GUIDANCE ON CONTROL OF EXPOSURES RELATED TO USE OF CARBON TETRACHLORIDE SOLVENT SUBSTITUTES IN THE FOUNDRY SECTOR




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

gtz PROKLIMA

On behalf of Federal Ministry for Economic Cooperation and Development

On behalf of Fonds Français pour l'Environnement Mondial

November 2009

GUIDANCE ON CONTROL OF EXPOSURES RELATED TO USE OF CARBON TETRACHLORIDE SOLVENT SUBSTITUTES IN THE FOUNDRY SECTOR

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 to compile the information provided in this manual, DEHE-SRU and GTZ-Proklima accept no liability related to its contents. The findings represent results of research exercises and stakeholder discussions and are not intended as applicable under all possible circumstances.

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- SRU 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 (ODS) similar to chlorofluorocarbons (CFCs). The UV-B and UV-C radiation coming from the sun interacts with CTC molecules that drift into the stratosphere and release their chlorine atoms. 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 released into the environment can cause tremendous damage to the ozone layer. Further, the global warming potential (GWP) of CTC has been estimated to be about 1,400 times higher than that of carbon dioxide (CO_2), the principal greenhouse gas. It is also hazardous to health via all routes of exposure viz., inhalation, ingestion and skin absorption. There is sufficient evidence of carcinogenicity in experimental animals with an increasing body of evidence for being a human carcinogen.

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 31st December 2009.

As the phase-out is progressing, CTC supplies in the market are dwindling rapidly. Beyond 31st 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.

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 volumes 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 for occupational exposures to 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 select ***Foundry*** 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. 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 of Mr. Gopalaraman Swaminathan, Scientist, Central Leather Research Institute (CLRI), Chennai and Mr. Markus Wypior, Project Manager, GTZ-Proklima, for their invaluable inputs in design and implementation of the manual.

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 Central Manufacturing Technology Institute (CMTI) Bangalore in granting us access to their facilities to execute the study.

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

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.

CONTENTS

ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienist
AFFF	Aqueous Film-Forming Foam
CAS	Chemical Abstract Services
CFCs	Chlorofluorocarbons
CIM	Centre for International Migration
CTC	Carbon tetrachloride
EHS	Environment Health and Safety
GG	Spectacles/Goggles
GL	Gloves
GTZ	German Technical Cooperation
GWP	Global Warming Potential
IPA	Isopropyl alcohol
LC50	Lethal Concentration
LD50	Lethal Dose
MSDS	Material Safety Data Sheet
NIOSH	National Institute for Occupational Safety and Health
ODS	Ozone Depleting Substance
OEL	Occupational Exposure Limits
OSHA	Occupational Safety and Health Administration
PCE	Perchloroethylene
PEL	Permissible Exposure Limits
PFTs	Pulmonary Function Tests
PLE	Permissible Limits of Exposure
PPEs	Personal Protective Equipments
R	Respirator
SRU	Sri Ramachandra University
STEL	Short Term Exposure Limit
TLV	Threshold Limit Value
TWA	Time Weighted Average
UNDP	United Nation Development Programme
UNIDO	United Nation Industrial Development Organization

LIST OF FIGURES, TABLES AND BOXES

1. INTRODUCTION

In foundry sector, a variety of processes are used to produce metal products, in which organic solvents are used for different applications. Particulate analysis (commonly known as Millipore test), precision cleaning and sampling of raw material are some of the processes, where solvents are used. In critical components, when the required level of cleanliness is specified by the customer, this is verified by particulate analysis test. The process usually involves cleaning of randomly selected cleaned components by spraying or immersion and agitation with solvent followed by collecting the dissolved impurities on a filter paper that is weighed to quantify the level of contamination. Instruments and gauges are subjected to precision cleaning before calibration and critical components are thoroughly cleaned before taking the final measurements, Solvents are also used for cleaning of sample scrap material to determine the actual quantity of metallic part in the scrap. It is also used for cleaning of electrical contacts during preventive maintenance. In foundries, cleaning process is very critical as the processes have to be carried out at high temperatures and dynamic load conditions under exposure to dust, soot, scales, grease etc.

With the most widely used solvent, CTC being an Ozone depleting substance (ODS), there is now a legal obligation to use alternative cleaning agents. This manual has been prepared to provide guidance on “safe use” of potential CTC substitutes on the basis of results of workplace exposure measurements, work practice assessments and the opinion and outcome of concerned stakeholder discussions. The suggested interventions thus are likely to be both feasible and effective on a sector-wide basis to reduce occupational health risks. However, occupational health risks covered in this manual need to be matched with environmental aspects as well as cleaning efficiency and costs acceptable to the industry before adopting a product “substitute”. Separate guidance on environmental and safety aspects that are general to all sectors using CTC substitutes is available at www.ctc-phaseout.org to enable the same.

2. WORK PRACTICES RELATED TO USE OF SOLVENTS IN FOUNDRY SECTOR

To achieve the desired cleaning efficacy, solvents are used to quickly dissolve and remove particles, inorganic and organic residues from equipments, gauges and scrap metals etc. Residual particle analysis, precision cleaning and sampling of raw material are the three major areas where solvents are employed.

2.1. Residual Particulate

In foundries, cleanliness of the components is critical as contaminants present on the components/castings may affect the performance of the system in which they are employed such as hydraulic systems, aeronautics, food processing equipment etc. Cleanliness verification is performed on random samples from every batch. This monitoring is performed through residual particulate analysis, commonly referred to as the Millipore test.

Contaminants are removed from the sample part by spraying (**Figure 1**), rinsing and/or flushing with a solvent. The solvent with sediments are collected and this solution is then filtered through a membrane filter (**Figure 2**) which is then analyzed and compared to with the specific acceptance criteria.

Figure 1: Cleaning by spraying method

Figure 2: Equipment for particulate analysis

2.2. Precision cleaning

Precision cleaning involves removal of particulate and/or other inorganic and organic residues from a surface and verifying its cleanliness through analytical methods. It is used to attain a very high degree of cleanliness. For example, in foundries critical components are thoroughly cleaned before taking the measurements, instruments and gauges are subjected to precision cleaning before

calibration and also for cleaning of sample components before metallurgical analysis.

2.3. Sampling of raw material

Scrap metal forms a major source of raw materials for foundries. Scrap collected from different sources usually contains a lot of contaminants. To decide the actual weight of the metallic part in the scrap, sample quantities are cleaned (**Figure 3**) with solvents like CTC by rinsing and then dried through heating. The difference in weight of the sample before and after rinsing determines the quantum of wastage.

Figure 3: Cleaning of scarp materials

3. HAZARD IDENTIFICATION AND RISK ASSESSMENT

The exposure concentration likely to be achieved with individual solvents primarily depends on physical, chemical and toxic properties, specific nature of cleaning procedures, work posture, work and hygiene practices, maintenance of machines and the workplace environmental conditions such as temperature, humidity and ventilation.

A key step in risk assessment is to recognize the job-specific exposure hazards and the associated risks. This can be done by shop floor visits/walk-through assessments, review of documents, interview with workers and supervisors and qualitative / quantitative assessments of workplace and environmental conditions. Based on a combination of such assessment methods, the following **Table 1** identifies the job-hazard-risk profile for key processes in the foundry sector.

Table 1: Job-hazard-risk profile

Job	Process/Hazard	Risk
Residual particulate analysis 	• Filling of solvent	• Inhalation, dermal (skin) and eye contact due to evaporation from spills and open containers, inadequate ventilation, handling with bare hands and naked eyes.
	• Spray cleaning.	• Exposure via lungs, skin and eyes due to solvent splashing and vaporization. • Enhanced skin absorption due to solvent contact from high pressure.
Cleaning of components 	• Cleaning by immersion/ wiping	• Absorption through skin during immersion/wiping. • Exposure via lungs due to solvent evaporation from open container. • Additional solvent exposure from evaporation of solvent from used cotton waste.
Cleaning of raw material samples 	• Cleaning by immersion/ Rinsing	• Absorption through skin during immersion/wiping. • Exposure via lungs due to solvent evaporation from open container. • Skin absorption through hand and feet due to spillage and no/improper protection. • Contamination of water and soil through disposal of solvent waste. • Risk of fire and explosion due to heating of sample over open flame.

4. EXPOSURE ASSESSMENT AND RISK CHARACTERIZATION

Exposure assessments that measure levels of solvent exposure under specific workplace conditions allow comparisons to be made with reference to the exposure standards. In order to capture alternative exposure conditions or wherever measurements are difficult to perform, exposures can also be simulated under laboratory conditions to estimate potential exposures that may be encountered in the workplaces. Such exercises in this sector have shown that Toluene and PCE levels consistently exceed the permissible exposure limits, whereas IPA levels are usually lower in most of the cleaning process. White Petrol and n-Hexane levels are intermediate between PCE and IPA. By using required quantity of solvents for specific cleaning applications, exposure concentrations are reduced significantly. However, the exposure concentrations of all the solvents are lower while cleaning by immersion method relative to spraying method. **Box 1** emphasizes the level of reduction in exposure concentration achievable through use of optimal quantity of solvents.

Box 1: Optimum use of solvent and percentage reduction in exposure concentration.

Around 20 to 30 percent reductions in exposure levels are achieved through optimum use of solvents.

Results of hazard recognition and exposure assessments made at individual work locations in this sector were used to characterize risks and provide job specific recommendations for prevention and control of exposures as described in the sections below.

5. CONTROL GUIDANCE

Risk management involves application of a sequence of control measures to minimize the exposures. A typical hierarchy of controls involves hazard (i.e. solvent) substitution, engineering, administrative and personal protective measures. While exposures are central in arriving at a control strategy, often exposure reduction goals have to be matched with feasibilities based on worker preference, skills and attitudes of workers/management, workplace environmental conditions and cost of control measures.

The following sections provide general and process/work practice specific guidelines for the foundry sector.

5.1. General Work Practice Guidelines

It is the employer's or the management's responsibility to provide guidance and instructions to workers on environment, health and safety (EHS) management. At the same time it is employees' responsibility to follow the instruction laid by the employer to create a healthier working environment. Although managements may have a policy that allocates resources for EHS management, it has to identify a responsible person to implement and supervise the EHS management programme. Simple generic guidelines are, therefore, separately provided for the supervisors/managers and workers to maintain minimum EHS standards. These guidelines are provided in **Tables 2** and **3**.

Table 2: General Guidelines for Managers and Supervisors

Storage and Handling

- Layout of storage facility should be planned at an early stage (Refer Figure 22 in the Part-I manual).
- Storage protocols should be prepared depending on the compatibility (Refer Figure 23 in the Part-I manual).
- MSDSs must be referred for chemical compatibility.
- In the event MSDSs are not available, information must be secured from the manufacturer/distributor.
- Adequate safety measures (First-aid, Firefighting equipments, emergency showers, PPEs etc.) must be provided in the storage facility.
- Safety equipment must be periodically checked for fit and performance.
- Safety sign boards specific to hazards must be provided and placed at required locations.
- Instructions on handling procedures must be provided to the workers.
- Expired chemicals must be returned to the manufacturer or disposed according to standard protocol.
- Empty containers must be returned immediately to the supplier or the manufacturer or disposed in a proper manner.

Labeling	Cleanup	Personal hygiene
• Labels to be prepared in local language in accordance to MSDS. • Label must contain key information (such as Flammability, Health Risks, etc.) • Hazard symbols must be provided on the label. • Caution words and statements (Danger, Toxic, Irritant, Corrosive etc.) for hazardous chemicals need to be provided. • Damaged or worn out labels must be replaced. • Embossed labels can be requested from the manufacturer.	• Routine implementation of clean up schedule and procedures. • Identification of a responsible and trained person for cleanup activities. • Planning and implementation of periodical maintenance of equipments and accessories. • Deployment of spill control procedures to prevent health and environmental risks. • Provision of appropriate PPEs during cleanup of spills. • Provisions of proper waste disposal protocols.	• Practice of good hygiene practice amongst the workers. • Provision of hand washing facility with adequate soaps and detergents. • Provision of a separate lunch room. • Provision of adequate work cloths. • Provision of shower stations.

Provision of training on

- The availability and importance of MSDS.
- Obtaining MSDS from the manufacturer or competent sources (Government or Safety Agencies) in case of non availability.
- Informing the workers on the importance of MSDS.
- Procedures and protocol development for safe handling of chemicals.
- Managing emergency situations.
- Risk assessment and implementing control measures.
- Evaluation of the training programs conducted for workers.
- Selection of appropriate PPEs.
- Importance of medical fitness for wearing PPEs and selecting workers for providing PPE.

Table 3: General Guidelines for Workers

Storage and Handling

- Follow storage and handling procedures.
- If safe handling procedures are not available, request your supervisor.
- Observe safety sign boards for recognizing the hazards.
- Handle any new chemicals in the presence of Manager/Supervisor at initial stage.
- Learn to use safety equipments.
- Use protective device while handling hazardous chemicals.
- Request for PPE if not available.
- Report any damage or inconsistency of safety equipments to the Manager/supervisor.
- Report if chemicals are used beyond expiry dates.
- Place back containers at designated location after use.
- Transport the containers in closed condition.
- Close the containers with air tight fittings to prevent spoiling of chemicals.
- Store drinking water separately away from the chemical store.

Labeling	Cleanup	Personal hygiene
• Request for label and label information in local language • Read the label before using the chemicals. • Care should be taken to prevent label damage while transferring, transporting and handling. • Request to your manager/ supervisor for replacing the damaged label.	• Remove dust, oils and dirt regularly from the machines and floors. • Regularly clean up at end of the shift or end of the day. • Report immediately about the spills to managers/supervisors. • Request for MSDS/instructions in local language for spill cleanup. • Immediately clean the spills according to the instructions and protocol. • Wear appropriate PPEs during cleaning the spills.	• Wash hands before eating. • Use soap for washing the hands. • Avoid smoking and eating at workplaces. • Avoid placing your fingers into mouth, ears and nose while handling chemicals. • Trim the nails periodically to prevent chemical accumulation. • Dress open wounds before handling the chemicals. • Wear clean work clothes. • Change work clothes before leaving the workplace. • Have a shower at the end of the shift (to reduce the dermal exposures and minimize the transportation of the contaminants to home) • Clearly mark the drinking water bottles and always keep them in a clean place.

Provision of training on

- Recognizing and understanding the hazardous nature and risk of using chemicals.
- Importance of material safety data sheet (MSDS)
- Good housekeeping procedures (Storage, handling, labeling and cleanup of chemicals).
- Handling the chemical spills and proper disposal methods.
- Managing emergency situations – using first-aid, handling fire extinguishers, communications (persons to be contacted, contact phone number) etc.
- Checking the functioning of pollution control systems.
- Incident or failure reporting systems.
- PPE - use, storage, cleaning and maintenance.

5.2. Process Specific Guidelines

Although generic guidelines provide an overall framework to design and implement an EHS policy, often supervisors and managers require customized guidance that is specific for a particular work situation and process, which is provided in **Table 4** & **5**. Each main process concerned with solvent use is provided with a set of engineering, administrative and personal protective controls applicable specifically for the nature of hazards and risks associated with the job. The guidance sheet may thus be used as a ready reckoner for implementing facility-wise or location specific controls. Instruction for using the guidance sheet is provided in **Box 2**.

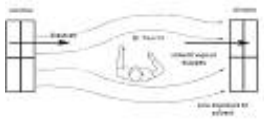
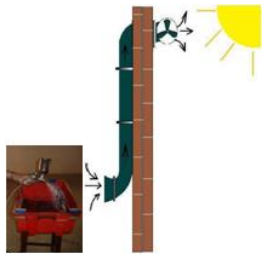
Box 2: Instruction for reading the guidance sheet

For identifying job specific hazard, risk and control measures, read the guidance sheet from left to right across the row.

It must be emphasized that the guidance sheets only provide information on "safe use" of specific solvents being used in each process. Selection amongst solvent substitutes is governed by considerations that often go beyond occupational exposures. On the basis of a limited set of exposure measurements, it has been observed that in general PCE concentrations are lower while immersion method of cleaning is employed for short duration. This is due to its higher boiling point and specific gravity as compared to other solvents used. However, in non-ventilated spaces, PCE concentrations may build up over time creating more risks of exposure and is also reported as suspected carcinogen. PCE concentration consistently exceeds prescribed exposure limits, particularly during spraying process.

Therefore, facilities are encouraged to prioritize the selected solvent against conditions required for safe use in a larger EHS (environment, health and safety) framework in order to provide best work practice in the process or sector. The information related to safe use of the solvents is provided in **Tables 6** to **9**.

Table 4: Job Specific Control Guidance Sheet

Job	Hazards/ Solvents	Risk/ Exposure Situation	Control Measures		
			Engineering	**Administrative**	**PPEs**
Cleaning of components by spraying method 	• Isopropyl alcohol • n-Hexane • White petrol • Perchloroethylene (PCE) • Toluene	• Inhalation, skin and eye contact due to spraying of solvents at high pressure. • Inhalation, dermal (skin) and eye contact due to solvent evaporation from spills and open containers, inadequate ventilation, handling with bare hands and naked eyes. • Enhanced skin absorption by not using gloves and from whole body exposure to solvent mist. • Additional inhalation exposure from solvent evaporation due to disposed cotton waste within the workplace. • Contamination of water and soil through disposal of solvent waste.	• Use funnel to transfer solvent. • Cleaning area should be well ventilated. • Select a location near a window in accordance to the wind direction.  • Use local exhaust system (LES). 	• Use optimum quantity of solvent. • Transfer the solvent into small container to avoid spillage and splash.  • Close the container after use. • Remove the spills immediately. • Prohibit smoking and place visual sign boards in the workplace to avoid fire hazard. • Provide eye washing bottles or eye cup (E1 or E2) to deal with splash.	**Gloves:** IPA: GL 1 n-Hexane: GL 2 PCE: GL 3 Toluene: GL 4 In addition to gloves use **CPC1**. **Spectacles/Goggles**: GG2 • Use solvent resistant goggle and power corrected if necessary. • Not required if respirator (R2) is used. **Respirator:** Use R2 in the absence of LES

Job	Hazards/ Solvents	Risk/ Exposure Situation	Control Measures		
			Engineering	**Administrative**	**PPEs**
Cleaning of components by Immersion method  **Cleaning by rinsing and agitation for sampling of raw material** 		• Dermal (skin) contact due to immersion with bare hand. • Lungs and eye contact due to vapourization from open container and spills. • Inhalation, dermal and eye contact due to splashing during rinsing, evaporation from open container, during heating, inadequate ventilation, handling with bare hands and naked eyes 	• Immersion cleaning should be carried out in well ventilated environment. • Immersion cleaning should be carried out in well ventilated environment.	• Close the solvent bottle/container after transferring is completed. • Close the solvent bottle/container after transferring is completed. • Close the components tray during rinsing and agitation.	**Gloves:** IPA: GL 1 n-Hexane: GL 2 PCE: GL 3 Toluene: GL 4 **Spectacles/ Goggles:** GG 1 • Use solvent resistant spectacle and power corrected if necessary. • Not required if respirator (R2) is used.

Job	Hazards/ Solvents	Risk/ Exposure Situation	Control Measures		
			Engineering	**Administrative**	**PPEs**
		• Disposal of waste solvent 		• Dispose the solvent according to the standard protocol (refer MSDS).	In the absence of natural or mechanical ventilation, use R1 or R2 while cleaning more than four times in a day.

Table 5: Codes and types of personal protective equipments

Sl. No	Code	Recommended protection	PPEs (Gloves/Goggles/Respirator)
1	GL 1	8 hr: Butyl, Nitrile, Viton	Butyl Nitrile Viton 
2	GL 2	8 hr: Nitrile, PVA, Viton	Nitrile PVA Viton 
3	GL 3	Nitrile latex gloves	
4	GL 4	8 hr: PVA, Viton	PVA Viton 
Sl. No	**Code**	**Recommended protection**	**Spectacles / Goggles**
1	GG 1	Solvent resistant spectacle	
2	GG2	Solvent resistant goggle	
3	CPC1	Chemical protective clothing (Refer GL1 to GL 6 for type of material)	

Sl. No	Code	Recommended protection	Respirator
1	R1	Half face respirator	
2	R2	Full face respirator	
Sl. No	**Code**	**Recommended protection**	**Other safety equipment**
1	E1	Eye washing bottle	
2	E2	Eye cup	

Source for selection of gloves: OSH Technical reference material, Department of Energy, USA and Chemical Protective Clothing, National Institute for Occupational Health and Safety (NIOSH), USA.

Table 6: Data Sheet for Isopropyl Alcohol (IPA)

Toxic, Chemical and Physical properties									
Type	**CAS number**	**LD_{50} and LC_{50}**	**Boiling point**	**Vapour pressure**	**Specific gravity**	**Flash point**	**Flammability**	**Dipole moment**	**Solvency power (Hansen parameter)**
Secondary Alcohol	(67-63-0)	**ORAL (LD50):** **Acute:** 5045 mg/kg [Rat]. 3600 mg/kg [Mouse]. 6410 mg/kg [Rabbit]. **DERMAL (LD50):** **Acute:** 12800 mg/kg [Rabbit].	82^0C	33mm Hg	0.79 g/cm 3	12. ^{0}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 and container well closed; Cool	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 7: Data Sheet for n-Hexane

Toxic, Chemical and Physical properties									
Type	**CAS number**	**LD_{50} and LC_{50}**	**Boiling point**	**Vapour pressure**	**Specific gravity**	**Flash point**	**Flammability**	**Dipole moment**	**Solvency power (Hansen parameter)**
Hydrocarbon alkane	(110-54-3)	**LD50 – Skin** >2 gm/kg rabbit; **LD50 -oral** >5 gm/kg rat LC50 – **inhalation** >3367 ppm - rat;	63.70^0 C	124 mm Hg	0.69 g/cm 3	-23 ^{0}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, respirator y 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 and container well	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 8: Data Sheet for Perchloroethylene (PCE)

Toxic, Chemical and Physical properties									
Type	**CAS number**	**LD_{50} and LC_{50}**	**Boiling point**	**Vapour pressure**	**Specific gravity**	**Flash point**	**Flammability**	**Dipole moment**	**Solvency power (Hansen parameter)**
Chlorinated hydrocarbon	(127-18-4)	**ORAL (LD50):** **Acute:** 2629 mg/kg [Rat]. **DERMAL (LD): Acute:**>3228 mg/kg [Rabbit]. **MIST (LC50): Acute:** 34200 mg/m 8 hours [Rat]. **VAPOR (LC50): Acute:** 5200 ppm 4 hours [Mouse].	121^{0}C	14 mm Hg	1.62 g/cm 3	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 (PCE) 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 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 9: Data Sheet for Toluene

Toxic, Chemical and Physical properties									
Type	**CAS number**	**LD_{50} and LC_{50}**	**Boiling point**	**Vapour pressure**	**Specific gravity**	**Flash point**	**Flammability**	**Dipole moment**	**Solvency power (Hansen parameter)**
Aromatic hydrocarbon	(108-88-3)	**ORAL (LD50):** **Acute:** 636 mg/kg [Rat]. **DERMAL (LD50):** Acute: 14100 mg/kg [Rabbit]. **VAPOR (LC50)**: Acute: 49000 mg/m 4 hours [Rat]. 440 ppm 24 hours [Mouse].	111^0C	21 mm Hg	0.87 g/cm 3	4-7^0C	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.

* 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