (VCM)	a) Liver function test: Bil, ALT, AST, SAP, GGT	Every 12 months	a) Liver function test: Bil, ALT, AST, SAP, GGT	

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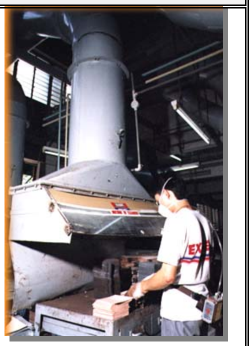
CONTROL MEASURES

Where the risk of exposure to chemicals is found not acceptable, suitable control measures must be implemented to minimise the exposure so as to safeguard the safety and health of the workers. Control measures can take the form of engineering measures, safe work practices, personal protection, administrative measures, training and education.

Basically, control measures can be applied at:

- the *source* where chemicals are located or emitted;
- along the *path* i.e. between the source and the receiver; and
- at the *receiver* or the exposed person.

The following table lists some control measures that can be applied at the source, along the path or at the receiver to eliminate or attentutate the risk of exposure.

Point of Control	**Control Measure**	**Examples**
At the source	Substituting with a less toxic or less harmful substance Changing to a less hazardous process Enclosing of source Isolation of source Wetting of dusty work Installing effective local exhaust ventilation Maintaining the machines regularly	
Along the path	Applying dilution ventilation Increasing the distance between the source and receiver Practising good housekeeping Improving general ventilation	

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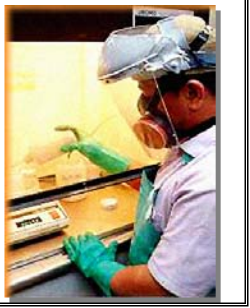
At the receiver	Enclosing of workers in control rooms Rotation of workers Training and education of workers Wearing suitable personal protective equipment	

ENGINEERING CONTROL

Substitution / Elimination

Toxic substances should as far as possible be substituted with less toxic or non-toxic substances. It is important to consider both the health and safety aspects when selecting a substitute. It may not be advisable to substitute a toxic but non-flammable solvent with a less toxic but flammable compound and vice versa.

It should be noted that many factors have to be considered before substituting an existing chemical. Some of the information required to be evaluated before usage include:

- physical and chemical properties
- toxicological information – health effects, the permissible exposure levels
- information pertaining to fire and reactivity hazards
- manner of handling or the mode of usage (manual/automated)
- anticipated exposure of workers
- existing control measures and their capabilities to control liberation of chemicals
- compatibility of the substitute with the present manufacturing processes
- requirement for workers to undergo training

Based on the above points, some principles of selecting safer alternatives can be generalised.

- Volatile solvents with low boiling points and high vapour pressures should as far as possible be substituted with solvents having high boiling points and low vapour pressures.

- Toxic substances with low permissible exposure levels should be substituted with less toxic substances having higher permissible exposure levels. However, the effects and the target organs should be taken into account when comparing permissible exposure levels.

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- Liquids with low flash points should as far as possible be substituted with liquids having higher flash points or no flash point to minimise or prevent fire risk.

- Materials in fine powder should be substituted with substances in granular, pellet or other bulk solid forms to reduce or prevent inhalation hazards.

- Chemicals in liquid form should be substituted with chemicals in paste, gelatinous or other viscous liquid to reduce exposure hazards.

Some examples of material substitution and their applications are listed in the following table.

Chemical / Substance	Substitute	Application
Benzene	Cyclohexane, toluene, xylene.	Printing and chemical industries.
Methyl alcohol	Ethyl alcohol	Cleaning of metal, glass parts.
Asbestos	Synthetic fibres such as calcium silicate, fibre glass.	Lagging of pipes and roofing materials.
Carbon tetrachloride	Other safer chlorinated hydrocarbons.	Starting material for some chemical processes.
White lead paint	Zinc or barium oxide paint.	Paints.
Solvent based paint	Water based paint	Paints, especially decorative paints.
Organic solvents	Detergents	Cleaning of surfaces, floors and housekeeping.

Please refer to the list of solvent substitutes for Trichloroethylene / Perchloroethylene in our website.

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Changing of Processes

Processes or operations that are capable of creating hazardous exposures can sometimes be replaced to reduce or eliminate the exposure hazards. The following are some examples of control of chemical hazards by changing of processes.

- Replace splash filling with submerged filling.
- Replace sand blasting with shot blasting.
- Replace fixed roof storage with floating roof storage.

Enclosure

An entire process or a portion of a process can sometimes be enclosed to prevent escape of contaminants into the workplace. Very toxic chemicals should be handled in enclosed systems. Effective hazard control is accomplished if the enclosure is kept under negative pressure. The following are some examples of control of chemical hazards by enclosure.

- Using glove box or booth for handling of radioactive or highly toxic materials.
- Using chamber for abrasive blasting.
- Using enclosures for mixing tank, spray cleaning, material conveying or transferring.

Isolation / Segregation

Hazardous or potentially hazardous processes or operations should as far as possible be isolated or segregated to minimise the number of exposed persons. Such processes should be operated using remote control devices. Some typical examples are the operation of manufacturing processes by a control system in petroleum refining, lead smelting, polymerisation and distillation.

Local Exhaust Ventilation

Toxic dust, fumes, gases and vapours from a process or operation can be effectively controlled by means of local exhaust ventilation applied at the source of generation. An exhaust system consists of exhaust hood(s) connected by ducting to an air cleaner and an exhaust fan.

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Proper design, installation and maintenance are essential for effective operation of the system. Local exhaust ventilation systems are commonly applied in processes or operations such as dipping of parts in degreasing tanks, paint spraying, welding and grinding operations.

Please refer to "Guidelines on Solvent Degreasing" published by the Ministry of Manpower for more details on ventilation for degreasing tank.

Dilution Ventilation

Dilution ventilation involves the use of exhaust fans and blowers to ensure that contaminants would not accumulate to an unhealthy level. As this method does not remove the contaminants at the source, it can only be used to dilute relatively less toxic gases or vapours. Very often, dilution ventilation is used together with other complementary measures.

Wetting / Suppression

The wetting of dusty processes or work using water or other agents is one of the oldest methods of control and can be very effective if properly applied. This method may be used to reduce dust emission when wetted materials are handled and water does not interfere with the process. Some typical examples are as follows.

- Wetting of asbestos before removal.
- Water spraying during granite or stone crushing
- Wet mixing of cement.

Housekeeping

Good housekeeping plays an important role in contaminant control. Toxic dust or other contaminants that fall and settle onto the floor or work surfaces may become airborne again by drafts or air currents and normal plant activity. Constant good housekeeping by vacuum cleaning or wet washing or other means is necessary to remove these contaminants.

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Personal Protection Equipment

Personal protective equipment (PPE) eg. respirators, gloves, etc, should be worn by personnel who could possibly be in direct contact with chemicals such as during maintenance or repair of machinery. Selection of PPE should be based on the type of chemicals used and the MSDS could provide information on the types of PPE required. Furthermore, users could seek advice on PPE suppliers of their proper selection, usage and maintenance. PPE should never be considered as a first priority in minimising chemical exposure; it is only an interim measure to protect the users.

Administrative Measures

Some of the administrative measures that can be developed to ensure safe work are as follows.

- Posting of signs at prominent places to warn workers of areas where hazards are present and to indicate that personal protective equipment (PPE) are required.

- Banning of smoking in all production areas and restricting smoking to designated areas, away from flammable or combustible materials.

- Prohibition of any taking of food and drinks in production area where toxic chemicals are used or handled.

- Conducting frequent checks and inspections to ensure that workers, including contractors observe all safety and health rules and regulations.

- Implementing a permit to work system for all hazardous works.

- Isolating susceptible (eg. pregnant women) or allergic personnel from exposure to certain chemicals.

- Shortening the duration of exposure to chemicals by rotation of workers.

- Restricting entry to high risk areas (e.g. places where radioactive materials are used, to a small number of trained personnel).

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Education & Training

Workers handling or exposed to hazardous chemicals should be continually advised and educated on the hazards through meetings, training sessions and courses. They should also be advised on good personal hygiene like washing their hands before meals. Workers must be taught to use and maintain their personal protective equipment. Workers should also be trained and drilled in emergency response and spillage control.

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STORAGE OF CHEMICALS

All chemicals should be properly stored within the factory premises. Chemical storage requirements depend on the types or properties of the chemicals, quantity of storage, operational and environmental conditions.

The following general precautions should be observed when storing chemicals.

- Chemicals should be stored in appropriate containers.
- All storage containers should be labelled to indicate the identity of the chemicals, the hazards involved and the precautions to be taken.

- The storage area for chemicals should be provided with adequate lighting and ventilation.
- Different classes of hazardous chemicals should be separated.
- Incompatible chemicals should not be stored together.
- Volatile liquids should be stored in a cool place, away from sunlight or heat sources. These containers should not be completely filled.
- Licensed chemicals must be stored in a locked cupboard with proper inventory records.
- All storage containers should be properly arranged.
- All supplies should be correctly recorded in stock books and inspected regularly.

The following outlines the general requirements for the storage of chemicals that are corrosive, flammable, reactive or toxic in nature respectively.

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STORAGE OF CORROSIVE CHEMICALS

- Acids or alkalis should be stored in plastic or other suitable containers
- Strong acids and bases should be kept in separate cabinets, preferably with catch trays.
- The main stock of concentrated acids and bases should be stored as near to the floor level as possible.
- The inventory of corrosive chemicals should be kept to a minimum.
- Protective gloves, safety glasses, face shields and aprons should be worn where appropriate.
- Provisions for safety showers and eyewash fountain must be available.
- Acids should be diluted with care - always add acid to water, never add water to acid.
- If a small amount of a strong corrosive chemical is spilled, use a neutralizing agent to neutralize it and flush with water; or use an absorbent to absorb it and dispose off in plastic bags.

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STORAGE OF FLAMMABLE CHEMICALS

- Flammable solvents should be stored in safety containers.
- Flammable liquids should be kept in steel cabinets away from any heat source.
- Flammable liquids should not be kept on open shelves.
- Flammable liquids should not be stored in refrigerators.
- No smoking at or near the storage area.
- Fire-fighting equipment should be available at the storage area.
- Amount of flammable liquids in working areas should be kept to a minimum.
- Flammable chemicals should only be handled in areas free of ignition sources.
- If there is a spillage of flammable liquids, turn off ignition and heat sources, and turn on the exhaust ventilation system if it is safe to do so. If necessary, evacuate all personnel from the spillage area.
- If the spilled liquid is volatile, let it evaporate and be exhausted by the ventilation system. (If it is safer to remove the spilled volatile solvent, proper procedures must be followed including the use of proper personal protective equipment, especially suitable respirators.)
- If the spilled liquid is not volatile, use sand to absorb the spillage or apply detergent to make an emulsion which can be mopped up.

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STORAGE OF REACTIVE CHEMICALS

- Reactive chemicals should be stored at isolated, cool, dry areas and away from direct sunlight.
- Open flames and other sources of heat must be kept away from reactive chemicals.
- Shock, friction and all forms of impact must be avoided.
- Incompatible materials should not be stored near each other to prevent any accidental contact.
- Chemicals which readily absorb moisture or reacts violently with air must be kept in tightly sealed containers or desiccators.
- Quantity of reactive chemicals stored or used should be kept to a minimum.
- Safety glasses or goggles and gloves must be worn during handling.
- All spillage must be cleaned up immediately.

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STORAGE OF TOXIC CHEMICALS

- Toxic chemicals should be stored in proper containers.
- Highly toxic chemicals should preferably be stored in double containment and kept in a locked cupboard.
- Minimum amount of toxic chemicals should be kept for current use.
- Toxic chemicals should not be stored on high shelves where there is a risk of dropping when taking down for use.
- Suitable types of personal protective appliances / equipment should be used when handling toxic chemicals.
- Appropriate decontamination procedures should be followed when handling spillages.

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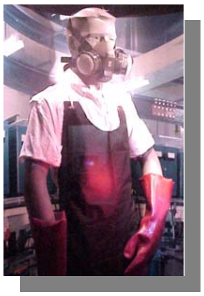
PERSONAL PROTECTION

The use of personal protective equipment (PPE) is appropriate in circumstances where:



- it is not feasible to control the hazard by more suitable means such as engineering control or administrative measures, eg. during maintenance or repair work;
- emergency situations require personnel to come into direct contact with high concentrations of chemicals; or
- it is employed as an interim measure while more effective solutions are being devised or in the process of implementation.

The use of PPE does not eliminate or reduce the hazard. Hence, should for some reasons the appliance fails, the wearer may be exposed to a hazardous situation. In some cases, PPE may be cumbersome and interfere with safe and effective performance of the task. Given the shortcomings, PPE should always be regarded as the last line of defence.

PPE include items of clothing, such as overalls, gloves, boots and aprons, and items of equipment such as respirators, safety glasses and face shields.

This section gives some details on skin and respiratory protection.

SKIN PROTECTION

Skin protection is required when handling corrosive chemicals, allergenic chemicals, and systemic toxic substances capable of penetrating the skin.

When selecting chemical protective clothing, the following points should be noted.

- Permeation of chemicals through protective barriers occurs sooner or later without indicating any visible sign on the protective clothing.

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- A protective material may protect against one chemical very well but perform poorly against another. No single protective material is an absolute barrier against all chemicals.

- Higher temperatures may decrease the breakthrough time of the chemicals. Some materials are also more sensitive to temperature changes than others.

- Generally, the thicker the protective clothing, the better it can protect against chemical penetration.

Barrier Creams

- Barrier creams should only be used to protect against relatively inert or less toxic chemicals where protective clothing may not be suitable or comfortable, e.g. near revolving machinery. These creams should be applied regularly throughout the workday on clean dry hands.

- Effectiveness of barrier creams should be evaluated before implementation. It should also be regularly assessed after implementation.

- Barrier creams should not be considered a substitute for gloves when working with toxic or hazardous substances.

Moisturising Creams

- Moisturising creams should be provided to workers handling chemicals which can cause mild irritation to the skin. These creams should be applied at the beginning and end of each workday.

- Moisturising creams should not be considered as a substitute for gloves when working with toxic or hazardous substances.

Gloves

Gloves should be used where hazardous chemicals such as acids, alkalis and systemic poisons may affect the skin adversely. Suitable gloves should be selected and tested with the particular chemicals involved, both for impermeability and for the ability of the gloves to maintain its strength after prolonged contact with the chemicals.

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- Gloves made of rubber or PVC are good for handling corrosive chemicals, allergens and systemic poisons.

- Gloves made of nitrile are good for handling hydrocarbons. They are also resistant to acids, cuts and abrasions.

- Gloves made of neoprene are good for handling oils.

The following is a list of different types of gloves materials with their advantages and disadvantages.

Glove Chart

Type	Advantages	Disadvantages	Use Against
Natural rubber	Low cost, good physical properties, dexterity	Poor vs. oils, greases, organics. May be of poor quality	Bases, alcohols, dilute water solutions; fair vs. aldehydes, ketones.
Natural rubber blends	Low cost, dexterity, better chemical resistance than natural rubber vs. some chemicals	Physical properties frequently inferior to natural rubber	Same as natural rubber
Polyvinyl chloride (PVC)	Low cost, very good physical properties, medium cost, medium chemical resistance	Plasticizers can be stripped; May be of poor quality	Strong acids and bases, salts, other water solutions, alcohols
Neoprene	Medium cost, medium chemical resistance, medium physical properties	NA	Oxidizing acids, anilines, phenol, glycol ethers
Nitrile	Low cost, excellent physical properties, dexterity	Poor vs. benzene, methylene chloride, trichloroethylene, many ketones	Oils, greases, aliphatic chemicals, xylene, perchloroethylene, trichloroethane; fair vs. toluene
Butyl	Speciality glove, polar organics	Expensive, poor vs. hydrocarbons, chlorinated solvents	Glycol ethers, ketones, esters

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Polyvinyl alcohol (PVA)	Specialty glove, resists a very broad range of organics, good physical properties	Very expensive, water sensitive, poor vs. light alcohols	Aliphatics, aromatics, chlorinated solvents, ketones (except acetone), esters, ethers
Fluoro-elastomer	Specialty glove, organic solvents	Extremely expensive, poor physical properties, poor vs. some ketones, esters, amines	Aromatics, chlorinated solvents, also aliphatics and alcohols
Norfoil (Silver Shield)	Excellent chemical resistance	Poor fit, easily punctures, poor grip, stiff	Use for Hazmat work

Glove Type and Chemical Use

Chemical	Neoprene	Natural Latex or Rubber	Butyl	Nitrile Latex
*Acetaldehyde	VG	G	VG	G
Acetic acid	VG	VG	VG	VG
*Acetone	G	VG	VG	P
Ammonium hydroxide	VG	VG	VG	VG
*Amyl acetate	F	P	F	P
Aniline	G	F	F	P
*Benzaldehyde	F	F	G	G
*Benzene	F	F	F	P
Butyl acetate	G	F	F	P
Butyl alcohol	VG	VG	VG	VG
Carbon disulfide	F	F	F	F
*Carbon tetrachloride	F	P	P	G
Castor oil	F	P	F	VG
*Chlorobenzene	F	P	F	P
*Chloroform	G	P	P	P
Chloronaphthalene	F	P	F	F
Chromic Acid (50%)	F	P	F	F

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Citric acid (10%)	VG	VG	VG	VG
Cyclohexanol	G	F	G	VG
*Dibutyl phthalate	G	P	G	G
Diesel fuel	G	P	P	VG
Diisobutyl ketone	P	F	G	P
Dimethylformamide	F	F	G	G
Dioctyl phthalate	G	P	F	VG
Dioxane	VG	G	G	G
Epoxy resins, dry	VG	VG	VG	VG
*Ethyl acetate	G	F	G	F
Ethyl alcohol	VG	VG	VG	VG
Ethyl ether	VG	G	VG	G
*Ethylene dichloride	F	P	F	P
Ethylene glycol	VG	VG	VG	VG
Formaldehyde	VG	VG	VG	VG
Formic acid	VG	VG	VG	VG
Freon 11	G	P	F	G
Freon 12	G	P	F	G
Freon 21	G	P	F	G
Freon 22	G	P	F	G
*Furfural	G	G	G	G
Gasoline, leaded	G	P	F	VG
Gasoline, unleaded	G	P	F	VG
Glycerine	VG	VG	VG	VG
Hexane	F	P	P	G
Hydrochloric acid	VG	G	G	G
Hydrofluoric acid (48%)	VG	G	G	G
Hydrogen peroxide (30%)	G	G	G	G
Hydroquinone	G	G	G	F
Isooctane	F	P	P	VG
Isopropyl alcohol	VG	VG	VG	VG
Kerosene	VG	F	F	VG
Ketones	G	VG	VG	P
Lacquer thinners	G	F	F	P
Lactic acid (85%)	VG	VG	VG	VG
Lauric acid (36%)	VG	F	VG	VG
Lineoleic acid	VG	P	F	G
Linseed oil	VG	P	F	VG
Maleic acid	VG	VG	VG	VG
Methyl alcohol	VG	VG	VG	VG

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Methylamine	F	F	G	G
Methyl bromide	G	F	G	F
*Methyl chloride	P	P	P	P
*Methyl ethyl ketone	G	G	VG	P
*Methyl isobutyl ketone	F	F	VG	P
Methyl methacrylate	G	G	VG	F
Monoethanolamine	VG	G	VG	VG
Morpholine	VG	VG	VG	G
Naphthalene	G	F	F	G
Naphthas, aliphatic	VG	F	F	VG
Naphthas, aromatic	G	P	P	G
*Nitric acid	G	F	F	F
Nitromethane (95.5%)	F	P	F	F
Nitropropane (95.5%)	F	P	F	F
Octyl alcohol	VG	VG	VG	VG
Oleic acid	VG	F	G	VG
Oxalic acid	VG	VG	VG	VG
Palmitic acid	VG	VG	VG	VG
Perchloric acid (60%)	VG	F	G	G
Perchloroethylene	F	P	P	G
Petroleum distillates (naphtha)	G	P	P	VG
Phenol	VG	F	G	F
Phosphoric acid	VG	G	VG	VG
Potassium hydroxide	VG	VG	VG	VG
Propyl acetate	G	F	G	F
Propyl alcohol	VG	VG	VG	VG
Propyl alcohol (iso)	VG	VG	VG	VG
Sodium hydroxide	VG	VG	VG	VG
Styrene	P	P	P	F
Stryene (100%)	P	P	P	F
Sulfuric acid	G	G	G	G
Tannic acid (65%)	VG	VG	VG	VG
Tetrahydrofuran	P	F	F	F
*Toluene	F	P	P	F
Toluene diisocyanate	F	G	G	F
*Trichloroethylene	F	F	P	G
Triethanolamine	VG	G	G	VG
Tung oil	VG	P	F	VG
Turpentine	G	F	F	VG

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*Xylene	P	P	P	F

*denotes limited service

VG	very good
G	good
F	fair
P	Poor (not recommended)

The above are obtained from CDC webpage (http://www.cdc.gov/od/ohs/manual/pprotect.htm)

Protective Boots

- Specialised footwear should be provided for protection against acids, alkalis, hot or molten metals.

Protective Clothing

- Coats, overalls and aprons made of neoprene or polyurethane coated with nylon or terylene are good for protection against solvents, oils and greases.

- Jackets, trousers and aprons made of PVC coated nylon or terylene are good for protection against most oils and acids. They are also resistant to abrasion and tearing.

RESPIRATORY PROTECTION

Respiratory protection is most important for dealing with harmful airborne contaminants. A hazardous or harmful atmosphere is one that is oxygen-deficient or contains toxic particulates, vapour or gas in a concentration that is immediately or ultimately dangerous to life or health.

Personal respiratory protection can be broadly classified into air-purifying respirators or air-supplied respirators. The former should not be used in an oxygen-deficient atmosphere.

Selection of an appropriate respirator will depend on several important factors as follows:

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- adequacy of the warning (usually by odour or visibility) given by the contaminant
- nature of the hazard, i.e. whether a particulates, gas or vapour, deficiency of oxygen, or a combination of these
- concentration of the contaminant
- acuteness of the hazard, i.e. whether failure of respirator will result in serious harm
- probable duration of stay by the wearer in the hazardous atmosphere
- location of the contaminated atmosphere with respect to source of air suitable for breathing
- access to and the nature of the working environment
- expected activity and mobility of the wearer
- whether the respirator is for regular use or for emergency or rescue purposes

PERSONAL PROTECTIVE EQUIPMENT (PPE) PROGRAMME

Given that PPE is the last line of defence, a comprehensive PPE programme is required to ensure that workers are protected when PPE is used. There are four key elements in a suitable PPE programme:

1. Selection

The equipment must meet the basic criterion of providing adequate protection to cope with the particular workplace hazard against which it is being applied. It is important to take into account factors such as the nature of the hazard, the circumstances of the task to be performed, the acceptable level of exposure and the performance requirement of the device.

2. Fitting

Correct fit and comfort are essential if the expected degree of protection is to be achieved.

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For most items of PPE, a range of sizes is needed to accommodate the full range of shapes and dimensions of users. This is often the only method to ensure that each user is supplied with equipment that correctly fits him or her.

If the wearer found the PPE uncomfortable, it is likely to be removed during at least part of the time when a hazard exists.

3. Maintenance & Storage

Poorly maintained equipment may result in serious health consequences. Some large organisations use specialised contract or in-house services to collect, clean, repair and re-issue items of PPE.

4. Education & Training

It is important that PPE users be trained in the correct manner to use their equipment. Instructions should cover topics such as the need for the device, its design features, its applications and limitations.

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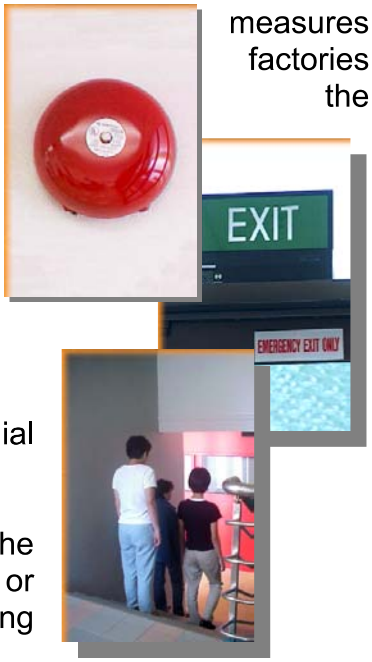
EMERGENCY PLANNING & FIRST AID PROCEDURES

EMERGENCY PLANNING



Emergency planning is a backup to the preventive measures for the control of chemical hazards. Occupiers of factories where hazardous chemicals are used should assess the following:

- what could happen to cause an emergency situation (CAUSE);
- what dangers could arise to people as a result of these emergencies (CONSEQUENCE); and
- how these could be mitigated by planned remedial and rescue measures (CONTROL).

An emergency plan should be formulated based on the particular hazards associated with the chemicals used or processes involved. The plan should contain the following elements:

- an assessment of the nature and size of the events;
- the actions to be taken on-site including where appropriate
  - first-aid arrangements,
  - fire-fighting procedures,
  - rescue and evacuation arrangements, and
  - decontamination procedures;
- setting up and operating an emergency control centre to co-ordinate rescue and mitigation activities; and
- liaison with the relevant authorities including emergency services.

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FIRST-AID PROCEDURES

The standard emergency treatments of victims involved in chemical accidents are as follows:

- Splashes on the skin

✓ remove contaminated clothing and flush with water for at least 10 minutes

  ✓ get medical help

- Splashes in the eye
  - ✓ flush the eyes with water for several minutes
  - ✓ seek medical treatment

- Inhalation of gases or vapours
  - ✓ remove casualty to a safe area
  - ✓ apply cardiac pulmonary resuscitation (CPR) if breathing has stopped
  - ✓ send for medical aid immediately

- Ingestion of poisonous chemicals
  - ✓ wash the mouth with water
  - ✓ do not induce vomiting
  - ✓ remove victim to hospital

In all cases of splashes, inhalation and ingestion of toxic or corrosive chemicals, information on the chemicals, obtain MSDS for the first aiders and medical personnel to apply proper treatment. This information is typically found in the MSDS of the chemicals.

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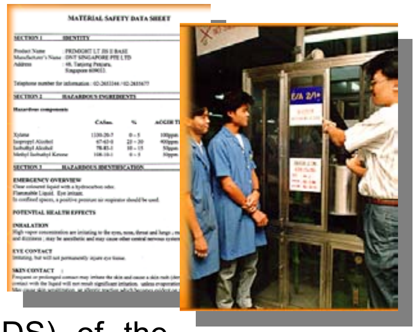
EDUCATION & TRAINING

All persons who work with chemicals should receive information and training on:



- legal requirements on the control of chemicals
- company policy on chemical hazard control
- the hazards involved and precautions to be taken – the information can be derived from the material safety data sheet (MSDS) of the respective chemicals that workers handled
- standard operating or handling procedures
- personal protective equipment, including topics on selection, fitting, use and maintenance
- procedures for emergency response

Training should be conducted at least once a year and :

- for each new employee before starting a job;
- for each new chemical introduced; and
- when new information about any chemical used becomes available.

All induction and training should be properly recorded and documented.

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HAZARDOUS MATERIAL MANAGEMENT PROGRAMME

Introduction

Chemical hazards are hazards arising from the use of toxic, harmful, corrosive, explosive, flammable, combustible, reactive (oxidising), cryogenic, or radioactive chemicals. Where these hazardous chemicals are used, handled or produced, a management programme should be established and implemented to safeguard the health and safety of persons who are liable to be exposed to these chemicals.

The hazardous material management programme should form part of the safety and health management system. It should cover all stages in the life cycle of the chemicals i.e. during manufacture, transport, storage, use, handling and disposal. The programme should be under the charge of a senior management staff. Written safe work procedures should be drawn up for implementation, objectives should be defined, target should be set and relevant records kept.

The programme shall include but shall not be limited to the following components. Individual components could be delegated to responsible persons.

Policy and strategy

The management should issue a written statement on hazardous material management policy. The policy statement should state explicitly the responsibility and commitment of management to ensure the safe use of chemicals and the protection of employees against chemical hazards. To give effect to the policy, the management should also outline a broad strategy on managing hazardous materials.

Register of Chemicals

A register of all hazardous chemicals, which are produced, stored, used or handled, should be kept. The register should contain information on the inventory and location of such chemicals. It should also indicate the number of persons who are at risk or liable to be exposed to the chemicals. The register must be updated whenever new materials are used or are no longer used.

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Provision and application of Material Safety Data Sheet (MSDS)

MSDS is the main hazard communication tool between the chemical suppliers and the end users. A copy of the MSDS of all hazardous chemicals listed in the register should be obtained and compiled. The MSDS should have the key information such as identity and properties of the chemicals, composition or ingredients, safety and health hazards, handling and storage, exposure control and personal protection.

Management should study the information provided in the MSDS and take the necessary measures to ensure the safe use of the hazardous chemicals. MSDS shall also be made available to persons who are exposed or liable to be exposed to the hazardous chemicals.

Selection and procurement procedures

A proper chemical selection and procurement approval procedure should be established. All new processes and chemical products should be investigated for known and potential hazards prior to acquisition or purchase.

Information on the protection against health and safety hazards should be obtained from suppliers and other sources, as necessary. Safer chemicals and processes should be considered more favorably.

Factors or information to be considered when selecting a safer chemical include the flammability (flash point), fire or explosion hazards, toxicity (lethal dose or concentration), health effects, routes of exposure, vapour pressure, and permissible exposure level of the chemical. Much of the information can be found in the MSDS of the chemical.

Risk assessment and control

Management shall ensure that a suitable and sufficient assessment is made of the risks arising from the use of any hazardous chemicals. The risk assessment should also be carried out for work on any process, plant, vessel or machinery that is liable to produce or give off to any hazardous substance. The risk assessment shall include:

- identification of the safety and health hazard events;
- determination of the degree of exposure to the hazardous chemicals or the frequency or likelihood of occurrence of the events; and
- analysis of the possible effects of exposure to the hazardous chemicals or the consequences of the events.

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A written description of the risk assessment shall be kept and reviewed regularly and immediately if there has been a significant change in the work to which the assessment relates, or there is reason to suspect that the assessment is no longer valid.

If the assessment reveals that the risk of exposure is not acceptable, control or preventive measures should be implemented to reduce the risk. The hierarchy of control is as follows: hazard elimination, process or chemical substitution, engineering control (e.g. process modification, containment, automation, local exhaust ventilation), administrative measures (e.g. safe work practices, reduction of exposure duration) and personal protection.

Safe work procedures

Written procedures on any work involving hazardous chemicals should be established and documented. The procedures should cover dispensing, transferring, use and disposal of any hazardous chemicals.

Where chemicals are used or manufactured in a process, written procedures should be established for the start up, routine operation, shut down and maintenance work

The safe work procedures should include the use of personal protective equipment and the safety and health precautions to be taken in the course of work.

Storage of chemicals

The potential hazards in chemical storage include catastrophic failure of a tank, leak or fugitive emission from storage containers. A proper system of storage of hazardous chemicals should be established taking into consideration the properties of the chemicals, incompatibility, quantity of storage, operational and environmental conditions.

Different chemicals may require different storage containers. Bulk storage of hazardous chemicals often requires adequate tank separation, and diking or curbing to contain spill.

Design of storage facilities should be based on statutory requirements, material safety data or other technical information. International or national standards should be followed, where applicable.

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Transportation of chemicals

An accident occurring during the transport of hazardous chemicals can have catastrophic consequences e.g. fire, explosion and toxic release. Whenever hazardous chemicals are transported, whether within or outside a company, certain measures should be taken to ensure that the potential risks are adequately communicated to all who may come into contact with the chemicals in the course of the transport.

This can be accomplished through labelling or marking of packages or containers to indicate the hazards of the consignment, by including relevant information in the transport documents, and by placing or sticking placards on the transport units i.e. vehicles and containers.

In addition, the vehicles should be equipped with appropriate fire fighting appliances and the drivers should be trained in the safe transport of dangerous goods as well as in dealing with emergency situations. The detailed technical requirements for different transport methods are usually given in national regulations.

Loading, unloading and transfer operations are especially accident prone, and so should be properly managed. Safe work procedures should be established and followed in order to avoid unnecessary risks.

Labelling and warning signs

All chemical containers should be labelled. A proper system of labelling should be followed. The label should indicate the identity of the chemical, the hazards involved and the precautions to take. Persons who are required to handle the chemical must be told of the potential hazards and the precautionary measures. Warning signs or notices specifying the nature of the danger of the hazardous substances should be posted at areas where such substances are used or handled.

Waste disposal

Chemical wastes may be classified as liquids, sludge, solids or mixed waste. Waste chemicals are either recycled, incinerated, buried or made to undergo a physical and chemical transformation (e.g. neutralisation and separation), or biological treatment. Improper handling of wastes may cause pollution and endanger the health and safety of the workers.

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Operations that generate hazardous wastes should therefore be governed by a hazardous waste management system. This should include proper labelling of waste by national or international codes, proper waste storage and treatment facilities, proper waste transport and disposal facilities e.g. by licensed or approved waste collectors, and proper emergency action plan to deal with any accidental release of hazardous wastes

Personal protection equipment

Personal protective equipment (PPE) or appliances include respirators, safety glasses, face shields overalls, aprons, gloves and boots. To ensure that employees are effectively protected, personal protective equipment should be properly selected, correctly used or comfortably fitted and regularly maintained. A suitable personal protective equipment programme should be implemented taking the above elements into consideration.

Workplace monitoring

Monitoring of the work environment provides basic information on the extent and magnitude of the hazard potential and the exposure of the workforce. It will also reveal which workers are most at risk or which areas of the workplace contain high levels of airborne contaminants.

Regular workplace monitoring by a competent person should be carried out in areas where hazardous chemicals are used or given off. Appropriate monitoring strategy should be established and followed. The results of monitoring should be correctly interpreted and records properly kept.

Medical Surveillance

Regular medical surveillance helps to detect early signs of overexposure to certain toxic chemicals which have suitable bio-indicators for exposure assessment. A medical surveillance programme should be established, where appropriate. Employees exposed to such chemicals should be identified for regular medical examinations. The results of examinations should be evaluated and medical records properly kept. Competent advice should be sought if necessary.

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Emergency planning, response and first-aid procedures

Emergency planning is needed to cope with chemical accidents such as fires, explosions, spills, leaks or release of hazardous chemicals. Emergency procedures should be established so that the source of release could be promptly rectified, the area of contamination could be contained and properly decontaminated. The procedures should also describe how the contaminated materials could be safely disposed.

A first-aid programme will ensure that provisions for emergency treatment of victims of chemical poisoning or excessive exposure to toxic chemicals are met. This should cover first-aid facilities, first-aid personnel, and types of first-aid treatment.

Information and training

Employees who handle chemicals or may be affected by them should be informed of the hazard potential of these chemicals and the procedures for safe handling, minimization of exposure and first aid. A training programme should be instituted to ensure that the safe handling procedures are both known and understood by all concerned. Information on hazardous chemicals and safe handling procedures should be disseminated regularly to employees involved via group and individual training, data sheets and other aids.

Contract work

Where contract work involving hazardous chemicals is carried out, the management should set up a system to ensure that such work is carried out safely within the plant.

Criteria should be established for the selection of contractors based on their safety and health awareness, management and performance. Clear communication link should be established between the management and contractors. Duties, responsibilities, authority and reporting relationships should be defined.

The management and the contractor should establish a safe work procedure to ensure that the safety and health of both employees and contract workers are protected. Training and health educational programmes should be developed for contract workers and supervisors who should be informed of potential health hazards of the work and their prevention, before they start work.

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Rules could be established to penalise the errant and recalcitrant contractors and contract workers. Incentive or award could be given to those who excel in safety and health performance.

Programme review and audit

The management should conduct an annual review of its hazardous material management programme to ensure that it is relevant and up to date.

The programme should be subjected to regular audits to ensure that it has been implemented effectively.

The management should implement the recommendations of the review and the audit to improve and enhance the programme.

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Acknowledgement

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