

# HEALTH, SAFETY AND ENVIRONMENTAL ASPECTS OF ALTERNATIVE SOLVENTS TO CARBON TETRACHLORIDE



**Department of Environmental Health Engineering**

**Sri Ramachandra University**

Porur, Chennai, Tamil Nadu, India.

*and*

**Deutsche Gesellschaft Für Technische Zusammenarbeit (GTZ) GmbH**

(German Technical Cooperation), GTZ- Proklima

A-33 Gulmohar Park, New Delhi - 110 049, India.



On behalf of  
Federal Ministry  
for Economic Cooperation  
and Development



On behalf of  
Fonds Français pour  
l'Environnement Mondial

**November 2009**

## **HEALTH, SAFETY AND ENVIRONMENTAL ASPECTS OF ALTERNATIVE SOLVENTS TO CARBON TETRACHLORIDE**

### **Prepared by:**

#### **Department of Environmental Health Engineering (DEHE)**

Sri Ramachandra University (SRU)

Porur, Chennai - 600 116

India

and

#### **Deutsche Gesellschaft Für Technische Zusammenarbeit (GTZ) GmbH**

(German Technical Cooperation), GTZ- Proklima

A-33 Gulmohar Park, New Delhi – 110 049

India

**November 2009**

### **Authors:**

Sankar Sambandam, Krishnendu Mukhopadhyay, Ayyappan Ramalingam, Chittaruvikkal John Mathew,  
Sona Mahajan and Kalpana Balakrishnan.

## **DISCLAIMER**

Though all care has been taken while researching and compiling the contents provided in this manual, DEHE- Sri Ramachandra University and GTZ Proklima accept no liability to its contents.

The reader is advised to confirm the product specifications and related health/environmental hazards prior to purchase or use of any of the solvents profiled. No claim is made here for the absolute suitability of any solvent as a substitute for CTC in any application. Suitability of a product or method of cleaning for a particular application would need to be verified through trials prior to any larger-scale application with due consideration of health and safety aspects.

Information provided here does not constitute an endorsement or recommendation of any brand or product by DEHE- Sri Ramachandra University and GTZ Proklima.

## PREFACE

Carbon Tetrachloride (CTC) is widely used as a solvent in many industrial sectors in India. It is an ozone depleting substance like chlorofluorocarbons (CFCs). It is also hazardous to health through the exposure route of inhalation, ingestion and skin absorption. It is reasonably anticipated to be a human carcinogen based on sufficient evidence of carcinogenicity in experimental animals.

To protect the ozone layer, India is one of the 196 signatories to the Montreal Protocol for phasing out the production and consumption of ozone depleting substances. Under this agreement India has committed to phase-out the use of CTC solvent completely by 31<sup>st</sup> December 2009.

As the phase-out is progressing, CTC supplies in the market are dwindling rapidly. Beyond 31<sup>st</sup> December 2009 CTC will not be available for use as a solvent. Given the reduction of supply, the price of CTC has risen substantially making it costlier today than most of its alternatives.

When heated to decomposition, it emits highly toxic fumes of phosgene. When CTC molecules drift into the stratosphere, the UV-B and UV-C radiation from the sun releases their chlorine atoms. Complex chemical reactions in the atmosphere result in the formation of chlorine monoxide, which reacts with the ozone molecule to form oxygen and regenerates more chlorine atoms that carry on converting the ozone molecules. Each chlorine atom can destroy as many as 100,000 ozone molecules over a period of nearly 100 years. Thus, even a small amount of CTC can cause tremendous damage to the ozone layer. CTC also harms the climate and its global warming potential is about 1,400 times higher than that of carbon dioxide (CO<sub>2</sub>).

Within the framework of the Multilateral Fund of the Montreal Protocol, the Governments of Germany and France have mandated GTZ-Proklima to provide technical assistance to CTC consuming industries in India. In addition, World Bank, UNIDO and UNDP (on behalf of the Government of Japan) are assisting India, to address this issue specifically in industry sectors with large volume of CTC use. These activities are coordinated under the National CTC Phase-out Plan by the World Bank as the leading implementing agency and the Ozone Cell of the Ministry of Environment and Forests, Government of India.

GTZ-Proklima offers technical assistance to industries using up to 10 metric tons of CTC per year. In close interaction with these industries, GTZ-Proklima aims to provide guidance in identifying CTC substitutes by addressing environmental, health and safety concerns without compromising on quality and cost effectiveness.

The Department of Environmental Health Engineering (DEHE), Sri Ramachandra University (SRU), Chennai (India) prepared a list of nearly 500 potentially hazardous substances that could be present in proprietary or non proprietary cleaning agents and provided the same to GTZ to enable comparisons across potential CTC substitutes. Moreover, initial assessments at different workplaces indicated the potential exposures of solvent vapours (from products currently being used as CTC substitutes). Building on these earlier efforts, the present exercise was aimed at conducting a systematic evaluation of exposures and identification of risks associated with selected CTC substitutes across a spectrum of few

industries in order to provide specific recommendations for control against workplace exposures to the solvents used.

The approaches adopted for risk management in the project have a dual focus on “risk prevention” through substitution and “risk mitigation” through installation of workplace engineering controls and improving general work practices.

Recommendations presented in this manual have been largely based on walkthrough visits and analytical results of workplace exposure measurements. Participatory discussions involving employers and professional organizations were used to generate feasible toolkits that can be readily implemented, accompanied by awareness raising efforts to change risk perceptions. Since improved handling also minimizes emissions and exposures, this manual is expected to contribute not only in improving occupational health and safety at work, but also facilitate the implementation of the Montreal Protocol with added environmental protection benefits as well.

## ACKNOWLEDGEMENT

We sincerely acknowledge the contributions from Mr. Gopalaraman Swaminathan, Scientist, Central Leather Research Institute, Chennai and Mr. Markus Wypior, Project Manager, GTZ-Proklima International, for their invaluable inputs in design and implementation of the project.

We are thankful to Dr. Ralf Steinberg, CIM expert, GTZ, Germany and Mr. Felix Nitz, Consultant GTZ-Proklima for their technical efforts and cooperation during the initial stage of the project.

We acknowledge the cooperation from eight industry sectors namely, Oxygen, Refrigeration & Air Conditioning, Offset Printing, Jewellery, Electrical, Foundry, Textile and Metal Degreasing in different parts of the country like Chennai, Karur, Tirupur, Salem, Bangalore, Belgaum, Ahmedabad, Barnala, Chandigarh and Solapur in granting us access to their facilities to execute the studies.

We are also thankful to M/S. Dew Point Appliances Pvt. Ltd., Bangalore for providing the facilities and support for carrying out simulation measurements with alternative solvents under laboratory conditions.

We are also grateful to all GTZ-Proklima consultants (Sector focal points) for their assistance with conduct of work-place assessments and discussions with stakeholders.

We are thankful to a few public domains, which provided references and figures to access and make use of the same in this document for the benefit of the concerned industries.

## CONTENTS

<b>1. Introduction .....</b>	<b>12</b>
1.1. Beneficiaries of this Manual .....	12
1.2. Structure of the Manual .....	13
1.3. Limitations .....	13
<b>2. Health, Safety and Environmental Hazards of solvents .....</b>	<b>14</b>
2.1. Health hazards .....	14
2.1.1. Routes of solvent entry .....	15
2.1.2. Exposure situations .....	16
2.2. Safety related hazards .....	36
2.2.1. Chemical safety .....	36
2.2.2. Machine safety .....	36
2.2.3. Workplace safety .....	36
2.2.3.1 Occupational exposures .....	37
2.2.3.2. Emergencies (Fire safety) .....	37
2.3. Environmental hazards .....	38
<b>3. Selection criteria for solvents .....</b>	<b>39</b>
3.1. Toxic, chemical and physical properties .....	39
3.2. Categories of industrial solvents .....	40
3.3. Selection considerations for solvents .....	41
<b>4. Guidance on hazard control .....</b>	<b>43</b>
4.1. Substitution and Process change .....	43
4.2. Optimization of solvent use .....	44
4.3. Administrative control .....	44
4.4. Engineering control .....	44
4.4.1. Ventilation .....	45
4.4.1.1. Natural ventilation .....	45
4.4.1.2 Mechanical ventilation .....	46
4.5. Good Housekeeping .....	48
4.5.1. Labeling .....	48
4.5.2. Storage .....	49
4.5.3. Clean up procedures .....	54
4.5.4. Training .....	54
4.6. Personal hygiene practice .....	55
4.7. Personal Protective Equipment (PPE) .....	56
4.7.1. Respirators .....	56
4.7.1.1. Air-purifying respirators .....	57

4.7.1.2. <i>Supplied-air respirators</i> .....	59
4.7.2. <i>Gloves</i> .....	61
4.7.3. <i>Goggles/Spectacles</i> .....	65
4.7.4. <i>Safety shoes</i> .....	66
4.8. <i>First aid measures</i> .....	67
4.9. <i>Fire extinguishers</i> .....	67
4.10. <i>Environmental Control Guidance</i> .....	69
4.10.1. <i>Safe transport</i> .....	69
4.10.2. <i>Guidance on selection of Industrial site and structures</i> .....	76
<b>5. Conclusion</b> .....	<b>77</b>



## ABBREVIATIONS

<b>ACGIH</b>	American Conference of Governmental Industrial Hygienists
<b>AFFF</b>	Aqueous film forming foams
<b>ANSI</b>	American National Standards Institute
<b>APF</b>	Assigned Protection Factor
<b>APR</b>	Air Purifying Respirators
<b>CAS</b>	Chemical Abstracts Service
<b>CETP</b>	Common Effluent Treatment Plant
<b>CFC</b>	Chlorofluorocarbons
<b>CO<sub>2</sub></b>	Carbon dioxide
<b>CSA</b>	Canadian Standards Association
<b>CTC</b>	Carbon tetrachloride
<b>DEHE</b>	Department of Environmental Health Engineering
<b>EfW</b>	Energy-from-Waste
<b>FFP</b>	Particle Filtering Face Piece
<b>GHS</b>	Globally Harmonized System
<b>GIT</b>	Gastrointestinal Tract
<b>GSM</b>	Geo Synthetic Materials
<b>GTZ</b>	Gesellschaft Für Technische Zusammenarbeit (German Technical Cooperation)
<b>GWP</b>	Global Warming Potential
<b>HDPE</b>	High Density Polyethylene
<b>HEPA</b>	High Efficiency Particulate Air
<b>HR</b>	Hazard Ratio
<b>IDLH</b>	Immediately Dangerous to Life or Health Concentrations
<b>IPA</b>	Isopropyl alcohol
<b>IS</b>	Indian Standards
<b>ISO</b>	International Organization for Standardization
<b>LC50</b>	Lethal Concentration
<b>LD50</b>	Lethal Dose
<b>LES</b>	Local Exhaust System
<b>LEV</b>	Local Exhaust Ventilation
<b>MDC</b>	Methylene dichloride
<b>MEK</b>	Methyl ethyl ketone
<b>MSDS</b>	Material Safety Data Sheet
<b>MUC</b>	Maximum Use Concentration
<b>NIOSH</b>	National Institute for Occupational Safety and Health

<b>NOx</b>	Nitrogen oxides
<b>ODS</b>	Ozone-Depleting Substances
<b>OEL</b>	Occupational Exposure Limits
<b>OSH</b>	Occupational Safety & Health
<b>OSHA CFR</b>	Occupational Safety and Health Administration Code of Federal Regulations
<b>PAPR</b>	Powered Air-Purifying Respirator
<b>PCE</b>	Perchloroethylene
<b>PFT</b>	Pulmonary Function Test
<b>PPE</b>	Personal Protective Equipment
<b>ppm</b>	Parts per million
<b>PVA</b>	Poly vinyl alcohol
<b>QLFT</b>	Qualitative Fit Test
<b>QNFT</b>	Quantitative Fit Test
<b>RAC</b>	Refrigerator & Air Conditioning
<b>SAR</b>	Supplied Air Respirator
<b>SCBA</b>	Self-Contained Breathing Apparatus
<b>SMEs</b>	Small and Medium Enterprises
<b>SOx</b>	Sulfur oxides
<b>SRU</b>	Sri Ramachandra University
<b>STEL</b>	Short Term Exposure Limit
<b>TCE</b>	Trichloroethylene
<b>TCLo</b>	Lowest Published Toxic Concentration
<b>TLV</b>	Threshold Limit Value
<b>TREM</b>	Transport emergency
<b>TWA</b>	Time Weighted Average
<b>UNDP</b>	United Nations Development Programme
<b>UNIDO</b>	United Nations Industrial Development Organization
<b>UV-B</b>	Ultraviolet-B
<b>UV-C</b>	Ultraviolet-C
<b>WtE</b>	Waste-to-Energy

## LIST OF FIGURES, TABLES AND BOXES

FIGURES	
Figure 01	Poor handling of chemicals
Figure 02	Chemicals exposures from poor handling
Figure 03	Exposure through lungs
Figure 04	Exposure through skin
Figure 05	Exposure through digestive system
Figure 06	Effects of solvents on various organs
Figure 07	Hierarchy of control methods
Figure 08	Model natural ventilation (good cross ventilation)
Figure 09	Effect of workers' position with respect to direction of air flow
Figure 10	Industrial fan
Figure 11	Exhaust fans
Figure 12	Local exhaust ventilation and its components
Figure 13	Local exhaust system (LES)
Figure 14	Stationary LEV with flexible duct
Figure 15	Mobile LEV with flexible duct
Figure 16	Chemical label on bottle
Figure 17	Layout design of chemical store facility
Figure 18	Organization of chemicals in storage facility
Figure 19	Model sign board in storage facility
Figure 20	Air purifying respirator for particles-disposable half face filter, reusable half face and full face piece
Figure 21	Air purifying respirator for gas/vapours- half face mask with dual cartridge, full face mask with single cartridge, full face PAPR with tight fitting and full face PAPR with loose fitting (hood).
Figure 22	Respirator and cartridge assembly
Figure 23	Supplied air-line respirator
Figure 24	Supplied air-line respirator-helmet type
Figure 25	SCBA with chemical protective clothing
Figure 26	SCBA with chemical protective clothing and helmet
Figure 27	Chemical protective gloves
Figure 28	Chemical protective clothing
Figure 29	Chemical splash goggles and spectacles
Figure 30	Chemical splash spectacles
Figure 31	Eye wash bottles
Figure 32	Eye cup
Figure 33	Safety shoes
Figure 34	Necessity for first-aid
Figure 35	Fire extinguishers
Figure 36	Elements of labeling
Figure 37	Labeling on the packing material and container

Figure 38	Symbols for labeling in accordance to the globally harmonized system of classification and labeling of chemicals (GHS)
Figure 39	Food chain
<b>TABLES</b>	
Table 01	List of industries monitored
Table 02	List of solvents for guidance sheet preparation
Table 03	Data sheet for acetone
Table 04	Data sheet for chloroform
Table 05	Data sheet for cyclohexane
Table 06	Data sheet for dichloroethane
Table 07	Data sheet for ethyl acetate
Table 08	Data sheet for hexane
Table 09	Data sheet for isopropyl alcohol (IPA)
Table 10	Data sheet for d-limonene
Table 11	Data sheet for methanol
Table 12	Data sheet for methyl ethyl ketone (MEK)
Table 13	Data sheet for methylene chloride
Table 14	Data sheet for mineral turpentine
Table 15	Data sheet for nc thinner
Table 16	Data sheet for perchloroethylene (PCE)
Table 17	Data sheet for toluene
Table 18	Data sheet for trichloroethylene (TCE)
Table 19	Data sheet for xylene
Table 20	Criteria for selecting solvent
Table 21	General chemical storage compatibility*
Table 22	Segregation of chemicals by type
Table 23	Selection of chemical cartridge and their colour code with respect to type of chemical
Table 24	List of recommended glove materials

## 1. Introduction

Solvents are widely used for cleaning components, materials and equipment to remove oil, grease, dirt and stains. For this purpose, most of the industries use solvents in pure form or in the form of mixtures. A wide variety of solvents are used in different industrial cleaning processes such as stain removal in textile industries, degreasing in engineering industries, contact cleaning in electrical applications, film cleaning in offset printing etc.

Solvents are chemical substances which are used to dissolve or dilute other substances. Water is the most commonly used solvent and is regarded as the universal solvent. However, some substances that cannot be easily dissolved in water require solvents with specific cleaning properties.

Most of the solvents used in the industries are 'organic' with strong properties to dissolve substances which are insoluble in water. High solvency power and non-flammability has made carbon tetrachloride (CTC) a popular solvent. Since CTC is being phased out under Montreal Protocol, there is an urgent need to find suitable alternative solvents in industries.

### 1.1. Beneficiaries of this Manual

Many of the industrial solvents have the potential to affect the health and environment. Although, there is no single alternate solvent which can replace CTC in all its applications, in the absence of sufficient information, enterprises may substitute CTC with an even more hazardous substance. Hence this manual is prepared to enable industries to take an informed decision.

This manual has been prepared based on the working conditions prevailing in some of the solvent using industries and aimed at helping them conform to the standards or guidelines for environment, health and safety (EHS). This will facilitate a better understanding among supervisors and workers who handle the solvents routinely and enable reduction of exposures and related health risks. The manual is compiled in a user friendly format so that the reader can understand and follow the best work practices to ensure a safe working environment. Since the use of CTC was initially identified in industries listed in **Table 1**, this publication has been prepared specifically for the processes in these industries.

**Table 1: List of industries monitored**

Refrigeration & Air conditioning
Jewellery
Oxygen Sector
Textiles
Metal Degreasing
Foundry
Offset Printing
Electrical Sector

## 1.2. Structure of the Manual

The manual is presented in two independent parts. The first part of the manual carries certain generic environment, health and safety guidelines, which may be applicable to a wide range of industries using chemicals, in general. This part of the manual provides information on some commonly used solvents in industries along with their health and safety information. The properties of the solvents provided in this manual have a greater emphasis on toxic, physical, chemical, environmental, health and safety aspects. This part of the manual is considered as a common publication for industries using solvents for cleaning application. The list of solvents considered in this manual is given in **Table 2**.

**Table 2: List of solvents for guidance sheet preparation**

Sl. No	Solvent	Sl. No	Solvent
1	Acetone	11	Methylene Chloride
2	Chloroform	12	Mineral turpentine
3	Cyclohexane	13	NC Thinner
4	Dichloroethane	14	N-Methyl pyrrolidone
5	Ethyl acetate	15	Perchloroethylene
6	Hexane	16	Toluene
7	Isopropyl alcohol	17	Trichloroethylene(TCE)
8	d-Limonene	18	White petrol
9	Methanol	19	Xylene
10	Methyl Ethyl Ketone		

The second part of the manual is specific to each of the industrial sectors listed in Table 1. Solvent exposures have been assessed for workers involved in different cleaning applications and recommendations have been prepared on the basis of processes, type of solvents, and exposure levels/exposure configurations accompanying various job profiles.

## 1.3. Limitations

Though efforts were made to conduct exposure assessments in actual working conditions for all the industrial sectors, measurements could not be performed for certain processes. Therefore, measurements were carried out in a laboratory by simulating the exposure under varying ventilation and exposure situations. In case of any difference observed in the use of solvents or operating procedures, the recommendations of the manual have to be followed in consultation with the technical advice.

## 2. Health, Safety and Environmental Hazards of solvents

Solvents can have a wide range of effects on the health and environment. Exposure to solvents above the permissible limits can cause wide spectrum of health effects ranging from simple irritation to fatal cancer. The use of solvents in the industries is usually based on the cleaning efficiency with little emphasis on exposure amongst the workers. Therefore, solvents should be used carefully based on their specific toxicity, cleaning efficiency, chemical and physical properties, safety features and effects on health and environment. In general, there is less awareness amongst the workers on health and safety problems related to the use of chemicals in the workplace, resulting in poor handling and high exposure to chemicals. (Figure 1 & 2)



**Figure 1:** Poor handling of chemicals  
(Photo courtesy: CMG-GTZ)



**Figure 2:** Chemicals exposure from poor handling

Organized industries have systems to implement health and safety standards through legal enforcement. On the other hand, unorganized (small scale) industries by virtue of not being under the legal obligations and being limited by lack of resources, are unable to maintain health and safety standards. Consequently, these industries contribute to a major share of health and environmental risks associated with the use of solvent. Use of solvent in unsafe methods not only has effects on human health but also on the environment causing damage to the atmosphere and natural resources such as lakes, rivers, estuaries, oceans and ground water. Recognition and proper management of EHS hazards of solvents thus becomes imperative in order to prevent dual risks for human health and the ecology.

### 2.1. Health hazards

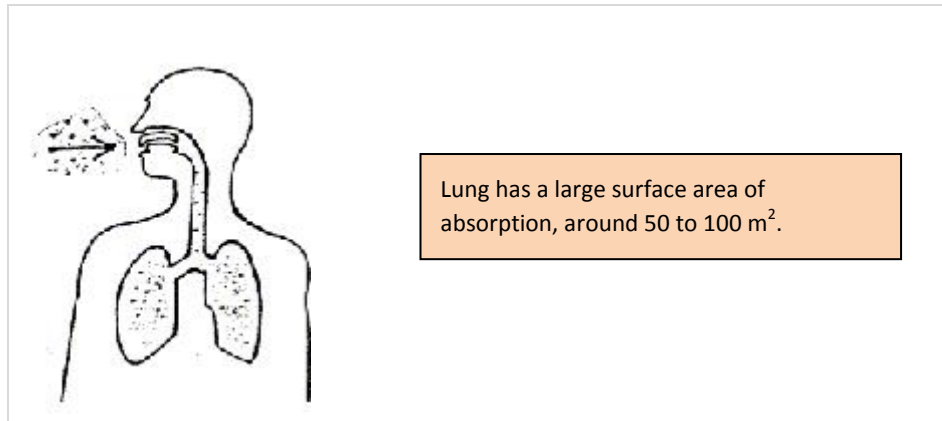
The health effects resulting from exposure to a solvent largely depends on the nature of the hazard, exposure concentration, duration and frequency of exposure and routes of exposure (inhalation, ingestion and dermal). In addition to the primary casual factors, other aspects such as poor hygiene or work practices and general health conditions of workers can significantly contribute to the deterioration of health of the workers. The following sections provide a brief summary of consequent health effects that result from exposure to solvents under a wide range of exposure conditions.

### 2.1.1. Routes of solvent entry

At the workplace, employees are exposed to solvents through three major routes such as inhalation, ingestion and dermal (lungs, digestive system and skin). Although, absorption through eye might seem to be trivial because of very low surface area, being a vital organ, it is also considered as an important route of exposure.

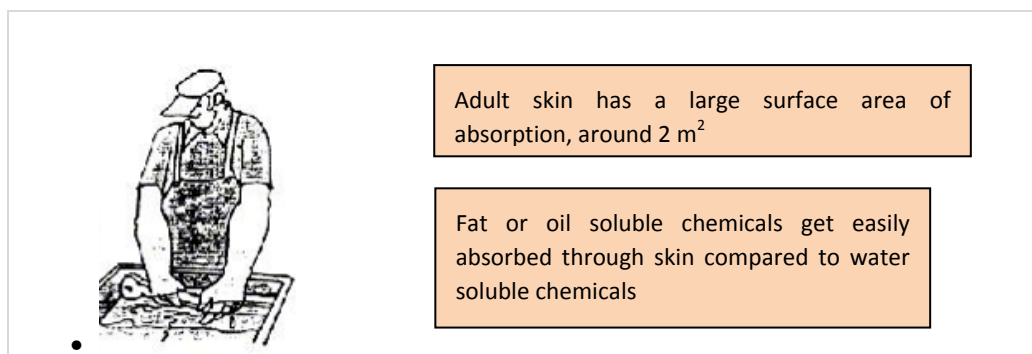
The level of solvent exposure depends on the methods of cleaning. Inhalation or dermal absorption may predominate during spraying or wiping depending on the exact nature of the cleaning method. Further, the contaminated materials (such as solvent soaked cotton or rags) that are improperly disposed or stored within the work area could also lead to cumulative exposure.

**Inhalation** – Airborne substances in the form of gases, vapours, mist, fumes and dust are absorbed through all regions of lungs, (**Figure 3**). Water soluble and lipid or oil soluble substances can easily diffuse through the thin lining of the lungs. The surface area of lung varies between 70 to 90 sq. m. approximately 50 times of the skin surface area. Due to the large surface area, the absorption potential is very high and therefore, inhalation is considered as a major route of exposure for all aerosols.



**Figure 3: Exposure through lungs**

**Skin** – Solvents can be absorbed through intact skin, while working with bare hands or through wounds, which subsequently enter into the blood stream. The surface area of absorption through human skin varies from 1.5 to 2 m<sup>2</sup>. Lipid (fat) or oil soluble substances are usually easily absorbed through skin layer.



**Figure 4: Exposure through skin**



**Ingestion:** Exposure through ingestion takes place through accidental swallowing, ingesting contaminated food or drink, poor hygiene practices (such as smoking, eating and drinking at workplaces) and due to inappropriate housekeeping practices. Absorption largely takes place in the stomach and small intestine of digestive system.



The small intestine of an adult human measure about 7 meters in length and the surface area of the inner lining approximately range from 500 to 200m<sup>2</sup>, roughly the size of a tennis court.

Absorption through stomach and intestine results from poor hygiene practices

*Figure 5: Exposure through Digestive system*

### 2.1.2. Exposure situations

Cleaning and removal of dirt is an essential process in the production, maintenance, and repair of manufactured products. Cleaning removes contaminants and prepares raw materials and parts for subsequent operations such as machining, painting, electroplating, inspection and packaging etc. Cleaning is used in furniture and fixtures, primary metal industries, fabricated metal products, machinery, transportation equipment, automobiles components, electronics and other miscellaneous manufacturing processes. Some of the common methods used for cleaning are as follows:

- Flushing
- Spraying
- Wiping
- Immersion
- Vapour degreasing
- Ultrasonic cleaning

The exact nature of the cleaning methods determines the exposure potential for a particular solvent. Certain cleaning methods such as spraying and flushing use high pressure resulting in significant exposure through inhalation due to high vaporization of solvents. In cleaning methods such as wiping and immersion, the major route of exposure is dermal absorption in addition to inhalation. Although vapour degreasing systems have provisions to control the solvent vapours by condensation, major exposure occurs through inhalation because of poor work practices. Ultrasonic cleaning method is not popular amongst the industrial applications; however, the risk of exposure through inhalation is substantially lower as exposures can usually occur only during opening of the cleaning chamber.

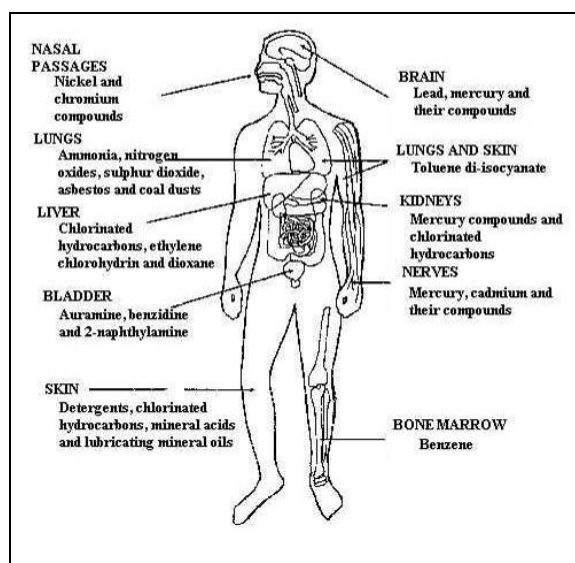
### 2.1.3. Health effects

Exposures in the workplace may be acute (high concentrations for short duration) or chronic (low concentrations for long duration). The health effect varies amongst solvents, from simple headache to fatal cancer and include reversible (symptoms/diseases end after the cessation of exposure) and irreversible effects (symptoms/diseases do not cease even after the exposure is terminated).

Short-term, low-level airborne exposure to most common organic hydrocarbon solvents may cause symptoms such as mild skin irritation, headache, dizziness (giddiness) and sense of intoxication, nausea (sensation to vomit), visual disturbances, and/or eye, nose, and throat irritation. Higher level exposure may cause disorientation, confusion, difficulty in concentrating, diarrhea, vomiting, shortness of breath and fatigue (muscle weakness, sleepiness and decreased attention). At very high levels, solvents may reduce the threshold for seizure (alteration in mental state and involuntary contraction of muscles) activity and cause cardiac arrhythmias (irregular heartbeats) and/or central nervous system depression, leading to coma and ultimately death.

Long-term dermal exposure to organic hydrocarbon solvents has been associated with an increased risk of de-fatting (removal of fat) and cracking of skin, rashes, and more rapid absorption of other chemicals. Inhalation exposure can cause blindness, irregular heartbeat, and damage to the kidneys, liver, lungs, and central nervous system. Regular exposure to solvents can cause memory and hearing loss, mental illness, depression, fatigue, confusion, dizziness, feeling drunk or lack of coordination, headache, nausea, stomach pains, skin rashes, cracking or bleeding skin, irritation of eyes, nose, and throat or affecting various organs (**Figure 6**). Exposure to solvent vapours can cause hoarseness (harsh and rough voice), coughing, lung congestion (stuffy or blocked lungs), chest tightness and shortness of breath.

Recent reports of National Toxicology Programme (USA) classify some solvents such as perchloroethylene (tetrachloroethylene) and trichloroethylene as suspected human carcinogen. Solvents like n-hexane, perchloroethylene and toluene are toxic to nerves, while methylene chloride, 2-methoxyethanol, 2-ethoxyphenol are toxic to reproductive systems.



**Figure 6: Effects of solvents on various organs**

Health effects from prolonged exposure to solvent vapors do not necessarily manifest in the form of symptoms, and this makes it difficult for the employees to recognize the extent of health damage that may be occurring with exposure. In order to recognize the hazardous nature of commonly used solvents, their health effects are provided in **Tables 3 to 19**.

Table 3: Data Sheet for Acetone

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Ketone	(67-64-1)	<b>ORAL (LD50):</b> Acute: 5800 mg/kg [Rat]. 3000 mg/kg [Mouse]. 5340 mg/kg [Rabbit]. <b>VAPOR (LC50):</b> Acute: 50100 mg/m <sup>3</sup> - 8 hours [Rat]. 44000 mg/m <sup>3</sup> - 4 hours [Mouse]	56 °C	180 mm Hg	0.79 g/cm <sup>3</sup>	-20 °C	Highly flammable	2.9 Debye	20.0
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
Irritation of eyes and the respiratory tract and may cause effects on the central nervous system, liver, kidneys and gastrointestinal tract	Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the blood and bone marrow	Eyes, skin, respiratory system, central nervous system	1000* 750****	750* 1000** 250*** 500****	Eye: Irrigate immediately Skin: Soap wash immediately Breathing: Respiratory support Swallow: Medical attention immediately	Testing whole blood for acetone at the end of the shift Testing expired air for acetone at the end of the shift Pulmonary Function Tests (PFTs) Testing urine for acetone at the end of the shift			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Oxidizers, acids	Fireproof Separate from strong oxidants	Powder, alcohol-resistant foam, water in large amounts, carbon dioxide	Improve the ventilation. Collect leaking liquid in sealable containers. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT wash away into sewer. Then wash away with plenty of water (extra personal protection: self-contained breathing apparatus)			Waste must be disposed of in accordance with federal, state and local environmental control regulations			

Table 4: Data Sheet for Chloroform

Toxic, Chemical and Physical properties									
Type	CAS number	LD50 and LC 50	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Chlorinated hydrocarbon	(67-66-3)	<b>ORAL (LD50):</b> Acute: 695 mg/kg [Rat]. 36 mg/kg [Mouse]. 820 mg/kg [Guinea pig]. <b>DERMAL (LD50):</b> Acute: >20000 mg/kg [Rabbit]. <b>VAPOR (LC50):</b> Acute: 47702 mg/m -4 hours [Rat].	62°C	160 mm Hg	1.48 g/cm <sup>3</sup>	None	None	1.2 Debye	19.0
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance irritates the eyes. The substance may cause effects on the central nervous system liver kidneys The effects may be delayed. Medical observation is indicated	The liquid defats the skin. The substance may have effects on the liver kidneys This substance is possibly carcinogenic to humans	Liver, kidneys, heart, eyes, skin, central nervous system	2***	10* 10****	Eye: Irrigate immediately Skin: Soap wash promptly Breathing: Respiratory support Swallow: Medical attention immediately	Liver Function Tests Urinalysis (routine) Testing Expired Air for Chloroform			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Strong caustics; chemically-active metals such as aluminum or magnesium powder, sodium & potassium; strong oxidizers	Separate from food and feedstuffs, incompatible materials See Chemical Dangers Ventilate along the floor	In case of fire in the surroundings: all extinguishing agents allowed	Evacuate danger area. Consult an expert. Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT let this chemical enter the environment. (Extra personal protection: complete protective clothing including self-contained breathing apparatus).			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			

Table 5: Data Sheet for Cyclohexane

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Alicyclic hydrocarbon	(110-82-7)	<b>ORAL (LD50):</b> Acute: 12705 mg/kg [Rat]. 813 mg/kg [Mouse]. <b>DERMAL (LD):</b> Acute: &gt; 18000 mg/kg [Rabbit]	81° C	78 mm Hg	0.78 g/cm <sup>3</sup>	-20 °C	Highly flammable	0 Debye	16.8
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance and the vapour in high concentrations irritates the eyes and the respiratory tract. Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. Exposure far above OEL may result in unconsciousness	Repeated or prolonged contact with skin may cause dermatitis	Eyes, skin, respiratory system, central nervous system		300** 300**** 100****	Eye: Irrigate immediately Skin: Water flush promptly Breathing: Respiratory support Swallow: Medical attention immediately	Testing whole Blood (chemical/metabolite) during the exposure Testing urine (chemical/metabolite) End-Of-Shift			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Oxidizers	Fireproof	Powder, AFFF, foam, carbon dioxide	Evacuate danger area! Consult an expert! Ventilation. Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT wash away into sewer (extra personal protection: self-contained breathing apparatus)			Waste must be disposed of in accordance with federal, state and local environmental control regulations			

Table 6: Data Sheet for Dichloroethane

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Chlorinated hydrocarbon	(107-06-2)	<b>ORAL (LD50):</b> Acute: 670 mg/kg [Rat]. 413 mg/kg [Mouse]. <b>DERMAL (LD50): Acute:</b> 2800 mg/kg [Rabbit]. <b>VAPOR (LC50):</b> Acute: 1414.2 ppm - 4 hour(s) [Rat]	84° C	64 mm Hg	1.24 g/cm <sup>3</sup>	13 °C	Highly flammable	1.6 Debye	18.5
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance may cause effects on the central nervous system. Exposure at high levels may result in unconsciousness	The liquid defats the skin. The substance may have effects on the kidneys and liver	Skin, liver, kidneys, lungs, central nervous system		100** 100*** 10****	Eye: Irrigate immediately Skin: Soap flush promptly Breathing: Respiratory support Swallow: Medical attention immediately	-			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Strong oxidizers, strong caustics	Fireproof See chemical dangers Keep the storage area cool	Powder, water spray, foam, carbon dioxide.	Collect leaking liquid in sealable containers. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT wash away into sewer (extra personal protection: self-contained breathing apparatus)			Waste must be disposed of in accordance with federal, state and local environmental control regulations			

Table 7: Data Sheet for Ethyl Acetate

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Ester	(141-78-6)	<b>ORAL (LD50):</b> Acute: 5620 mg/kg [Rat]. 4100 mg/kg [Mouse]. 4935 mg/kg [Rabbit]. <b>VAPOR (LC50):</b> Acute: 45000 mg/m 3 hours [Mouse]. 16000 ppm - 6 hours [Rat].	77° C	76 mm Hg	0.90 g/cm <sup>3</sup>	-4 °C	Highly flammable	1.8 Debye	18.1
Health guidance									
Acute (Immediate) effects		Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance		
				STEL	TWA				
The substance irritates the eyes and the respiratory tract. The substance may cause effects on the central nervous system. Exposure far above the OEL may result in death		The liquid defats the skin	Eyes, skin, respiratory system		400* 400** 400*** 400****	Eye: Irrigate immediately Skin: Water flush promptly Breathing: Respiratory support Swallow: Medical attention immediately	-		
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Nitrates; strong oxidizers, alkalis & acids	Fireproof Separate from strong oxidants. Keep the storage area cool and closed	AFFF, alcohol-resistant foam, powder, carbon dioxide	Evacuate danger area. Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT wash away into sewer (extra personal protection: complete protective clothing including self-contained breathing apparatus).			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			



Table 8: Data Sheet for Hexane

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Hydrocarbon alkane	(110-54-3)	LD <sub>50</sub> – Skin >2 gm/kg rabbit; LD <sub>50</sub> -oral >5 gm/kg rat LC <sub>50</sub> – inhalation >3367 ppm - rat;	63.70° C	124mm Hg	0.69 g/cm <sub>3</sub>	-23 °C	Highly flammable	0 Debye	14.9
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance irritates the skin. Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. Exposure at high levels could cause lowering of consciousness	Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the central nervous system peripheral nervous system , resulting in polyneuropathy. Animal tests show that this substance possibly causes toxic effects upon human reproduction	Eyes, skin, respiratory system, central nervous system, peripheral nervous system		500** 50*** 50****	Eye: Irrigate immediately Skin: Soap wash immediately Breathing: Respiratory support Swallow: Medical attention immediately	Testing urine for 2,5-hexanedion in the end of shift at end of workweek			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Strong oxidizers	Fireproof Separate from strong oxidants Keep the storage area closed	Powder, AFFF, foam, carbon dioxide	Consult an expert. Remove all ignition sources. Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT wash away into sewer. Do NOT let this chemical enter the environment. (Extra personal protection: filter respirator for organic gases and vapours).			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			

Table 9: Data Sheet for Isopropyl Alcohol (IPA)

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Secondary Alcohol	(67-63-0)	<b>ORAL (LD50):</b> Acute: 5045 mg/kg [Rat]. 3600 mg/kg [Mouse]. 6410 mg/kg [Rabbit]. <b>DERMAL (LD50):</b> Acute: 12800 mg/kg [Rabbit].	82°C	33 mm Hg	0.79 g/cm <sup>3</sup>	12. °C	Highly flammable	1.7 Debye	23.5
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance irritates the eyes and the respiratory tract. The substance may cause effects on the central nervous system, resulting in depression. Exposure far above the OEL may result in unconsciousness	The liquid defats the skin	Eyes, skin, respiratory system	500*** 200****	400** 400*** 400****	Eye: Irrigate immediately Skin: Water flush Breathing: Respiratory support Swallow: Medical attention immediately	Testing whole blood, expired air and urine for IPA or for the metabolites			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Strong oxidizers, acetaldehyde, chlorine, ethylene oxide, acids, isocyanates	Fireproof Separate from strong oxidants Keep the storage area cool and closed	Powder, alcohol-resistant foam, water in large amounts, carbon dioxide	Collect leaking liquid in sealable containers. Absorb remaining liquid in sand or inert absorbent and remove to safe place. (Extra personal protection: filter respirator for organic gases and vapours).			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			

Table 10: Data Sheet for d-Limonene

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Terpene	(5989-27-5)	<b>ORAL (LD50):</b> Acute: 4400 mg/kg [Rat]. 5600 mg/kg [Mouse]. <b>DERMAL (LD50):</b> Acute: >5000 mg/kg [Rabbit]	176°C	2 mm Hg	0.84 g/cm <sup>3</sup>	43°C	Flammable	206 Debye	16.6
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance may irritate slightly the eyes and the skin	Repeated or prolonged contact may cause skin sensitization if the substance has been oxidized	Eye and Skin			Eye: Irrigate immediately Skin: Water flush promptly Breathing: Respiratory support Swallow: Medical attention immediately	-			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
-	-	-	-			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			

Table 11: Data Sheet for Methanol

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Alcohol	(67-56-1)	<b>LD Lo</b> Human 143 mg/kg; Eye, Pul, GIT <b>LD50</b> - Mouse: 7300 mg/kg <b>LC50</b> - Rat: 64,000 ppm / 4 hours <b>LC50</b> - Goldfish: 250 ppm / 11 hours	64°C	96 mm Hg	0.79 g/cm <sup>3</sup>	11°C	Highly flammable	107 Debye	29.6
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance irritates the eyes, the skin and the respiratory tract. The substance may cause effects on the central nervous system, resulting in loss of consciousness. Exposure may result in blindness and death. The effects may be delayed. Medical observation is indicated	Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the central nervous system, resulting in persistent or recurring headaches and impaired vision	Eyes, skin, respiratory system, central nervous system, gastrointestinal tract	250* 200*** 250****	200* 200** 200*** 250****	Eye: Irrigate immediately Skin: Water flush promptly Breathing: Respiratory support Swallow: Medical attention immediately	Testing urine for methanol content in the end of the shift			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Strong oxidizers	Fireproof Separate from strong oxidants, food and feedstuffs Keep the storage area cool	Powder, alcohol-resistant foam, water in large amounts, carbon dioxide	Evacuate danger area. Ventilation. Collect leaking liquid in sealable containers. Wash away remainder with plenty of water. Remove vapour with fine water spray. Chemical protection suit including self-contained breathing apparatus.			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			

Table 12: Data Sheet for Methyl Ethyl Ketone (MEK)

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Ketone	(78-93-3)	<b>ORAL (LD50):</b> Acute: 2737 mg/kg [Rat]. 4050 mg/kg [Mouse]. <b>DERMAL (LD50):</b> Acute: 6480 mg/kg [Rabbit]. <b>VAPOR (LC50):</b> Acute: 23500 mg/m 8 hours [Rat]	79°C	78 mm Hg	0.81 g/cm <sup>3</sup>	-9°C	Highly flammable	208 Debye	19.0
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance irritates the eyes and the respiratory tract. The substance may cause effects on the central nervous system. Exposure far above the OEL may result in unconsciousness	The liquid defats the skin. Animal tests show that this substance possibly causes toxic effects upon human reproduction	Eyes, skin, respiratory system, central nervous system	300*** 300****	200** 200*** 200****	Eye: Irrigate immediately Skin: Water wash immediately Breathing: Fresh air Swallow: Medical attention immediately	Pulmonary Function Tests Testing urine for Methyl Ethyl Ketone in the end of the shift			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Strong oxidizers, amines, ammonia, inorganic acids, caustics, isocyanates, pyridines	Fireproof Separate from strong oxidants, strong acids Keep the storage area cool and closed	Powder, AFFF, foam, carbon dioxide	Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT wash away into sewer. (Extra personal protection: self-contained breathing apparatus).			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			

Table 13: Data Sheet for Methylene Chloride

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Chlorinated hydrocarbon	(75-09-2)	<b>ORAL (LD50): Acute:</b> 1600 mg/kg [Rat].	40°C	350 mm Hg	1.33 g/cm <sup>3</sup>	NONE	None	1.6 Debye	20.3
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance irritates the eyes, the skin and the respiratory tract. Exposure could cause lowering of consciousness. Exposure could cause formation of carboxyhaemoglobin	Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the central nervous system liver This substance is possibly carcinogenic to humans	Eyes, skin, cardiovascular system, central nervous system	125**	25** 50****	Eye: Irrigate immediately Skin: Soap wash promptly Breathing: Respiratory support Swallow: Medical attention immediately	Testing urine for dichloromethane in the end of the shift			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Strong oxidizers; caustics; chemically-active metals such as aluminum, magnesium powders, potassium & sodium; concentrated nitric acid	Separate from metals See for chemical dangers Keep away from food and feedstuffs Ventilate cool air along the floor	In case of fire in the surroundings: all extinguishing agents allowed	Improve the ventilation. Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand or inert absorbent and remove to safe place. (Extra personal protection: filter respirator for organic gases and vapours.)			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			

Table 14: Data Sheet for Mineral Turpentine

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Blend of aliphatic and aromatic hydrocarbons. Composition varies with manufacture.	(Not available)	<b>TCLo (inhaled, human):</b> 600mg/m <sup>3</sup> /8H; <b>LC50 (inhaled, rat):</b> 3400ppm/4H; Eye (human): 880ppm/15min: irritant effect	146-197°C (approx)	25 mm Hg	0.80-0.86 g/cm <sup>3</sup>	36-38°C (approx)	Flammable	(Not available)	15.8
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The vapour is irritating to the eyes the skin and the respiratory tract If this liquid is swallowed, aspiration into the lungs may result in chemical pneumonitis. The substance may cause effects on the central nervous system bladder kidneys , resulting in irritability convulsions kidney impairment Exposure at high levels may result in tachycardia, unconsciousness death	Repeated or prolonged contact may cause skin sensitization. The liquid defats the skin	Eyes, skin, respiratory system, central nervous system, kidneys		100** 100*** 20****	Eye: Irrigate immediately Skin: Soap wash promptly Breathing: Respiratory support Swallow: Medical attention immediately	-			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Strong oxidizers, chlorine, chromic anhydride, stannic chloride, chromyl chloride	Fireproof Separate from strong oxidants, incompatible materials See chemical dangers Keep the storage area cool and well ventilated	Foam, dry powder, carbon dioxide	Cover the spilled material with dry earth or sand or other non-combustible material. Ventilation. Remove all ignition sources. Do NOT wash away into sewer. Sweep spilled substance into containers then remove to safe place. (Extra personal protection: self-contained breathing apparatus.) Do NOT let this chemical enter the environment.			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			

Table 15: Data Sheet for NC Thinner

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Blend of ketones, esters, alcohol and hydrocarbons.	(Not available)	<b>Not available</b>	56-138°C (approx)	60 mm Hg	0.79 g/cm <sup>3</sup>	-15°C (approx)	Highly flammable	(Not available)	17.6-17.8
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance irritates the eyes. Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. The substance may cause effects on the central nervous system. Exposure could cause lowering of consciousness. Exposure could cause cardiac arrhythmias	Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the nervous system, liver and kidneys. May cause reproductive toxicity in humans	Eyes, skin and inhalation	-	-	Eye: Irrigate immediately Skin: Water flush promptly Breathing: Respiratory support Swallow: Medical attention immediately	-			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
-	Fireproof Separate from strong acids, oxidants Keep the storage area well closed	Powder, AFFF, foam, carbon dioxide	Improve the ventilation. Collect leaking liquid in sealable containers. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT wash away into sewer. (Extra personal protection: A/P2 filter respirator for organic vapour and harmful dust).			-			



Table 16: Data Sheet for Perchloroethylene (PCE)

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Chlorinated hydrocarbon	(127-18-4)	<b>ORAL (LD50):</b> <b>Acute:</b> 2629 mg/kg [Rat]. <b>DERMAL (LD):</b> <b>Acute:</b> & gt;3228 mg/kg [Rabbit]. <b>MIST (LC50): Acute:</b> 34200 mg/m 8 hours [Rat]. <b>VAPOR (LC50): Acute:</b> 5200 ppm 4 hours [Mouse].	121°C	14 mm Hg	1.62 g/cm <sup>3</sup>	None	None	0 Debye	20.3
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance irritates the eyes, the skin and the respiratory tract. Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. The substance may cause effects on the central nervous system. Exposure at high levels may result in unconsciousness	Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the liver and kidneys. This substance is probably carcinogenic to humans	Eyes, skin, respiratory system, liver, kidneys, central nervous system	100****	100** 25****	Eye: Irrigate immediately Skin: Water flush promptly Breathing: Respiratory support Swallow: Medical attention immediately	Testing tetrachloroethylene content in end-exhaled air in prior to shift Testing tetrachloroethylene content in blood in prior to shift			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Strong oxidizers; chemically-active metals such as lithium, beryllium & barium; caustic soda; sodium hydroxide; potash	Separate from metals See chemical dangers Keep away from food and feedstuffs Keep in the dark Ventilate along the floor	In case of fire in the surroundings: all extinguishing agents allowed	Improve the ventilation. Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT let this chemical enter the environment. (Extra personal protection: filter respirator for organic gases and vapours).			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			

Table 17: Data Sheet for Toluene

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Aromatic hydrocarbon	(108-88-3)	<b>ORAL (LD50):</b> <b>Acute:</b> 636 mg/kg [Rat]. <b>DERMAL (LD50):</b> <b>Acute:</b> 14100 mg/kg [Rabbit]. <b>VAPOR (LC50):</b> Acute: 49000 mg/m 4 hours [Rat]. 440 ppm 24 hours [Mouse].	111°C	21 mm Hg	0.87 g/cm <sup>3</sup>	4-7°C	Highly flammable	0.3 Debye	18.2
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance irritates the eyes and the respiratory tract. Exposure could cause central nervous system depression. Exposure at high levels may result in cardiac dysrhythmia, unconsciousness and death	Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the central nervous system, resulting in decreased learning ability and psychological disorders. Animal tests show that this substance possibly causes toxic effects upon human reproduction	Eyes, skin, respiratory system, central nervous system, liver, kidneys	150* 150***	100* 100** 100*** 20****	Eye: Irrigate immediately Skin: Water flush promptly Breathing: Respiratory support Swallow: Medical attention immediately	Testing O-cresol content in urine or (Hippuric acid in urine) in end of the shift Testing toluene content in blood in prior to last shift to workweek			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Strong oxidizers	Fireproof Separate from strong oxidants	Powder, AFFF, foam, carbon dioxide	Collect leaking liquid in sealable containers. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT wash away into sewer (extra personal protection: self-contained breathing apparatus).			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			

Table 18: Data Sheet for Trichloroethylene (TCE)

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Chlorinated hydrocarbon	(79-01-6)	<b>ORAL (LD50): Acute:</b> 5650 mg/kg [Rat]. 2402 mg/kg [Mouse]. <b>DERMAL (LD50): Acute:</b> 20001 mg/kg [Rabbit].	87°C	58mm Hg	1.47 g/cm <sup>3</sup>	None	None	0.8 Debye	19.0
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance irritates the eyes and the skin. Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. The substance may cause effects on the central nervous system, resulting in respiratory failure. Exposure could cause lowering of consciousness	Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the central nervous system, resulting in loss of memory. The substance may have effects on the liver kidneys (see notes). This substance is probably carcinogenic to humans	Eyes, skin, respiratory system, heart, liver, kidneys, central nervous system	200* 25****	50* 100** 10****	Eye: Irrigate immediately Skin: Water flush promptly Breathing: Respiratory support Swallow: Medical attention immediately	Testing Trichloroacetic acid in urine in end of the shift at end of workweek Testing Trichlorethanol in blood in end of the shift at end of workweek Testing Trichloroethylene in blood in end of the shift at end of workweek Testing Trichloroethylene in end-exhaled air in end of the shift at end of workweek Pulmonary Function Tests Blood Plasma			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Strong caustics & alkalis; chemically-active metals (such as barium, lithium, sodium, magnesium, titanium & beryllium)	Separate from metals See chemical dangers strong bases Keep away from food and feedstuffs Keep in the dark Keep the storage area dry and ventilate along the floor	In case of fire in the surroundings: all extinguishing agents allowed	Improve the ventilation. Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand or inert absorbent and remove to safe place. (Extra personal protection: filter respirator for organic gases and vapours). Do NOT let this chemical enter the environment			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			

Table 19: Data Sheet for Xylene

Toxic, Chemical and Physical properties									
Type	CAS number	LD <sub>50</sub> and LC <sub>50</sub>	Boiling point	Vapour pressure	Specific gravity	Flash point	Flammability	Dipole moment	Solvency power (Hansen parameter)
Aromatic hydrocarbon	(1330-20-7)	<b>ORAL (LD50): Acute:</b> 5000 mg/kg [Rat]. <b>DERMAL (LD50): Acute:</b> 12400 mg/kg [Rabbit]. <b>VAPOR (LC50): Acute:</b> 4550 ppm 4 hour(s) [Rat].	138°C	6-16 mm Hg	0.86 g/cm <sup>3</sup>	38°C	Flammable	0.6 Debye(approx)	18.0
Health guidance									
Acute (Immediate) effects	Chronic (Delayed) effects	Target organ affected	Permissible limits of exposure		First aid	Medical Surveillance			
			STEL	TWA					
The substance irritates the eyes. Exposure far above the OEL may result in central nervous system depression, unconsciousness and death.	The liquid defats the skin. The substance may have effects on the central nervous system, resulting in decreased learning ability	Eyes, skin, respiratory system, central nervous system, gastrointestinal tract, blood, liver, kidneys	150* 150*** 150****	100* 100** 100*** 100****	Eye: Irrigate immediately Skin: Water flush promptly Breathing: Respiratory support Swallow: Medical attention immediately	Complete Blood Count Liver Function Tests Testing Methylhippuric acids in urine in the end of shift			
Safety and environmental guidance									
Incompatible chemicals	Storage condition	Type of fire extinguisher	Spill control			Waste disposal			
Strong oxidizers, strong acids	Fireproof Separate from strong oxidants	Powder, AFFF, foam, carbon dioxide	Collect leaking and spilled liquid in sealable containers as far as possible. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT let this chemical enter the environment			Waste must be disposed of in accordance with federal, state and local environmental control regulations.			

\* Permissible Limits of Exposure (PLE) prescribed by Indian Factories Act, 1948

\*\* Permissible Exposure Limits (PEL) prescribed by Occupational Safety and Health Administration (OSHA), USA

\*\*\* Recommended Exposure Limit (REL) prescribed by National Institute for Occupational Safety and Health (NIOSH), USA

\*\*\*\* Threshold Limit Value (TLV) recommended by American Conference of Governmental Industrial Hygienists (ACGIH, 2008), USA

## 2.2. Safety related hazards

Safety is a broad terminology and it encompasses important aspects such as chemical safety, machine safety and electrical safety, workplace environmental conditions and dealing with emergencies such as fire and explosion. Solvents have the potential to become a safety hazard under each of these dimensions depending on the nature of use.

### 2.2.1. Chemical safety

Chemical safety becomes an issue with solvents most often due to improper handling (by not following the procedures prescribed in the MSDS). Good practices for processes such as loading, unloading, transfer, mixing, washing and disposal often are specific to a particular solvent and therefore non-availability of MSDS at the workplace can result in significant risks to workers and workplaces handling these solvents. Information, such as flammability, explosion limits, storage incompatibilities, physical and chemical properties, toxicity, emergency spill control procedures, safe disposal, first aid guidance and medical management are crucial for recognition and management of chemical safety concerns with solvents. However, often these are not available in easily accessible formats in many industries; even the most innocuous of solvents under conditions of improper handling and storage may become extremely dangerous to life and property. Chemical safety thus remains as one of the most important safety concerns while working with solvents.

### 2.2.2. Machine safety

Machine safety can be compromised under a variety of situations in workplaces not all of which may be related to how solvents are primarily used. However, in the absence of standard machine safety procedures, solvents could be expected to cause damage similar to other chemicals and in some exceptional cases, special precautions may need to be exercised. General unsafe machine safety conditions that may compound solvent related risks include

1. Generation of excessive heat, fumes, vapour and mist due to poor maintenance.
2. Improper site-selection for machines and inadequate hazard-proofing/guarding.
3. Unsafe electrical installations (without flame/chemical-proof cables/ switches/control panels), lack of electrical grounding of metal boxes/ static dischargers etc.
4. Inadequate preventive maintenance (due to constraints in securing appropriate tools and required space).

### 2.2.3. Workplace safety

General considerations of workplace safety are applicable while working with solvents as shortfalls in work layout and organization could be expected to adversely affect worker productivity and performance in addition to increase in the incidence of injury and disease. While these are not specific to use of solvents per se, some general hazards related to workplace safety include inadequate physical structures (such as bad flooring without slip-proof protection), poor drainage, insufficient ventilation, poorly controlled temperatures and humidity, lack of insulation, inadequate lighting and poor organization of machine layout in relation to required work flow. The presence of any of these deficiencies in the work

environment could be expected to increase overall occupational risks including those related to solvents.

### **2.2.3.1 Occupational exposures**

Worker performance and health can be affected by a range of physical, chemical and biological hazards. While physical and biological hazards do not directly pertain to solvents, it is important that occupational exposures to all hazards are kept within permissible exposure limits which are considered safe for worker's health. Specifically for solvents, it may be impossible to ascertain safety of the working environment in the absence of actual quantification of air borne or surface concentrations. A range of laboratory methods are available for such assessments and it would be necessary to sample and analyse individual solvents as per local legislation to establish if prevalent exposure conditions are adequate to prevent occupational health risks. Since many solvents are volatile and dispersion even within the work areas may differ substantially over time, a rigorous sampling strategy would be needed to establish conformity to standards. Given the relative expense of monitoring and analyses, it is not uncommon to find simple "grab samples" substituting for long-term and/or longitudinal samples to establish compliance. Resources for standards and monitoring methods are listed below and hazards related to workplace exposures need to be assessed as per protocols stipulated in the same.

#### **Standards & Guidelines:**

- Indian Factories Act 1948 and Respective State Rules for Permissible Limit of Exposure to chemicals
- American Conference of Governmental Industrial Hygienist Guidelines for Threshold Limit Value for chemicals and Biological Exposure Indices
- NIOSH Manual of Analytical Methods

### **2.2.3.2. Emergencies (Fire safety)**

One of the commonest emergencies encountered with solvents is the risk of fire. Three basic elements would need to be kept dissociated to prevent massive fires viz. combustible or flammable materials, source of ignition and oxygen. Fires often result from

1. Lack of segregation of flammable, combustible and explosive materials (on the basis of physical form of chemical, flash point, boiling point, vapour pressure and specific gravity etc.).
2. Inadequate hazard labeling for sources of fire and explosion (such as sparks, static electricity, short circuits, open flame, friction and heat).
3. Insufficient preparation for fire-fighting (such as limited mock drill experience and training to use fire fighting equipments).
4. Poor organization of physical layout (such as poorly labeled fire and emergency exits).
5. Lack of availability of appropriate fire-fighting equipment.
6. Non-availability of an on-site/off-site emergency team (including responsible officers, contact persons, first aid providers, drivers and secondary/ and tertiary care providers).

Other emergencies such as spills, leaks, explosions require similar considerations to be followed as fire safety to prevent catastrophic consequences.

### 2.3. Environmental hazards

Solvents may exist in the form of liquid, mists, gases and vapours and are released to the environment during their use in the process, cleaning and disposal as waste into the soil, air and water. The environmental media that are often affected are air, soil, biota (aquatic and terrestrial organisms), and water. While the primary contamination may occur in the environment media in the vicinity of a industry, environmental transport mechanisms such as wind, erosion, surface runoff, flooding and leaching of soil may also carry the contaminants from the source of discharge to the point where human exposure may occur through multiple pathways.

Contamination of air occurs while solvents during the course of their use are released into the atmosphere. These vapors may undergo photolysis or degradation to form secondary compounds and could be carried to long distances depending on the meteorology such as wind velocity, wind direction, temperature and humidity. The solvent can cause either direct impact on the environment through its parent compound or through its degradation products (such as photochemical smog or ground-level ozone). These pollutants in air also have the potential to precipitate during the monsoon entering the soil and ground water table which also could be carried to other geographical regions.

Solvents can contaminate surface soil, subsurface soil, ground water tables, surface water and sediments, if disposed without proper treatment. During the penetration into the soil table, solvent undergoes degradation and could be available as parent compound or its degradation products. The solvents entering the ground water could be carried down gradient in the water table with different concentration gradients along the water stream. The population using this water, down stream of contaminated sites is usually at the greatest health risk from exposure.

Solvents in all environmental matrices (air, soil and water) can enter the food chain, affecting the primary producers (microscopic plants and animals) all the way to the secondary (fish) and tertiary consumers (humans). Thus, if a solvent is eco-toxic it can potentially cause damage at all of tropic levels of the food chain.

### 3. Selection criteria for solvents

As discussed in previous section, considerable knowledge on properties of solvent is required for using them in a safe manner. To an extent, the structural formula is considered as one of the important characteristics that determines the toxicity of the chemical substances. The toxic properties are also determined by the biotransformation product of the chemical, for example, the immediate oxidation products of aromatic compounds are more toxic than the parent compound. These occupational health relevant characteristics of solvents have to be matched with other considerations of environmental health and safety before selection for a particular use can be made. The following sections provide an overview of important properties of solvents that may be applied for selection of solvents appropriate for a particular application.

#### 3.1. Toxic, chemical and physical properties

Amongst a wide range of solvent properties, only a few of the toxic, physical and chemical properties are relevant for selecting the solvent as a cleaning agent. **Tables 3 to 19** provide information to the user about recognizing the degree of toxicity, the environmental condition under which the solvents get in the breathing zone and the solvency power. The definitions related to certain toxic, physical and chemical parameters are as follows:

##### **LD50**

LD stands for "Lethal Dose". LD50 is the amount of a material, given all at once, which causes the death of 50% (one half) of a group of test animals. The LD50 is one way to measure the short-term poisoning potential (acute toxicity) of a material.

##### **LC50**

LC stands for "Lethal Concentration". LC50 is the amount of a material, given all at once, which causes the death of 50% (one half) of a group of test animals. LC values usually refer to the concentration of a chemical in air but in environmental studies it can also mean the concentration of a chemical in water.

##### **Flash point**

The flash point (in °C) is the lowest temperature at which a flammable solvent can form an ignitable mixture with air. As a rule of thumb, the higher the flash point temperature the lower is the fire hazard risk. Non-flammable solvents do not have a flash point.

##### **Flammability**

Flammability is defined at how easily solvents will burn or ignite, causing fire or combustion.

##### **Boiling point**

The boiling point (in °C) is the temperature at which the liquid will start boiling. A lower boiling point means higher losses of solvent into the atmosphere but higher cleaning efficiency.



### Vapour pressure

Vapour pressure (in mm Hg) is an indicator for the rate of evaporation under atmospheric conditions. The higher the value, the faster the solvent evaporates. If the substance is stored in an open container it can also be considered as a measure of evaporation losses.

### Specific Gravity

The specific gravity of a material is the ratio of its density to the density of water ( $1.00 \times 10^3 \text{ kg/m}^3$ ).

### Dielectric Constant

The dielectric constant of a solvent is a relative measure of its polarity. The lower the dielectric constant of a solvent the better it is for use.

### Dipole Moment

Dipole moment (in Debye) is a measure of the polarity of a solvent. It determines what type of compounds it can dissolve and with what liquids it is miscible. Typically, polar solvents dissolve polar compounds best and non-polar solvents dissolve non-polar compounds. Similarly, polar contaminants dissolve in polar solvents, while non-polar compounds, like oils or waxes, dissolve in non-polar solvents.

### Hansen Solubility Parameter

The Hansen solubility parameter is a numerical value that indicates the relative solvency behaviour of a specific solvent and is available for any solvent, liquid and polymer. This number is calculated from the dispersion, polarity and hydrogen bonding properties of the solvent and is indicative of the forces that hold the molecules together.

## 3.2. Categories of industrial solvents

**Aliphatic hydrocarbons:** A hydrocarbon in which no carbon atoms are joined to form a ring. Cyclohexane, n-hexane, pentane, cyclopropane etc., are the members of this class.

**Aromatic hydrocarbons:** One of a special class of cyclic unsaturated hydrocarbons; the simplest of which is benzene. Other examples are xylene, toluene etc.

**Chlorinated hydrocarbons:** These are chemicals composed of carbon, chlorine and hydrogen. Most of the solvents in this class have more number of substituted chlorine atoms attached to the carbon atoms. Examples are carbon tetrachloride, chloroform, trichloroethylene etc.

**Alcohols:** Organic compounds containing the hydroxyl (O-H) group attached to a carbon atom of an alkyl or substituted alkyl group. The general formula for a simple acyclic alcohol is  $C_nH_{2n+1}OH$ . Examples are Methyl alcohol (methanol), ethyl alcohol (ethanol), propyl alcohol (propanol) etc.

**Esters:** organic compounds produced by the reaction between alcohols and acids. The word 'ester' alone now signifies by common usage that the acid is an organic acid, but inorganic acids can also form esters. Common esters used as industrial solvents are ethyl acetate, amyl acetate etc.

**Ethers:** It is a class of organic compounds connected to two alkyl or aryl groups — of general formula R-O-R (R is alkyl or aryl group). Examples are methyl ethyl ether, diethyl ether etc.

**Glycols:** A class of organic compounds of the alcohol family, in which two hydroxyl groups (-OH) are attached to different carbon atoms. The term is often used for the simplest of the class, ethylene glycol (1,2-ethanediol), propylene glycol (1,2-propanediol) etc.

**Glycol ethers:** These are a group of solvents based on alkyl ethers of ethylene glycol commonly used in paints. These include ethylene glycol monomethyl ether (2-methoxyethanol), ethylene glycol monoethyl ether (2-ethoxyethanol) etc.

**Ketones:** It is a type of compound that features a carbonyl group (C=O) bonded to two other carbon atoms. Acetones, Methyl ethyl ketone (MEK) etc., are examples of this class.

**Aldehydes:** It is an organic compound containing a terminal carbonyl group. This functional group, which consists of a carbon atom bonded to a hydrogen atom and double-bonded to an oxygen atom (chemical formula O=CH-). Examples are Acetaldehyde, Formaldehyde etc.

### 3.3. Selection considerations for solvents

It would be impossible to suggest a unique or a single best solvent for a particular cleaning application. Many considerations have to be applied to make this selection that include nature and composition of the contaminants, nature of cleaning process, physical, chemical and toxicological properties and cost of solvent.

For example, Methylene dichloride (MDC) has good cleaning power and has a boiling point of 40 °C which makes it very volatile and unsuitable for high-temperature work. High volatility may also render some cleaning applications that require extended contact ineffective. Use of larger volumes increases costs as well. Previous literature did not demonstrate the adverse health effects of MDC in humans, but recent publications have shown evidence of MDC as a probable carcinogen. Similarly, Trichloroethylene (TCE) has good cleaning properties and is used by few industries, but its usage is strongly discouraged because of the inherent cancer risk. Process optimization and exposure concentration at work place also play an important role. Perchloroethylene (PCE) has a boiling point of 121°C which makes it evaporate slowly that may result in some residual solvent on the components. When using this solvent further step of air drying may be necessary to evaporate the solvent residues. Another implication related to the use of PCE is that the vapour concentration builds up in the workplace due to slow evaporation compounded by continuous use in the process.

Therefore, the selection of any substitute to CTC, should be guided by reliable recent studies that provide on-going scientific evidence hitherto unknown health outcomes.

In order to address environmental, health and safety concerns without compromising on quality and cost effectiveness, any substitute for CTC should broadly meet the following criteria as listed in **Table 20**.

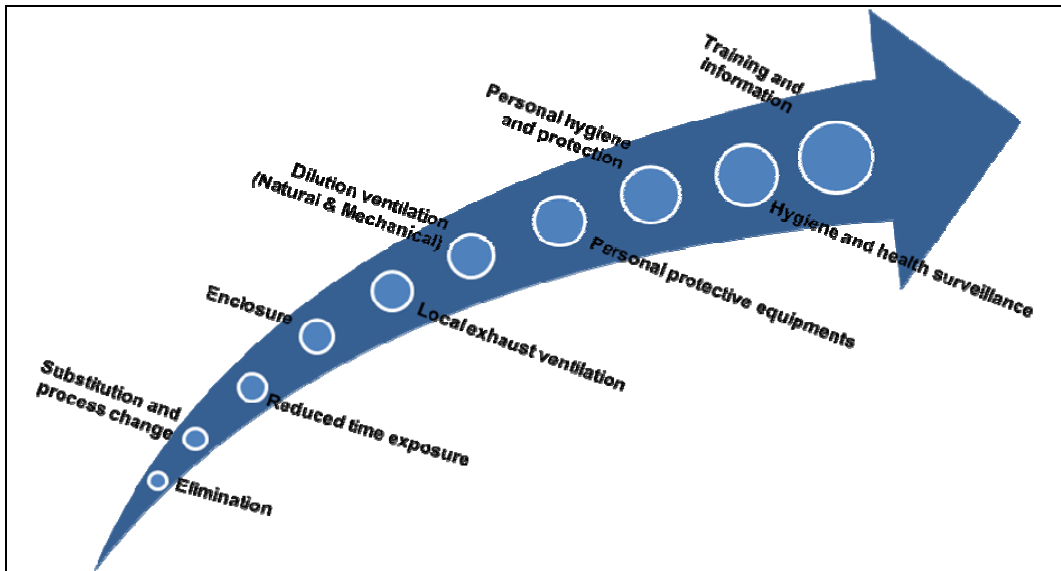
**Table 20: Criteria for selecting solvent**

- Non-ozone-depleting substance (non-ODS)
- Non-carcinogenic
- Good cleaning efficacy
- Low toxicity
- High Dielectric strength
- Compatible with component (e.g. non-corrosive, non-abrasive)
- Not leaving any residue
- Equal or lower cost compared to CTC
- Locally available

**[N.B.: Tables 3 through 19 provide relevant information for industries to apply one or more of these criteria for solvent selection as a CTC substitute]**

## 4. Guidance on hazard control

Improving occupational safety and health in the workplace is a comprehensive exercise that involves industry policy, resource allocation, occupational hygiene and health surveillance and active worker and employer training/participation. The most widely used options of controlling the hazards follow the hierarchy as shown in **Figure 07**.



*Figure 07: Hierarchy of control methods.*

### 4.1. Substitution and Process change

Several initiatives have been taken by the industries to phase out the use of hazardous substances. The use of cyanide in zinc and copper plating has been totally replaced by acid chloride non-cyanide plating process and is restricted for use, only in gold plating. Chromium, another hazardous substance used in the cooling system has been substituted with less hazardous zinc and orthophosphate-based systems.

Cyanide, which had been used in the heat treatment process of electronic industries, has been totally replaced by the gas carburization process. Similarly, mercury that was used in the process of manufacturing caustic soda (sodium hydroxide) has been eliminated totally by switching over to membrane process.

Wherever solvent degreasing is followed, the possibilities of replacing the same with acid or alkali degreasing method can be employed.

Other control methods are discussed in the following sections with priority given to administrative controls in the hierarchy since this method of control involves less resources, which may motivate the industries to get involved in the OSH management.

#### 4.2. Optimization of solvent use

In general, employees use excess amount of solvents during cleaning process, which lead to higher exposure and concentration in the workplace environment. It is necessary to use the required quantities of solvent not only to reduce the employee's exposures and environmental contamination but also to reduce the cost associated with solvent loss.

#### 4.3. Administrative control

Administrative control tries to bring the exposure to solvents to acceptable levels with least investment. The following control methods could be adopted in the industries using solvents for cleaning and other purposes.

**Segregation:** Segregation of the hazardous process is the best way to minimize the exposures of the work force. If segregation cannot solve the problem or it is not feasible to implement these control methods, engineering controls need to be introduced.

**Timing the operation:** Since most of the solvents are volatile in nature, cooler parts of the day like early hours or late evenings or nights can be chosen for carrying out the cleaning operations so that the evaporation of the solvents can be minimized and hence the exposure.

**Job Rotation:** This is another way of reducing the workers' exposure to the solvent vapors by rotating the job among the group of workers. However, care should be taken to employ this control method only when the permissible limits are marginally high.

**Supplementation of workers:** When the quantum of work is high and demands high levels of possible exposures, more workers can be deployed to execute the work with in short duration and also to keep exposure at minimum levels.

Apart from these, good work practices, housekeeping, proper maintenance schedules and health and hygiene surveillance could be followed for effective administrative control.

#### 4.4. Engineering control

Engineering control plays an important role for the reduction of workers exposure to airborne toxic chemicals or flammable vapours. The hazards can be physical (noise, radiations, illumination etc), chemical (dust, vapours, fumes, aerosols etc), biological (bacteria, virus, animal secretions and excretion etc) and ergonomic in nature. The type of engineering control might vary according to the hazards that exist in the workplace. Engineering control includes enclosures, industrial fans, exhaust fans, local exhaust ventilation etc. This section briefs about the commonly employed engineering controls across a wide spectrum of industries.

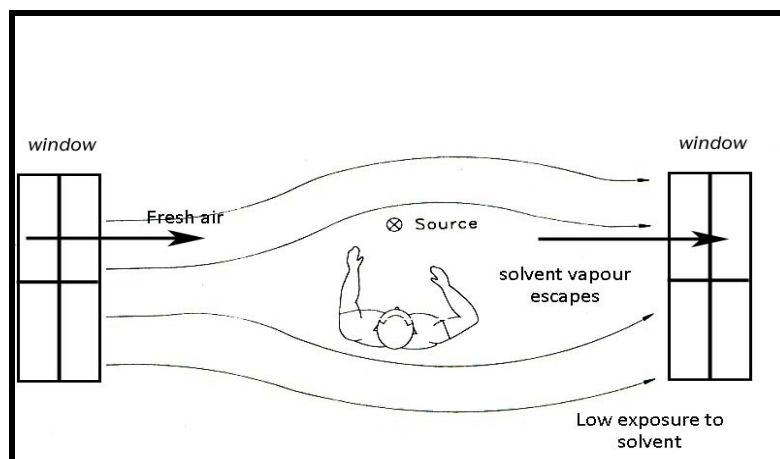
#### 4.4.1. Ventilation

Ventilation can dilute or exhaust the contaminated air away from the workplace by replacing with fresh and clean air. Ventilation is broadly divided into two categories namely natural and mechanical. The mechanical ventilation can be further divided into general and local exhaust. Requirement of the type of ventilation to a particular situation varies according to the nature and quantity of toxic chemicals used, method of use, workplace environmental condition and working posture.

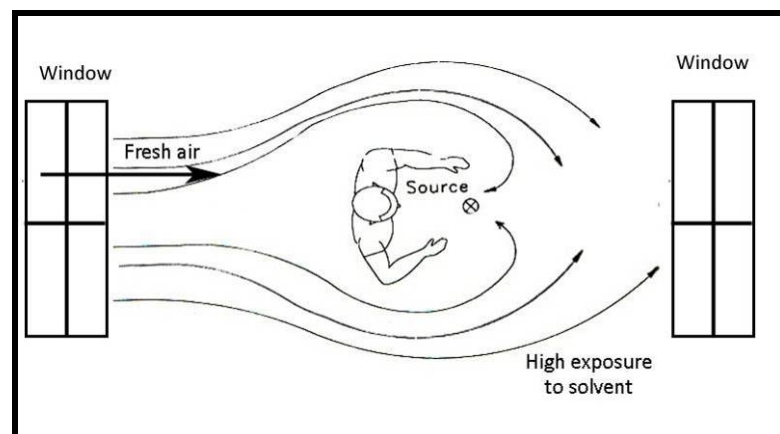
##### 4.4.1.1. Natural ventilation

Natural ventilation is a process where the fresh air is brought inside the workplace without use of energy i.e. industrial fans. Natural ventilation is achieved by keeping the doors and windows open with good cross ventilation. The ventilation in this case would be proportional to the size of the opening.

Position of the worker with respect to the air flow direction is an important parameter in determining the breathing zone concentration. Working in front of the wall will accumulate the contaminant causing additional exposure in the workplace. It is also recommended that the cleaning process should be carried out in a location near to the window and the position of the worker should be decided according to the wind direction.



**Figure 08: Model Natural Ventilation (Good Cross Ventilation)**



**Figure 09: Effect of workers' position with respect to direction of air flow**

**Figure 08** shows the best possible use of natural ventilation when the exchange of fresh air is utilized fully by opening both side windows situated just in opposite directions to each other. In this circumstance, the exposure can also be minimized by standing  $90^{\circ}$  to the air flow direction.

**Figure 09** is also an example of better use of natural ventilation but obviously a lower grade approach in comparison to the former one. In this case, the retardation of air flow occurs due to the position of the worker facing towards the downwind causing relatively more exposure.

It is to be remembered that the use of natural ventilation is ineffective when one side window is open and other side is closed. If there is no possibility of improving cross or natural ventilation, Mechanical ventilation such as industrial fans should be used to enhance the dilution of solvent vapor.

#### **4.4.1.2 Mechanical ventilation**

Mechanical ventilation is the process where the outside air is forcefully allowed into the workplace by means of mechanical devices, usually exhaust and industrial fans. There are two methods by which the concentrations of the contaminants are diluted, one by general dilution and the other by capturing the contaminants at the source.

##### ***Industrial and exhaust fans***

Generally, industrial fans (**Figure 10**) are used to provide comfort to the workers rather than dilution purpose. Positioning of these fans in the workplace is crucial in reducing the concentration to acceptable levels. When the industrial fans are used in opposite directions, this would increase the concentration of contaminants by means of accumulation process. However, the accumulated contaminants could be diluted by means of providing exhaust fans (**Figure 11**) together with the use of industrial fans. This combination along with good natural ventilation can substantially reduce the workplace concentration to a reasonable level.



**Figure 10 Industrial Fan**

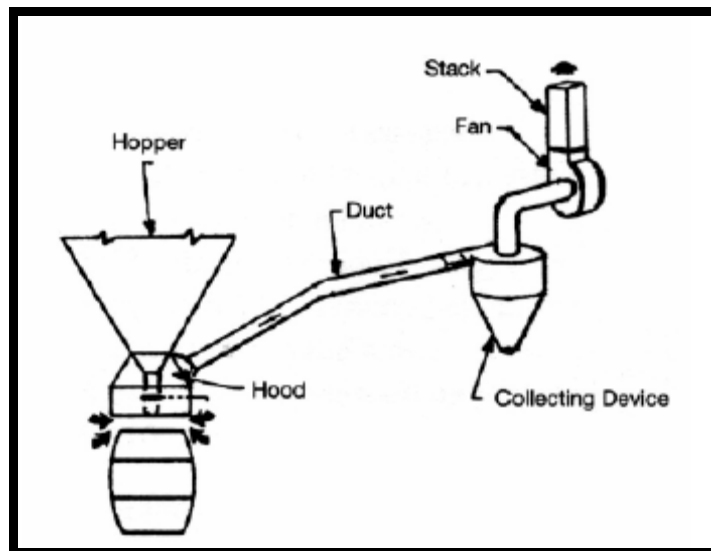


**Figure 11 Exhaust Fans**

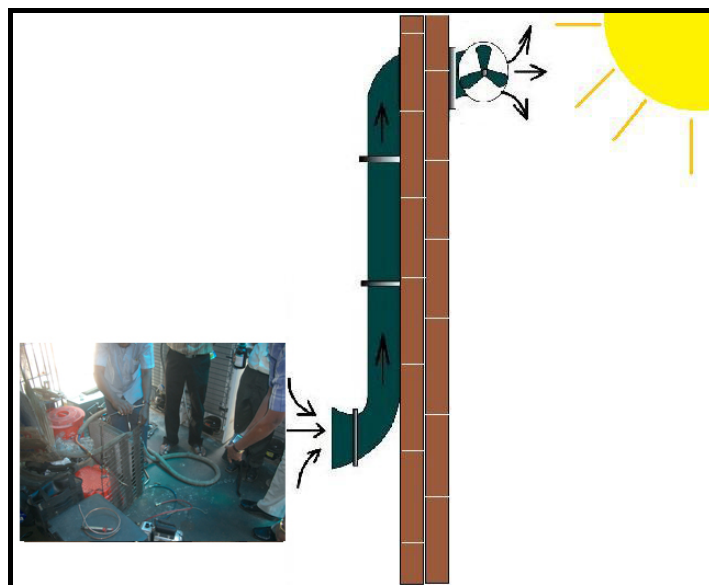
### ***Local Exhaust System (LES/LEV)***

Local Exhaust System (LES) and Local Exhaust Ventilation (LEV) capture the contaminants at the source. The key difference between the nomenclatures is the presence of air filtering or purifying device in LEV. Since LEV is highly expensive because of the air purifying device and costly to maintain, most of the industries do not use this system. LEV (**Figure 12**) is highly recommended because the contaminants are removed before entering the environment, whereas in LES, the contaminants are exhausted directly into the external environment. LES (**Figure 13**) is a cost effective alternate to LEV and since most industries use widely due to its cost effectiveness, LES is recommended in this manual as first choice compared to LEV. Both LEV and LES can be designed with flexible duct (**Figure 14**) or mobile (**Figure 15**) that can be used in other work stations.

The LES can be applied to a range of tasks involving small, medium and large scale operations. Where ever a total enclosure of a process is impossible, this kind of system can be used.



***Figure 12: Local Exhaust Ventilation and its Components***



***Figure 13: Local Exhaust System (LES)***



In order to ensure the highest efficiency of capture, the hood should be as close as possible to the point of emission of hazardous vapours. The main advantage of the LES is that it requires less airflow than the dilution ventilation for the similar application. However, the LES is slightly more difficult to design relative to dilution ventilation. The hood and capture point must be properly designed with emphasis on shape and position. Similarly, the duct and the fan must be designed appropriately to draw the desired volume of air to remove the contaminants. While designing a LES, it should be ensured that the contaminants are removed to a safe place to prevent the spread of hazardous exposure conditions. If the contaminated air from the LES is let into the workplaces, a suitable filtering/purifying device should be installed or the air should be treated to avoid further hazard as in the case of LEV.



*Figure 14: Stationary LEV with flexible duct*



*Figure 15: Mobile LEV with flexible duct*

#### **4.5. Good Housekeeping**

Engineering controls do not provide a complete protection against hazards in certain cases. Although good engineering control measures are in place, comprehensive hygiene practices are required to keep the contaminants under control. It is important that a company emphasizes good housekeeping practices regularly in order to prevent accidents, reduce operation and handling time, improve health and hygiene, use of available space in the workplace effectively and reduce disposal cost.

Good housekeeping practices that can be implemented through various initiatives are as follows:

##### **4.5.1. Labeling**

Chemical labeling practice must be improved to communicate the hazardous nature of the solvent used in the process (**Figure 16**). Labeling should be practiced in accordance to the Globally Harmonized System.



**Figure 16: Chemical label on bottle**

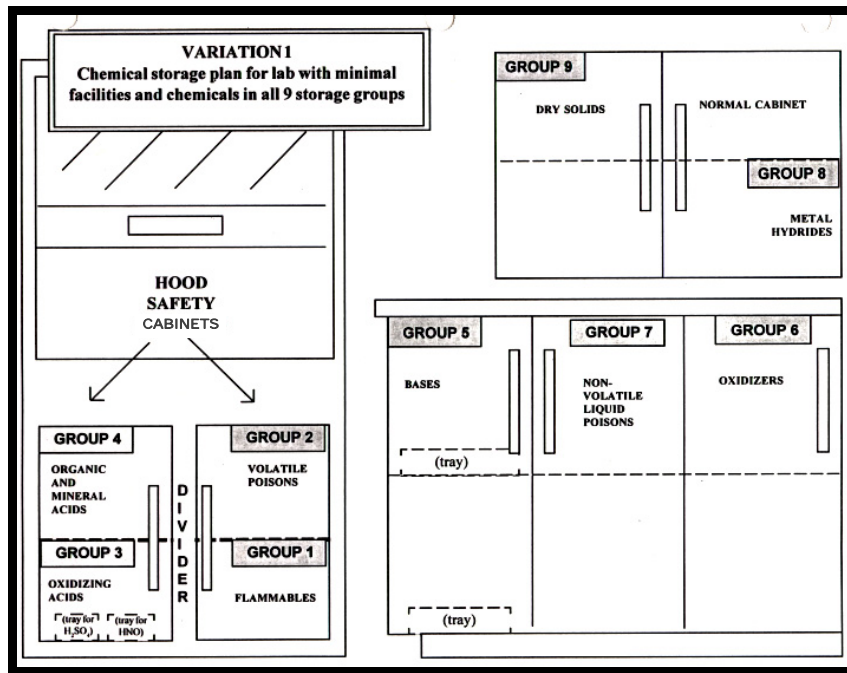
The following practices should be considered while communicating the hazard nature.

- Labeling the containers with key information (Flammability, Health Risks, etc.)
- Preparing the labels in local language
- Labels with contain hazard symbols

#### **4.5.2. Storage**

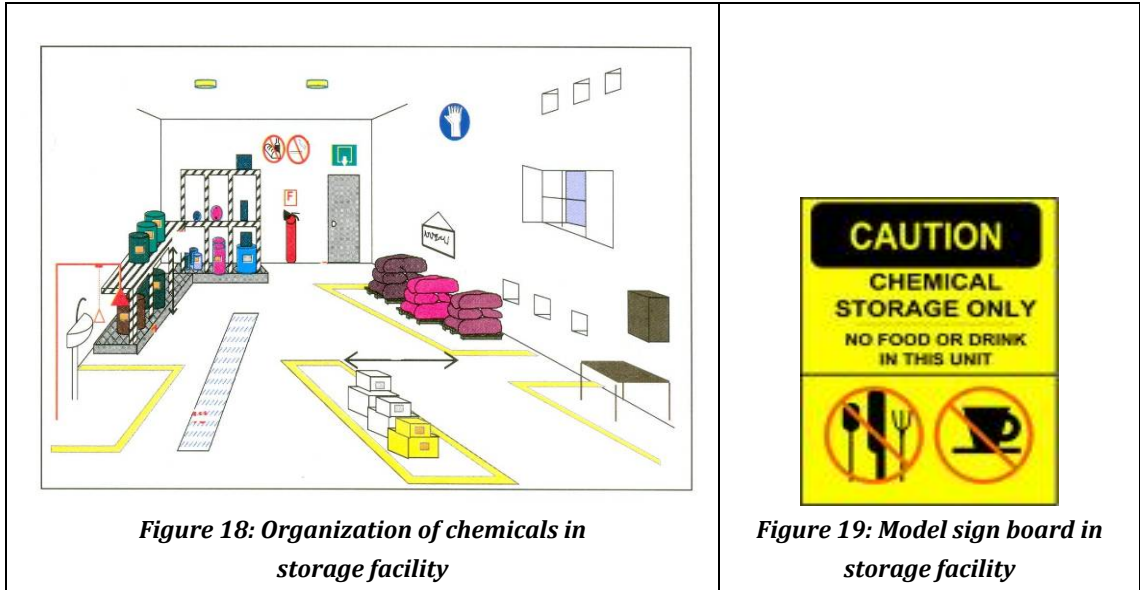
Safe storage is an important stage of the chemical life cycle. Any chemical storage facility should meet certain level of standard irrespective of size and scale of operation. This section provides basic instruction for chemical storage that may be required to meet the expected standards. These include

1. Proper layout of chemical store (**Figure 17**):
  - a. The storage room should be separated from production areas, sources of ignition such as electrical panel and transformers.
  - b. The chemical store should have adequate (minimum two) emergency exits (doors and windows).
  - c. The pathway should be enough for comfortable movement of forklift or trolley
  - d. The entry and exit should be kept free of obstacles.
  - e. The store room should be provided with ramp facilities for the easy transport of chemicals.
  - f. The floor of the store room must be even and should be non permeable to prevent soil contamination resulting from chemical spill.
  - g. The store should have chemical drain system that is connected to the waste treatment facility.



*Figure 21: Layout design of chemical store facility*

2. Organization
  - a. An inventory of chemicals in the store.
  - b. Categorizing the chemicals depending on the hazardous nature (use MSDS).
  - c. Storing the chemicals not directly on the floor.
  - d. Separating the incompatible chemicals (**Refer Table 21 & 22**) (**Figure 18**).
  - e. Keeping the heavy/bulky/liquid substances at the bottom and small containers or lighter containers at the top of the shelf.
3. Chemical labeling
  - a. Label should have text or pictorial presentation of hazards.
  - b. Labeling should be done in accordance with Globally Harmonized System of Classification and Labeling of Chemicals (GHS) (**Figure 19**).



**Figure 18: Organization of chemicals in storage facility**

**Figure 19: Model sign board in storage facility**

#### 4. Safety systems

- a. Restricted access to the chemical store.
- b. Keeping the chemical store room under lock and key access or swipe card access.
- c. Fire extinguishers placed in accessible locations.
- d. Electrical switches, boxes, fittings should be flame and explosion proof.
- e. Controlling the environmental conditions such as temperature, humidity and air velocity by providing natural or mechanical ventilation.
- f. Providing openings at floor level to dilute heavy chemical substances that have high specific gravity.
- g. Installing emergency shower or eye wash facility inside the chemical store.
- h. First aid box with complete set of medicines and accessories.

**Check the Safety Systems at periodic intervals**

#### 5. Sign boards

- a. Display of 'Restricted Entry' sign board at the entrance of the store.
- b. Emergency Exit sign boards should be clearly visible and should be in bilingual
- c. "No Smoking" sign board both inside and outside the store room.
- d. Sign boards of personal protective equipments should be displayed and should be specified to the task carried.

**Requirements:**

- Inspection of storage area and drain at periodic intervals to maintain them in good condition.
- Always using standard storage shelves with side shield.
- Corrosive chemicals should be stored in corrosion proof shelves.
- Secured the storage shelf to the wall to prevent from fall during earthquake, shocks, tremors and vibrations.
- Inspecting for damaged containers and replace them immediately if noticed.
- Returning the expired chemicals to the manufacturer or dispose according to the manufacturer protocol or standard procedures.
- Ensuring the safety systems are not bypassed.
- Providing sufficient and appropriate personal protective equipment.
- Adequate number of firefighting equipment should be made available to the capacity of the storage facility and should be in working condition.
- At least, one fire- fighting equipment should be placed outside the storage facility to gain inside access during fire.
- Elimination of all ignition sources inside the chemical store.
- Emergency shower or the eye wash facility must be in working condition. Draining the stagnant water periodically from the pipe to avoid biologically contaminated water coming in contact with the body or eye.
- Periodical replacement of expired medicines in the first aid box.
- Providing separate welfare room for having lunch.
- Training to employees in safe handling of chemicals.

**Standards & Regulation:**

- Refer IS: 5571-2000, Guide for Selection of electrical equipment for Hazardous areas.
- Refer IS: 7724-1975 for Specification for Sand-Filled Protection of Electrical Equipment for Use in Explosive Atmospheres.
- Manufacture, Storage and Import of Hazardous Chemicals Rules (1989), for list of hazardous chemicals and threshold quantities for storage

**Table 21: General Chemical Storage Compatibility\***

+ means these groups may be stored together in most cases			* means store these groups AWAY from water and water sources			
Group 1 +	Group 2 +	Group 3 + *	Group 4 *	Group 5 *	Group 6 *	Group 7 *
<b>Halogenated compounds</b>	Ketones	Organic acids	Amines & Alkanolamines	Caustics	Oxidizers	Inorganic acids
<b>Olefins</b>	Saturated hydrocarbons	Acid anhydrides	Ammonia	Hydroxides	Nitrates	Hydrochloric
<b>Alcohols, glycols &amp; glycol ethers</b>	Aromatic hydrocarbons	Acetic acid		Carbonates	Persulfates	Sulfuric
<b>Phenol</b>	Oils					Phosphoric
<b>Chloroform</b>	Aldehydes					Halogens
<b>Dyes &amp; stains</b>	Olefins					
<b>Ethidium bromide</b>	Esters					
	Formaldehyde					

Source: <http://orf.od.nih.gov/AboutORF/Organization/>

\* Read vertically for compatible chemicals

**Table 22: Segregation of Chemicals by Type**

<b>Refer to Material Safety Data Sheets (MSDSs) for specific incompatibilities.</b>			
<b>1.</b>	<b>Acids</b>	<i>Segregate from</i>	Organic acids Flammable, and/or combustible materials Active metals such as sodium, magnesium, and potassium Chemicals which can generate toxic gases upon contact such as sodium cyanide and iron sulfide Caustics
<b>2.</b>	<b>Caustics</b>	<i>Segregate from</i>	Acids
<b>3.</b>	<b>Flammables</b>	<i>Segregate from</i>	Oxidizers
<b>4.</b>	<b>Oxidizers</b>	<i>Segregate from</i>	Flammable, combustible materials Reducing agents (e.g., zinc, alkaline metals)
<b>5.</b>	<b>Compressed Gases</b>		Cylinders should be secured in an upright position with safety caps in place – Should be chained in a secured manner from falling; Store flammable gases separately from other gases

#### 4.5.3. Clean up procedures

Use of lubricating oils and greases is essential in industrial process. During use, spills can happen during the transfer from one container to another, or on the machine. Generally solvents are used to clean the spilled or leaked oils and dirt on the machine. Certain dusts generated during the process deposited on the machine are also cleaned using solvents. The dust and dirt remains on machine would pose a substantial risk to the employees' exposure in addition to the exposure that occurs from use of cleaning solvents. Regular cleanup procedures, would therefore, reduce the use of chemicals for cleaning, thus reducing the exposures. Chemical spill occurs during cleaning and this is an additional hazard in the workplace. Hence, the following should be practiced to minimize the employees' exposure as well as the environment contamination. The following should be considered as good practices:

- Removal of dust and dirt regularly from the machines and floors
- Regular clean up during the shift and day-to-day cleanup
- Ensuring spill control programme to prevent health and environmental risks
- Following proper waste disposal protocols
- Periodical maintenance of the equipments and accessories

#### 4.5.4. Training

The purpose of the training is to communicate to the worker about the harmful nature of the chemical substances they are handling. Safe handling of chemicals encompasses several aspects amongst which few are more critical to communicate to the employees for effective use and management. For effective

management of chemicals, the employees should be provided periodical training in the areas mentioned below:

- Recognizing and understanding the hazardous nature of the chemicals
- Importance of Material Safety Data Sheet (MSDS)
- Good house keeping
- Proper handling of chemicals
- Handling the chemical spills and proper disposal methods
- Managing the emergency situations - First aid, handling fire extinguishers, communications.
- Checking the functioning of pollution control systems.
- Incident or failure reporting systems
- PPE - use, storage, cleaning and maintenance

Whenever a worker is involved in new process or handling new chemical substances, adequate training should be provided before involved in new tasks. Induction training should be made mandatory for newly employed workers. For detailed information on good housekeeping refer GTZ's 'Chemical Management Guide' at [www.chemicalmanagement.org](http://www.chemicalmanagement.org).

#### **4.6. Personal hygiene practice**

Exposure to chemical substances does not necessarily arise from handling chemical substances during the work process, but also from poor hygiene practices of the employees. Exposures can significantly be reduced by means of following a simple cost effective personal hygiene measures. Some common personal hygiene practices are:

- Keeping the hands clean while working
- Trimming the nails periodically to avoid contaminant deposits
- Avoiding working with open wounds
- Washing the hands before eating
- Use of detergents for washing hands
- Avoiding smoking and eating at workplaces
- Cleaning the personal protective equipments and storing it in proper place
- Not reusing the disposable articles (PPEs)
- Wearing clean work clothes
- Changing the work clothes before leaving the workplace
- Having shower at the end of the shift (to reduce the dermal exposures and minimize the transportation of the contaminants home)



#### 4.7. Personal Protective Equipment (PPE)

Personal protective equipments are devices that are worn by workers to protect exposures form toxic substances. The use of personal protective equipment (PPE) is an immediate solution but it only affords protection for a short duration. The use of PPE should be considered as the last in the hierarchy of control. Though use of PPE is the last measure of control, it can be permitted as an interim method of control under circumstances where the engineering control is in the process of implementation. PPE can also be considered as supplementary solution, where it is not possible to completely control hazards by engineering and administrative methods.

The most commonly needed PPE are:

- Respirators
- Goggles or Spectacles
- Protective clothing (whole body and hand protection)
- Shoes
- Hearing protection

It is the employer or the managements' responsibility to provide appropriate PPE and training to employees to keep them in good condition and periodically inspect and replace whenever necessary.

The following is the sequence for selecting the PPEs:

- Identifying the potential hazards
- Determining the types of protective equipment available for the present hazards
- Selecting appropriate protective equipment
- Providing a variety of sizes to properly fit all users
- Selecting equipment that is compatible with other PPE
- Evaluating the effectiveness of the PPE

It is also the employees' responsibilities to wear the provided PPEs, maintain in good condition and report any uneasiness and damage immediately to the supervisor or manager to get it replaced.

**Complete protection depends on appropriate type, fit and training to use and maintenance of the PPEs**

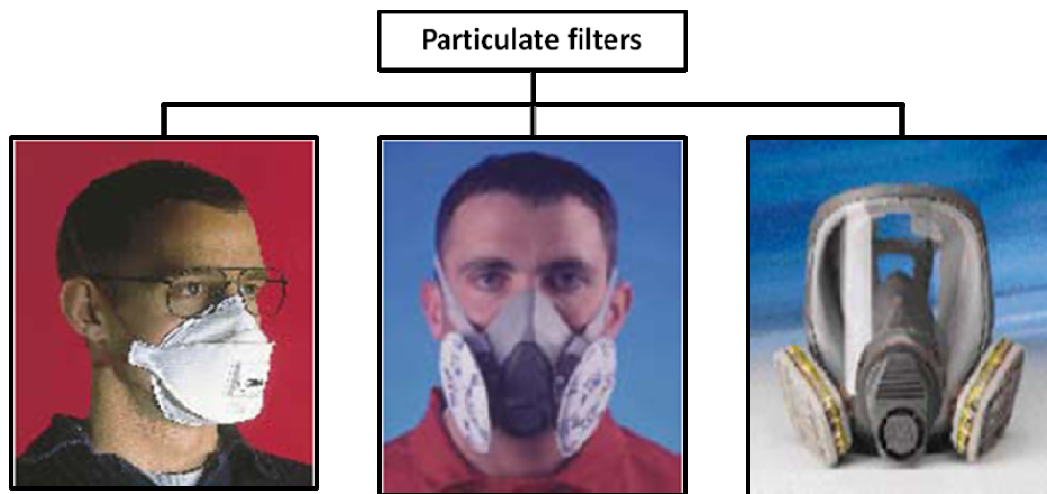
##### 4.7.1. Respirators

Respirators protect from the user entry of substances through inhalation and include different types, covering mouth and nose (quarter face), mouth, nose and chin (half face) and mouth, nose, and face (full face). Depending on the mechanism of protection the respirators are classified in two; air purifying and supplied air respirator.

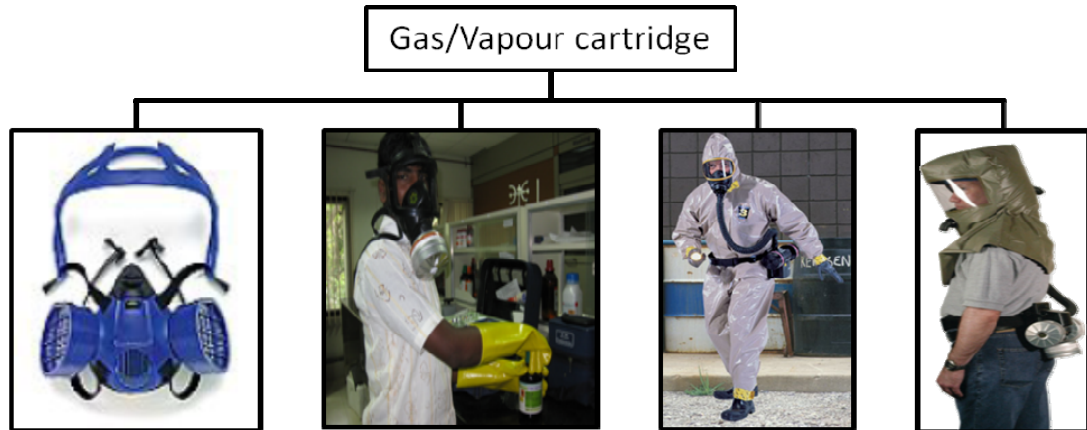
#### 4.7.1.1. Air-purifying respirators

An air-purifying respirator causes ambient air to be passed through an air-purifying element that removes the contaminants. Air is passed through the air-purifying element by means of the breathing action (negative pressure respirators). Use of negative pressure respirators generally increases the breathing resistance and most of the users may feel uncomfortable. To provide low breathing resistance, another type of respirator (powered air-purifying respirators, or PAPRs) is used where the air is constantly made to flow through the respirator by using a blower.

The type of air-purifying element will determine which contaminants are removed. Contaminants are removed by filtering particles e.g., dusts, metal fumes, mists, aerosols (**Figure 20**) or by purifying gases or vapours through absorbing or adsorbing material provided in the cartridge (**Figure 21**). Filters of varying efficiencies (95%, 99% and 100%) are used to remove aerosols. The choice of filter depends on the properties of the aerosol; normally, particle size is the most important characteristic. Chemical cartridges are filled with a material that is specifically chosen to absorb or react with the vapour or gaseous contaminant. **Table 23** provides a list containing type of respirator that can be selected to fit to the air purifying respirator. **Figure 22** shows the assembly of chemical cartridge to the full face piece respirator.



**Figure 20: Air purifying Respirator for Particles-Disposable Half face filter, Reusable Half face and Full face piece**













**Figure 21: Air purifying Respirator for Gas/Vapours- Half face mask with dual cartridge, Full face mask with single cartridge, Full face PAPR with tight fitting and Full face PAPR with loose fitting (hood).**



**Figure 22: Respirator + Cartridge = Respirator and cartridge assembly**

There are workplace environments, where the contaminants are present in both particle and in gaseous or vapour forms. In this specific type of situation a combination of filters should be used, pre filter (particle) followed by appropriate chemical cartridge.

**Table 23: Selection of chemical cartridge and their colour code with respect to type of chemical**

The combination of colour code and filter type help you to select the right type of filter for the chemical you should get protection		
Colour code	Filter/ Cartridge type	For which chemicals indicated
	AX	Gases and vapour of organic compounds with boiling point > 65°C
	A	Gases and vapour of organic compounds with boiling point < 65°C
	B	Inorganic gases and vapours e.g. chlorine, hydrogen sulphide, hydrogen cyanide,
	E	Sulphur dioxide, hydrogen chloride
	K	Ammonia
	CO	Carbon monoxide
	Hg	Mercury vapour
	NO	Nitrous gases including nitrogen monoxide
	Reactor	Radioactive iodine including radioactive methyl iodide
	P1- P3	Particles

#### 4.7.1.2. Supplied-air respirators

Atmosphere-supplying respirators are a class of respirators that supply clean compressed air through hose at breathing zone independent of the workplace atmosphere. One type is commonly called an *air-line respirator* (**Figures 23 & 24**) and operates in one of three modes: demand, continuous flow or pressure demand. Respirators operating in demand and pressure-demand modes can be equipped with either a half-face or a full face piece inlet covering. The continuous-flow type can also be equipped with a helmet/hood or a loose-fitting face piece.



**Figure 23: Supplied Air-line respirator**



**Figure 24: Supplied Air-Line Respirator-Helmet type**

A second type of atmosphere-supplying respirator, called a *self-contained breathing apparatus* (SCBA), is equipped with a self-contained air supply (**Figures 25 & 26**). It may be used for escape only or for entry into and escape from a hazardous atmosphere. The air is supplied from a compressed-air cylinder that can be carried on the back or by a chemical reaction.



**Figure 25: SCBA with chemical protective clothing**



**Figure 26: SCBA with chemical protective clothing and helmet**

Some supplied-air respirators are equipped with a small supplemental air bottle. The air bottle provides the person using the respirator with the ability to escape if the main air supply fails.

Industries providing respiratory protection for the workers should administer respirator programme to successfully implement the inhalation protection. The respiratory protection programme should have program administrator, written procedures for implementation of this programme, training for selection, using and maintenance, medical evaluation for use of respirator and use of approved respirators. The complete reference material for administering the respirator programme can be downloaded from <http://www.cdc.gov/niosh/docs/2005-100/pdfs/05-100.pdf>

### 4.7.2. Gloves

Hand protection is for protecting from hazards such as those from exposure to harmful substances, extreme temperatures, burns, cuts and abrasion. In industries, workers are exposed to solvents during transferring and cleaning the components with bare hands. Solvents are absorbed through skin very quickly by passive means and in processes where high pressures are applied the absorption becomes more significant.

Most gloves come in different sizes, viz. extra small, small, medium, large, and extra large; some come in numbered sizes. Tight-fitting gloves can cause restricted motion and discomfort while loose-fitting gloves can be hazardous. Sizes may vary among styles and manufacturers.

The selection of suitable protective gloves is a complicated procedure and the degree of protection they give is not always easy to establish. It is especially important in these situations that it is advisable to seek expert help or from the manufacturer or distributor of the chemical agent or glove manufacturer. There is no glove currently available that is resistant to all chemicals or for an indefinite period of time.

In order to select a suitable glove, the following requirements should be considered.

- Appropriate for the risk(s) and the conditions where it is used.
- Consider the exposure duration of solvents and choose a glove with an appropriate breakthrough time.
- Take into account the ergonomic requirements and state of health of the person wearing it (working with wounds in hand etc.).
- Should fit the user correctly, if necessary, after adjustments.
- Either prevent or control the risk involved without increasing the overall risk.

Proper selection should, therefore, be made taking into consideration about the health of the person wearing the gloves, the workplace conditions and the type of protective glove used. Improper wearing of gloves has every possibility to increase the wearer's overall risk to health because:

- contaminant may get inside the glove to reside permanently against the skin which could cause greater exposure than if a glove had not been worn at all; or,
- wearing a glove for extended periods can lead to the development of excessive moisture (sweat) on the skin which in itself will act as a skin irritant; or,
- wearing gloves manufactured in natural rubber (latex) can cause an allergic reaction in susceptible individuals, causing the skin disease contact urticaria.

Because glove selection is a complex issue, employers and others responsible for selection will inevitably demand a simple, easy-to-read guide. **Figures 27 & 28** and **Table 24** provide a simple guide to select with choice of glove material for selected chemicals.

The following factors should be considered during glove selection.

- Type of solvents used
- Frequency and duration of solvent contact (often to rarely)
- Nature of contact (total immersion, splash, mist)
- Abrasion, puncture, tear resistance requirements of the job
- Body part to be protected (hand only, forearm, arm)
- Grip requirements (dry grip, wet grip, oily)
- Size and comfort requirements



**Figure 27: Chemical protective gloves**



**Figure 28: Chemical Protective clothing**

**Table 24: List of Recommended Glove Materials**

Sl. No	Solvents	Recommended protective clothing
1	Acetone	8 hr: Butyl, PE/EVAL, Barricade, CPF3, Responder, Trelchem, Tychem
2	Chloroform	8 hr: PVA, Viton, PE/EVAL, Barricade, Responder, Trelchem, Tychem 4 hr: Teflon
3	Cyclohexane	8 hr: Nitrile, Viton, PE/EVAL, Barricade, Responder 4 hr: PVA, Teflon
4	Dichloroethane	8 hr: Tychem
5	Ethyl acetate	8 hr: PE/EVAL, Barricade, CPF3, Responder, Trelchem, Tychem 4 hr: PVA, Teflon
6	n-Hexane	8 hr: Nitrile, PVA, Teflon, Viton, PE/EVAL, CPF3, Responder, Trelchem, Tychem 4 hr: Barricade
7	Isopropyl alcohol	8 hr: Butyl, Nitrile, Viton, PE/EVAL, CPF3, Responder 4 hr: Neoprene, Teflon
8	d-Limonene	Contact the manufacturer for recommendations
9	Methanol	8 hr: Butyl, Teflon, Viton, Saranex, PE/EVAL, Responder, Trelchem, Tychem
10	Methyl ethyl ketone	Butyl gloves
11	Methylene chloride	8 hr: PVA, PE/EVAL, Responder, Trelchem, Tychem 4 hr: Teflon, Barricade
12	Mineral turpentine	Contact the manufacturer for recommendations
13	NC thinner	Contact the manufacturer for recommendations



Sl. No	Solvents	Recommended protective clothing
14	N-Methyl pyrrolidone	Contact the manufacturer for recommendations
15	Perchloroethylene	Nitrile latex gloves
16	Toluene	8 hr: PVA, Teflon, Viton, PE/EVAL, Barricade, CPF3, Responder, Trelchem, Tychem
17	Trichloroethylene(TCE)	8 hr: PVA, Viton, PE/EVAL, Barricade, Trelchem, Tychem 4 hr: Teflon, Responder
18	White petrol	Contact the manufacturer for recommendations
19	Xylene	Nitrile latex gloves

Butyl = Butyl Rubber (Gloves, Suits, Boots)	Viton = Viton™ (Gloves, Suits)
Neoprene = Neoprene Rubber (Gloves, Suits, Boots)	Saranex = Saranex™ coated suits
Nitrile = Nitrile Rubber (Gloves, Suits, Boots)	PE/EVAL = 4H™ and Silver Barricade = Barricade™ coated suits
PE = Polyethylene (Gloves, Suits, Boots)	CPF3 = CPF3™ suits
PVA = Polyvinyl Alcohol (Gloves)	Responder = Responder™ suits
PVC = Polyvinyl Chloride (Gloves, Suits, Boots)	Trelchem = Trelchem HPS™ suits
Teflon = Teflon™ (Gloves, Suits, Boots)	Tychem = Tychem 10000™ suits

\* Department of Labour, Occupational Safety and Health Administration, 3151, 2000 (Reprinted) USA.

8 hr = More than 8 hours of resistance to breakthrough >0.1 µg/cm<sup>2</sup>/min.

4 hr = At least 4 but less than 8 hours of resistance to breakthrough >0.1 µg/cm<sup>2</sup>/min.

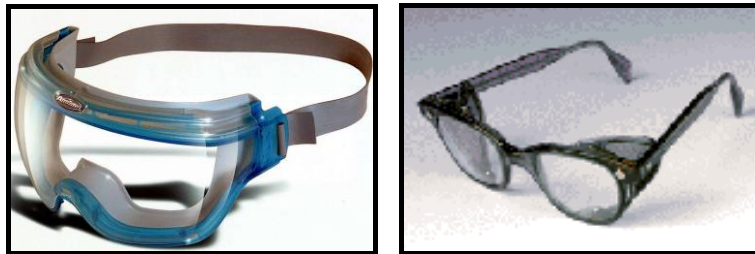
To ensure enough protection, adequate training should be provided to employees for use, store and maintenance.

## Legal obligation

- OSHA CFR 29: Standard Number 1910.138 Hand Protection.
- IS: 8807-1978 (Reaffirmed 1996)-Guide for Selection of Industrial Safety Equipment for Protection of Arms and Hands.
- IS: 8519-1977 (Reaffirmed 1996)-Guide for Selection of Industrial Safety Equipment for Body Protection.

### 4.7.3. Goggles/Spectacles

Chemical Splash Goggle should be used for protection of eyes from any accidental solvent splash (**Figures 29**). For certain processes that involve occasional cleaning with brushing operation a spectacle (**Figure 30**) with side shields should be provided.



*Figure 29 & 30: Chemical Splash Goggles and spectacles*

Eye wash facilities like eye wash bottle (**Figure 31**); eye cup (**Figure 32**) or eye wash fountain should be made available near the working area for any emergency situation.



*Figure 31 & 32: Eye wash bottles and eye cup*

#### Requirements:

- Ensure to buy goggles or spectacles certified by CE, ANSI/ NIOSH, ISO/EN.
- Ensure to buy safety glasses certified by competent/regulatory authorities.
- Clear glass is required to check for effective cleaning.
- Workers in need of lens correction should be provided with optical corrected safety glass.
- In the presence of electrical hazard metal framed glass should be avoided.

- Any defective or broken parts should be replaced immediately.
- Glass should be cleaned frequently with muslin cloth and stored in secured place.

#### Legal obligation

- The eye protection device should meet the ANSI standard [ANSI Z87.1-1989], [CAN/GSA Standard Z94.3-99] or for use in
- OSHA CFR29: Standard number 1910.133, Eye and face protection
- Indian Standards [IS: 7524 (part I)-1975 and IS: 2553-1971. Referred from Guide for Selection of Industrial Safety Equipment for Eye, Face and Ear Protection, IS: 8520-1977 (Reaffirmed 1996)].

#### 4. 7.4. Safety shoes

Safety shoes are available for different types of hazards, such as protection against heat, electricity, slip, falling objects, sharp objects, acids and alkalis and solvents. Solvent proof safety shoes (**Figure 33**) should be provided to avoid dermal contact from the occurrence of spills that are not removed immediately in the workplace. During fire, safety shoes that are heat resistant should be used for involvement in fire extinction process.



*Figure 33: Safety shoes*

#### Requirements:

- Ensure to buy footwear certified by CE, ANSI/ NIOSH, ISO/EN.
- Chemical resistant footwear should be used to provide protection against corrosives and toxic substances.
- Safety footwear should also suit protection from additional hazards such as electric shock and slippery surface,
- Select good fit footwear to avoid cramp or chafe.
- Clean the footwear frequently and sterilize according to the instructions of manufacturer.
- Keep the footwear as dry as possible. If they get wet, dry slowly.
- Wash feet and socks daily before wearing the footwear.

- Wear cotton or woollen socks to absorb perspiration.
- Replace the damaged sole before the wearing down of inner sole.

- OSHA-CFR29: Standard number 1910.136, Occupational foot protection.
- Protective footwear must meet [ANSI Z41-1999], [CAN/CSA Standard Z195-M92] or equivalent design requirements.
- For use in India refer IS: 10667-1983 Guide for Selection of Industrial Safety Equipment of Foot and Leg.

#### 4.8. First aid measures

Providing first aid is an important and instant process in the injury or illness management. Failing to provide first aid immediately after the incident may lead to permanent damage to the worker. Hence, immediate aid can make a great difference in preventing the deterioration of health while dealing with injured person (**Figure 34**).

The employer should provide certified first-aid equipments and medicines at all times and should be easily accessible throughout the place of work. First aid stations and rooms should be equipped with gloves, chemical protective clothing, and masks for protection against direct contact with blood and other body fluids. The medicines in the first aid box must be inspected periodically for expiry dates together with other kits and if found should replace with new batch of medicine and kits.

Remote sites and in places especially where lone workers are involved, written emergency procedures should be in place for dealing with cases of trauma or serious illness up to the point at which worker can be transferred to an appropriate medical facility.



**Figure 34: Necessity for first-aid**

In case of any incident while handling solvents, the first aid measures to be followed are provided in **Tables 3 to 19**. The workers should be trained to carry out first aid measures or a trained specialist should be available in each department to handle the emergency situation. After providing first aid measures, it is advisable to seek medical advice to prevent any future health implications.

#### 4.9. Fire extinguishers

Equipping facilities with fire detectors, alarm systems, and fire-fighting equipment is vital in combating the fire at an early stage by preventing the escalation into major catastrophes. The equipment should be maintained in good working order and be readily accessible. It should be adequate for the dimensions

and use of the premises, equipment installed, physical and chemical properties of flammable substances present. An example of CO<sub>2</sub> type of fire extinguisher is shown in **Figure 35**.

### Requirements

- Manual firefighting equipment that is easily accessible and simple to use must be provided
- Fire and emergency alarm systems must be both audible and visible



### Different types of fire extinguishers

**Class A** extinguishers are effective on ordinary combustibles such as wood, paper, cloth, rubber and certain types of plastic. The extinguisher cools the temperature of the burning material below its ignition temperature. The extinguishers use pressurized water, foam or multi-purpose dry-chemical agents. Class A extinguishers carry a numerical rating that indicates how large a fire one can safely put out with that extinguisher.

**Class B** extinguishers should be used on flammable liquids or gases such as gasoline, kerosene, paint, paint thinners or propane. Class B extinguishers may come in several types including foam, carbon dioxide, ordinary dry-chemical, multi-purpose dry-chemical or halon replacements.

**Class C** extinguishers are to be used specifically on electrical fires such as appliances, switches or power tools. Class C extinguishers may contain carbon dioxide, ordinary dry-chemical, multi-purpose dry-chemical or halon replacements.

**Class D** extinguishers should only be used on combustible metals such as magnesium, titanium, potassium or sodium. Class D extinguishers are made with agents specially designed for the material involved. In most cases, they absorb heat and cool the material below its ignition temperature. Class-D fires react violently to water and other types of chemicals. Class D extinguishers carry only a letter rating to indicate their effectiveness on certain amounts of specific metals. Sand is an appropriate material to put out small metal fires, if a class D extinguisher is not available. Only use a fire extinguisher when it is safe to do so; if the fire is too big and is spreading or threatening to block the path to escape leave the area immediately. If necessary, don't hesitate to use the extinguisher to clear an escape path.

#### **4.10. Environmental Control Guidance**

##### **4.10.1. Safe transport**

Transport of chemicals is a major activity in industry irrespective of the quantity used. Transport can occur within the industry (onsite) or outside the industry (offsite). There are few national and international regulations that guide the users in safe transport of chemicals. The relevant key elements for safe transport provided below may be applicable to both onsite and offsite transport.

- Emergency centre to handle accident
- Transport the chemicals in certified or good fit vehicles or carriers.
- Ensure proper packing and labeling with safety and health information (**Figure 36, 37 & 38**) during transport.
- Permit only trained and fit vehicle drivers.
- Transport en route should be identified and informed to competent authorities.
- Track the truck or carriers until the destination point.
- Transport emergency (TREM) cards should be carried during transport.

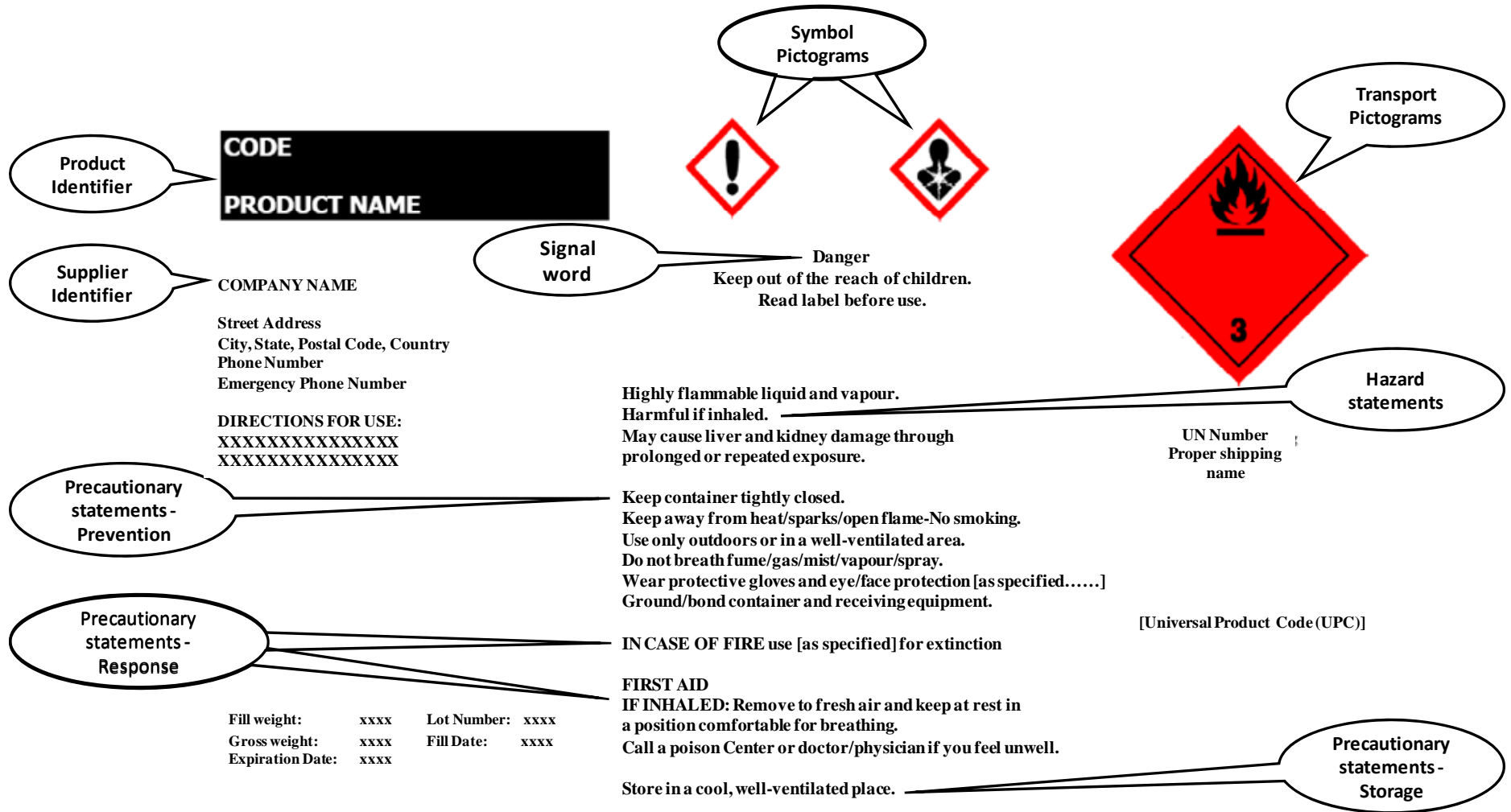
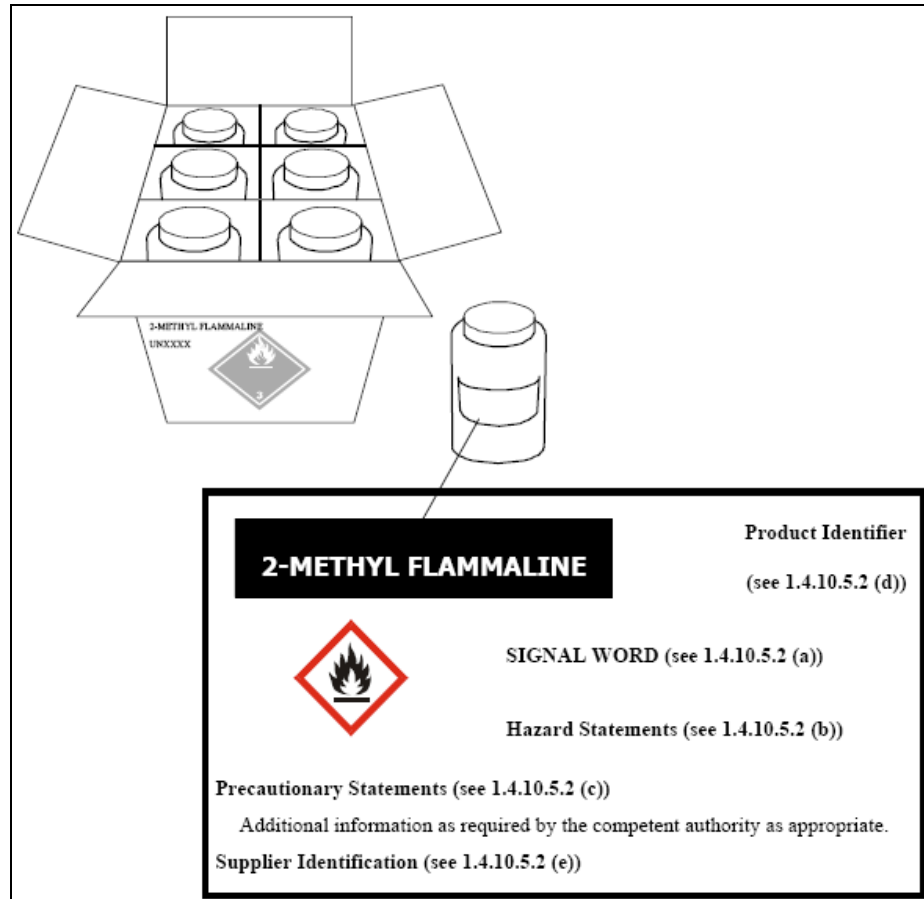


Figure 36: Elements of labeling



**Figure 37: Labeling on the packing material and container**





**Figure 38: Symbols for labelling in accordance to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS)**

### Requirement

- Communicate to the fire departments on the type of chemical transported to equip with appropriate firefighting equipments.
- The trucks, or trolleys carrying the chemicals should regularly be inspected or fit tested.
- The truck drivers or employees carrying chemicals should be trained to manage with any emergencies during transport and should be able to use and maintain the PPE properly.
- The distributor or the receiver or the supervisor should track the chemicals until destination.
- TREM card should be bilingual (one in local language).
- The transport vehicle should be provided with first aid box and information on medical centers en route.

**Standards, International guidelines and Recommendations:**

The central Motor Vehicles Act and Rules (1989) for transportation of chemicals

There are international conventions providing guideline and recommendations for good labeling practice The Globally Harmonized System of Classification and Labeling of Chemicals (GHS) and Recommendations on the Transport of Dangerous Goods (United Nations).

The Globally Harmonized System of Classification and Labeling of Chemicals (GHS) provide a basis for harmonization of rules and regulations on chemicals at national, regional and world-wide level. The GHS focuses on the classification of chemicals by the types of hazards they present. It also proposes standard hazard communication elements such as labels and safety data sheets. This publication is extremely useful for national and regional governments as well as for those in industries that will ultimately implement the requirements that have been adopted.

Full official text of the Globally Harmonized System of Classification and Labeling of Chemicals (GHS), Second revised edition is available on the web at

[http://www.unece.org/trans/danger/publi/ghs/ghs\\_rev02/02files\\_e.html](http://www.unece.org/trans/danger/publi/ghs/ghs_rev02/02files_e.html)

or

Print copy of Globally Harmonized System of Classification and Labeling of Chemicals (GHS), can be availed through ISBN: 9211168406.

The Recommendations on the Transport of Dangerous Goods are addressed to governments and to the international organizations concerned with safety in the transport of dangerous goods. These Recommendations have been developed by the United Nations Economic and Social Council's Committee of Experts on the Transport of Dangerous Goods in the light of technical progress, the advent of new substances and materials, the exigencies of modern transport systems and, above all, the requirement to ensure the safety of people, property and the environment. They do not apply to the bulk transport of dangerous goods in sea-going or inland navigation bulk carriers or tank-vessels, which is subject to special international or national regulations.

Full text of the UN Recommendations on the Transport of Dangerous Goods Model Regulations (Fifteenth ed.), is available at

[http://www.unece.org/trans/danger/publi/unrec/rev15/15files\\_e.html](http://www.unece.org/trans/danger/publi/unrec/rev15/15files_e.html)

or

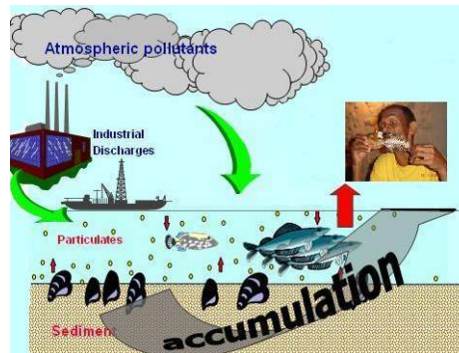
Print copy through ISBN 978-92-1-139120-6, reference. New York and Geneva: United Nations, 2007, ST/SG/AC.10/1/Rev.15

**Waste Disposal**

Waste generated from the industries may be in the form of solid, liquid and gases. Solid and liquid waste have the potential of polluting soil and water while gases, vapours and mist pollute the indoor and outdoor atmosphere. Solvents or any other solid wastes generated from the industrial process using hazardous material should be considered as hazardous wastes and should be disposed by following standard protocols. Managing these wastes are challenging for the developing countries and are often

discharged in the sewer, burned, dumped at unauthorized sites and disposed at sites not meeting the design and construction specifications. This can cause contamination of soil, ground water table and the atmosphere leading to penetration into the food chain causing damage to animal and human health, **Figure 39**. At the moment there are ranges of options available to dispose the waste with reference to local situation. Depending on the nature of the wastes, they can be treated by any one of the following methods.

- Recovery and recycling
- Incineration
- Co-processing



*Figure 39: Food chain*

### Recovery and recycling

The first and foremost step in waste disposal is to recover and recycle the waste back to the process. A typical example where recovering and recycling applied is in the tannery sector. Most of the units recover chromium and use back into the process by adding fresh chemicals to maintain the concentration. Solvents used by spraying vapour degreasing and immersion cleaning process should also be recycled back by removing the contaminants.

### Incineration

Incineration is a disposal method that involves combustion of waste material at high temperatures. Incineration is carried out both on a small scale by individuals and on a large scale by industry. It is used to dispose of solid, liquid and gaseous waste. It is recognized as a practical method of disposing of certain hazardous waste materials including biological medical waste. Incineration is a complex method of waste disposal, due to issues such as emission of hazardous gaseous pollutants such as CO<sub>2</sub>, Sox, Nox, and dioxins etc. This method produces heat that can be used as energy.

- Central Pollution control Board Emission guideline for common waste incinerator. The guideline can be downloaded from <http://www.cpcb.nic.in/contents.php> and emission standard for common hazardous waste incineration from <http://www.cpcb.nic.in/Annexure-1.php>

## Co-processing

Co processing is a widely used method for waste disposal. In developed countries like USA, Canada, Japan and Germany, hazardous wastes, mostly waste solvents are co-processed and used in the cement kilns as a source of energy.

Co-processing is also pilot tested in cement industries using paint sludge and incinerable wastes as fuel in India. Lime rich sludge from effluent treatment plant of certain industries can be used as a raw material in cement industry and is experimented in India. Used solvents can also be collected at a central facility and used as source of energy for certain industrial processes.

Based on the initiatives of bilateral and multilateral organizations to improve waste management at national and local levels, the guideline on co-processing waste material in cement production has been prepared from a public-private partnership between Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ) ([www.gtz.de](http://www.gtz.de)) and Holcim Group Support Ltd. ([www.holcim.com](http://www.holcim.com)). The findings and recommendations have been prepared with the experience learned from the developed and developing countries from public and private sectors.

Electronic copy of the Guidelines on Co-processing Waste Materials in Cement Production can be downloaded at [http://www.coprocem.com/Guidelines/unterordner/guideline\\_coprocem\\_v06-06.pdf/view](http://www.coprocem.com/Guidelines/unterordner/guideline_coprocem_v06-06.pdf/view)

Co-processing should be carried under the supervision of competent person or technical expert, since this process may generate highly hazardous substances or affect the quality of the process or product.

## Common Effluent Treatment Plant

Another method of disposing the waste is through Common Effluent Treatment Plant (CETP). While the organized big industries have the resources to have their own effluent treatment plant, small and medium industries cannot afford to have one. To save cost, space and human resources, several small or medium industries at the cluster level can operate the CETP, thereby reducing the pollution burden on the environment.

### Requirements:

- Hazardous Wastes should properly be packed, labeled, stored and transported.
- Mixing incompatible wastes should be avoided.
- Waste should be treated and disposed at authorized sites.

**Legal obligation for Hazardous Wastes:**

- Refer Indian legislation, Hazardous Waste (Management, Handling & Transboundary Movement) Rules, 2008, for procedures to handle, recycle, reprocess, reuse, import, export, packaging, labeling and transport, treatment storage and disposal facility of hazardous wastes.

This document can be downloaded from web at

<http://www.cpcb.nic.in/divisionsofheadoffice/hwmd/mhtrules2008.pdf>

- Waste constituents and their concentration limits can be downloaded at  
<http://www.cpcb.nic.in/divisionsofheadoffice/hwmd/Schedule%20%20II.pdf>
- Environmental standards can be downloaded at [http://www.envfor.nic.in/legis/env\\_stand.htm](http://www.envfor.nic.in/legis/env_stand.htm)

**4.10.2. Guidance on selection of Industrial site and structures**

Selection of industrial site should be according to the standards. Key elements to be considered in selecting location for industry are space requirement for the industrial plant, standard plant layout, location of building and structures within the site, layout of equipments inside the plant, installation of electrical equipment, adequate storage facility and providing good ventilation and welfare facilities.

For industrial site selection refer Indian Standards: 8091-1976 for code of safe practice for industrial plant layout.

## 5. Conclusion

The health, safety and environmental guidance document has been dealt in relation to some general issues such as handling, transport and disposal of solvents. There are lots of opportunities and possibilities for small and medium enterprises (SMEs) to play a key role in reducing and controlling the release of hazardous solvents in the workplace and the environment. It is the moral responsibility of the management to ensure that substitute solvents are selected after careful evaluation of their effectiveness to meet the process requirements. The employer and the employee have a central role in executing the health, safety and environmental program in the workplace to the expected standards. Employers must ensure that the exposure of employees to substances hazardous to health is either prevented or, where this is not reasonably practicable, adequately controlled as discussed in this manual. All employees are encouraged to use any control measures and safe systems of work which have been introduced to reduce the risk of exposure to hazardous substances and also to inform or report to their management any defects in the control measures.

As a social responsibility, unnecessary release of chemicals into the environment has to be controlled abiding by the local regulations. To comply with these requirements proper documentation on any chemicals stored, used, handled, produced, transported or disposed either in the employers' premises or outside. Therefore, SMEs can use this manual to bring awareness amongst employers and employees on environmental, health and safety aspects and also to initiate hazardous chemical management program that will meet the objectives of national and international standards and agreements.