Organic Solvents

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INTRODUCTION

A solvent can be defined as a substance that dissolves another substance to form a liquid. Solvents can be broadly classified as either aqueous (water-based) or organic (hydrocarbon-based) and within each classification, further classifications are necessary to account for differences in structure and physical properties. Given the widespread industrial and domestic use of organic solvents this document will be limited to organic solvents.

USES

Organic solvents are widely used to dissolve and disperse fats, oils, waxes, pigments, varnishes, rubber and many other substances. They are frequently used in paints, varnishes, lacquers, thinners, waxes, floor and shoe polishes, glues, fuels, antifreeze, degreasing, cleaning and dry cleaning agents, inks, pharmaceutical and pesticide products, preservatives, and laboratory processes.

SOLVENT CLASSIFICATION

Most organic solvents can be classified into chemical groups based on the configuration of the hydrogen and carbon atoms and the presence of different functional groups[1]. Chemical groups that are commonly used are straight or branched chains of carbon and hydrogen (eg. hexane, heptane), cyclic hydrocarbons (eg. cyclohexane, turpentine), esters (ethyl acetate, isopropyl acetate), aromatic hydrocarbons (eg. benzene, toluene, xylene), alcohols (eg. ethanol, isopropanol), ketones (eg. acetone, methyl ethyl ketone), halogenated hydrocarbons (eg. carbon tetrachloride, chloroform), aldehydes (eg. acetaldehyde, formaldehyde), ethers (eg. diethyl ether, isopropyl ether), glycols (eg. ethylene glycol, hexylene glycol) and nitro-hydrocarbons (eg. nitroethane, nitromethane).

SOLVENT PROPERTIES

Solvents from different chemical groups can differ markedly in their characteristics; however, within each group, chemical and solvent properties change only slightly as the molecular weight of the solvent increases.

The main factors which influence the properties of organic solvents are:

- The number of carbon atoms present;
- The presence of only single bonds (saturated molecules) or double or triple bonds (unsaturated molecules) between adjacent carbon atoms,
- The configuration of the solvent molecule ie. straight chain (aliphatic), branched chain or ring (ie. cyclic and aromatic);
- The presence of functional groups, eg. Nh_2.

The solvent properties of organic solvents tend to increase with fewer numbers of carbon atoms in the molecule. Unsaturated molecules tend to be more reactive than their saturated counterparts.

SOLVENT CHARACTERISTICS

The following characteristics of organic solvents determine the type of hazards they present:

Volatility

As organic solvents are volatile (ie. tend to evaporate), inhalational exposure is an important exposure pathway to be considered when assessing the health hazards that solvents may present. The greater the volatility of a solvent the greater the vapour concentration in the air. Two measures of volatility are the vapour pressure and evaporation rate. Both measures are temperature dependent and increase as the temperature increases.

1 Functional group: The group of atoms responsible for the characteristic reaction of a compound. For example the functional group is -OH for alcohols and -CHO for aldehydes.

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The density of the solvent vapour may also need to be considered in emergency situations. As the density increases the rate at which the solvent dissipates will decrease. As a general rule, a vapour that is heavier than air (vapour density >1) will tend to pool and spread near ground level in confined spaces, whereas a vapour which is lighter than air (vapour density <1) will tend to rise and dissipate.

Water and lipid solubility

The water and lipid solubility of a solvent will determine how readily it will be absorbed through the skin. Given that the skin can be described as a lipid-water bilayer, solvents such as dimethylsulfoxide and glycol ethers which are readily dissolved in both are well absorbed through the skin.

Chemical structure

The chemical structure of a solvent including any attached functional groups will determine its toxicological properties. Toxicological properties tend to be similar within chemical groupings.

Flammability and explosiveness

The flammability and explosiveness of a solvent are clearly important determinants of hazard. Measures frequently used to give an indication of the flammability and explosiveness of solvents include the flash and fire points, and the autoignition temperature. Explosive ranges or flammability limits have been determined for different solvents and refer to the concentrations over or above which a particular vapour will burn when ignited. Many organic solvents have low flash points and will burn if ignited. Chlorinated solvents have quite high flash points and are not usually flammable under conditions of normal use.

The following classification is used to qualify the flammability hazard associated with a solvent:

HIGHLY FLAMMABLE
flash point < 23°C
FLAMMABLE
flash point 23-61°C
COMBUSTIBLE
flash point 61-150°C

Some solvents may also be explosive, eg. nitrocellulose. There may also be a risk of exothermic reactions of some solvents with other materials, which may lead to fire or explosion.

OCCUPATIONAL EXPOSURE

Given the tendency for most organic solvents to evaporate at ambient temperatures and to be absorbed through the skin, the two most important exposure pathways for organic solvents in the workplace are through the lungs and skin.

The Worksafe Australia Standard - **Exposure Standards for Atmospheric Contaminants in the Occupational Environment** lists exposure standards (eg. TWA, STEL[2]) for solvents (among other chemicals) in workplace air. In some circumstances engineering controls and protective equipment/clothing may be required to ensure that worker safety is not compromised. Such requirements are generally detailed in the Material Safety Data Sheet (MSDS) for the solvent.

ENVIRONMENTAL EXPOSURE

Although widely used, environmental exposure levels to organic solvents are usually much lower and of a shorter duration than those encountered in the workplace. The use of solvents in household products and in arts, crafts, and hobbies has significantly increased the population that may be affected by repeated exposure. However, problems are usually only encountered when the products are used incorrectly or in situations where exposure levels may be higher than normally expected (eg. in confined spaces).

HEALTH EFFECTS

Nervous system

Most organic solvents adversely affect the function of the central nervous system (CNS). The severity and type of effect depend on the vapour concentration, duration of exposure, and toxicity of the solvent. The effect observed may also depend on whether exposure to other materials occurred and whether the individual is particularly sensitive to the solvent.

Signs and symptoms suggestive of CNS involvement range from headaches, tiredness, and dizziness to behavioural changes ("drunkenness"), unconsciousness, and death. Notwithstanding death, the CNS effects generally wear off on cessation of exposure. However, prolonged repeated exposure to some solvents may impair perceptions and cause behavioural changes as well as other changes, and in some cases normal function may not return. Psychological tests can be used to assess CNS function. Such tests may include evaluation of language comprehension, logical and spatial thinking, power of observation, coordination and memory tests.

Long term exposure to high levels of n-hexane and methyl n-butyl ketone is associated with degeneration of nerve cells in the peripheral nervous system. Restless legs, muscle cramps, pain, weakness and loss of sensation in limbs are suggestive of such degeneration.

2. STEL: A 15 minute TWA exposure which should not be exceeded at any time during a working day even if the eight-hour TWA average is within the TWA exposure standard.
TWA: The average airborne concentration of a particular substance when calculated over a normal eight-hour working day, for a five-day working week.

Skin

Although solvents belong to a diverse range of chemical groups, their effects on skin are generally similar. The skin contains quite high levels of fats and on contact with skin, solvents will remove the fat (defatting). This makes the skin dry, scaly and eventually cracked. Deteriorated skin also allows greater absorption of solvent through the skin following direct skin contact.

Solvents like toluene, xylene, butanol and styrene cause skin irritation and irritant dermatitis. Wood turpentine, water-based paint preservatives (eg. formaldehyde) and epoxy resins may cause allergic contact dermatitis.

Respiratory tract

All organic solvents irritate the respiratory tract to some degree. Such irritation typically involves the upper respiratory tract (eg. upper airways, nose, throat and trachea). Long-term exposure to the more potent irritants (eg. aldehydes) may lead to chronic or persisting cough and increased sputum production.

Other effects

Solvents may also affect other organs in the body. Chloroform and carbon tetrachloride are toxic to the liver. Glycol ethers and some chlorinated solvents may damage the kidneys.

Chlorinated organic solvents, such as methylene chloride and trichloroethane are noted for their harmful effects on the heart. Chronic exposure to carbon disulphide is considered a contributory factor in coronary heart disease. Cardiac sensitisation may occur following repeated exposure to some solvents. It is due to increased sensitivity of the muscle of the heart to the effects of epinephrine on the rhythm of the heart. It can produce life threatening irregularities in the rhythm of the heart and should be considered as a possible cause of sudden death in otherwise healthy individuals who have been exposed to high levels of organic solvents. It has been reported to cause death following solvent abuse (eg. glue sniffing).

Although organic solvents readily cross the placenta, most are not considered teratogenic. Notable exceptions are ethanol and some of the smaller chain glycol ethers.

Cancer

The International Agency for Research on Cancer has classified a number of solvents in regard to their carcinogenicity.

Benzene has been classified as a Group 1 (recognised human carcinogen) carcinogen as it has been associated unequivocally with certain forms of leukaemia in heavily exposed workers. However, it has not been associated with carcinogenic effects in any circumstances other than heavy occupational exposure.

Dichloromethane, ethyl acrylate, tetrachloroethylene and styrene are classified as Group 2B (possible human carcinogens).

Other solvents including methyl acrylate, methyl chloride, methylmethacrylate monomer, petroleum solvents, toluene, 1,1,1-trichloroethane, 1,1,2-trichloroethane and xylene are in Group 3 (not classifiable as to their carcinogenicity to humans).

MIXED SOLVENT EXPOSURE

Given that more than one organic solvent may be present in a product (eg. paint thinners may contain toluene, xylene, ethylbenzene, methylethylketone and acetone) it is important that not only are the effects of each solvent considered when determining the potential for the product to induce adverse effects, but the potential for additive or synergistic[3] effects are also considered.

BIOLOGICAL MONITORING

Occupational exposure to some organic solvents can be monitored by measuring the level of solvent or in some cases its metabolites in the urine. For all solvents, biological monitoring may also include estimations of the unchanged compound in exhaled air or in blood, though such testing is not readily available and has logistical difficulties.

Interpretation of the results of biological monitoring need to take into account the duration since exposure, the distribution of the solvent or its metabolites in the body, and the rate at which the solvent or its metabolites are eliminated from the body. Other factors may also need to be considered. For instance, alcohol intake several hours or just before inhalation exposure to an organic solvent may inhibit its metabolism, thereby reducing the rate at which its metabolites are excreted. However, chronic alcohol consumption induces microsomal enzyme activity and may increase the metabolism of a solvent.

The American Conference of Governmental Industrial Hygienists has recommended Biological Exposure Indices[4] for the following solvents: n-hexane, benzene, toluene, xylenes, ethyl benzene, styrene, phenol, methyl ethyl ketone, perchloroethylene, trichloroethane, trichloroethylene, dimethylformamide, and carbon disulfide. For many solvents, significant levels may be present only in exhaled air. For solvents with relatively slow excretion, such as perchloroethylene and trichloroethane, analysis of blood is a reasonable alternative to exhaled air.

3. Additive effect: Combined effect of two or more chemicals equal to the sum of their individual effects.
   Synergistic effect: Combined effect of two or more chemicals is greater than the sum of their individual effects.
4. Biological exposure index: The index provides a warning level of biological response to a substance or agent, or warning levels of the substance or agent or it metabolite(s) in the tissues, fluids or exhaled air of an exposed worker.

LEGISLATION

The Standard for the Uniform Scheduling of Drugs and Poisons has entries concerning certain common solvents likely to be found around the home. Solvents used only in industry are not covered in the Poisons Schedules.

In Schedule 5 is the entry:- **Hydrocarbons, liquid,** including kerosene, mineral turpentine, white petroleum spirit, toluene, xylene and light mineral and paraffin oils (but excluding their derivatives) distilling under 300°C, **except:**

(a) toluene and xylene when included in Schedule 6;
(b) benzene when included in Schedule 7;
(c) in solid or semisolid preparations;
(d) in preparations containing 25 per cent or less of designated solvents;
(e) in preparations packed in pressurised spray packs;
(f) in adhesives packed in containers each 50 grams or less of adhesive; or
(g) in writing correction fluids, packed in containers having a capacity of 20 ml or less.

Other solvents may also be listed in the Poisons Schedules but the entries are not reproduced here.

State legislation relevant to organic solvents is the Flammable and Combustible Liquid Regulations. The transport of organic solvents is covered by the Australian Code for the Transport of Dangerous Goods by Road and Rail.

Organic solvents should be stored separately from other classes of chemicals and should be labelled to show the contents, hazards and storage precautions.

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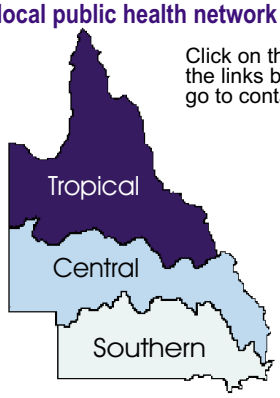
For more information, contact your local public health network



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Environmental Health Unit
10th floor, Queensland Health Building
147-163 Charlotte Street,
BRISBANE 4000
GPO Box 48 BRISBANE 4001
Ph: +61 7 3234 0938
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