

# GUIDANCE ON CONTROL OF EXPOSURES RELATED TO USE OF CARBON TETRACHLORIDE SOLVENT SUBSTITUTES IN THE REFRIGERATION AND AIR CONDITIONING (RAC) 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.



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**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

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**Authors:**

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

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## 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<sub>2</sub>), 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 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.

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 the 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 **Refrigeration and Air Conditioning (RAC) enterprises** 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, when accompanied awareness raising efforts to change risk perception. 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.

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## 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
LC50	Lethal Concentration
LD50	Lethal Dose
MEK	Methyl ethyl ketone
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
TCE	Trichloroethylene
TLV	Threshold Limit Value
TWA	Time Weighted Average
UNDP	United Nation Development Programme
UNIDO	United Nation Industrial Development Organization



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## 1. INTRODUCTION

In the RAC sector, ozone depleting substances such as CFCs (refrigerants) and CTC (cleaning agents) have been used over many years. CTC continues to be used as an agent for cleaning the circuitry in majority of this sector. In refrigeration systems, circuitry cleanliness is critical for obtaining optimum performance. The presence of contamination in the circuitry can result in poor cooling effect in the refrigeration system, leading to recurring failures and reduced life. Even while using CFCs, many refrigeration manufacturing and servicing industries were using CTC for cleaning the circuitry and still continue to use the same. Historically, when CFCs were used as refrigerants, the effect of contamination on the circuitry system was lower as compared to present situation of using non-CFC substitutes which are even more sensitive to moisture, dirt and other contaminants. With the phase out of CFCs, it has become essential to select substitutes that can provide optimal cleaning performance.

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](http://www.ctc-phaseout.org) to enable the same.

## 2. WORK PRACTICES RELATED TO USE OF SOLVENTS IN THE REFRIGERATION AND AIR CONDITIONING (RAC) SECTOR

A variety of contaminants accumulate in the refrigeration circuitry over a period of use. Some of them originate from the system and other contaminants such as moisture, non-condensable gases, chemical residues, dust, metal particles and organic compounds are 'imported' from other systems or service equipment in the process of servicing. The use of petrol for cleaning, anti moisture reagents for preventing freezing of water inside the tubes and air for flushing also contribute to system contamination. Contaminants also enter when the circuitry is kept open for a long duration during the process of servicing. Over a period of time, contaminants present in the system get circulated and under high temperature and pressure, gradually forms into sludge. Sludge forms a plaque deposit in the capillary and gradually chokes the system. Sludge inside the condenser tubing reduces the heat transfer. This results in an increased condensing temperature and pressure, reducing the system performance and the compressor life. To ensure good system performance, the industry needs to maintain high cleanliness standards during manufacturing and servicing.



*Figure 1: Filling of solvent*



*Figure 2: Flushing with solvent*




Circuitry is cleaned by filling with solvent (**Figure 1**) followed by flushing with dry nitrogen under high pressure (**Figure 2**). Solvents are filled directly from the bottle into the circuitry and the cleaning is often performed without wearing any personal protective equipment and usually in the sitting position, bringing the face close to the circuitry.

### 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 refrigeration and air conditioning sector.

**Table 1: Job-hazard-risk profile**

Job	Process/Hazard	Risk
<p data-bbox="352 367 580 398">Circuitry cleaning</p> 	<ul data-bbox="683 376 1054 472" style="list-style-type: none"> <li>• Cleaning is carried out by filling solvents into the circuitry.</li> </ul>  <ul data-bbox="683 1182 1102 1249" style="list-style-type: none"> <li>• Flushing the solvent with dry nitrogen at high pressure</li> </ul> 	<ul data-bbox="1144 367 1437 1964" style="list-style-type: none"> <li>• Absorption through lungs, skin and eye due to evaporation from spills and open containers; handling with bare hands and naked eyes.</li> <li>• Exposure via lungs and eyes due to splashing and vaporization of solvent.</li> <li>• Enhanced skin absorption due to spraying at high pressure.</li> <li>• Additional skin absorption by not using gloves and absorption through open wounds or skin ruptures that are caused by friction with sharp edges.</li> <li>• Skin absorption through hand and feet from solvent discharge within the workplace with no/inappropriate protection</li> <li>• Contamination of water and soil through disposal of solvent waste.</li> <li>• Risk of fire and explosion from discharged solvents</li> </ul>

#### 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 Acetone levels are constantly lower than the permissible limits of exposure, Methyl ethyl ketone (MEK) levels consistently exceeds the permissible limits during most of the cleaning process, with n-Hexane, PCE and TCE levels intermediate between Acetone and MEK. By using required quantity of solvents for specific cleaning applications, exposure concentration is reduced significantly. **Box 1** emphasizes the level of reduction in exposure concentration achievable through use of optimum 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 RAC sector.

### 5.1. General Work Practice Guidelines

It is the employer or the managements' responsibility to provide guidance and instructions to workers on environment, health and safety (EHS) management. At the same time it is employees' responsibilities 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**

<b>Storage and Handling</b>		
<ul style="list-style-type: none"> <li>Layout of storage facility should be planned at an early stage (Refer Figure 22 in the Part-I manual).</li> <li>Storage protocols should be prepared depending on the compatibility (Refer Figure 23 in the Part-I manual).</li> <li>MSDSs must be referred for chemical compatibility.</li> <li>In the event MSDSs are not available, information must be secured from the manufacturer/distributor.</li> <li>Adequate safety measures (First-aid, Firefighting equipments, emergency showers, PPEs etc.) must be provided in the storage facility.</li> <li>Safety equipment must be periodically checked for fitness and performance.</li> <li>Safety sign boards specific to hazards must be provided and placed at appropriate locations.</li> <li>Instructions on handling procedures must be provided to the workers.</li> <li>Expired chemicals must be returned to the manufacturer or disposed according to standard protocol.</li> <li>Empty containers must be returned immediately to the supplier or the manufacturer or disposed in a proper manner.</li> </ul>		
<b>Labeling</b>	<b>Cleanup</b>	<b>Personal hygiene</b>
<ul style="list-style-type: none"> <li>Labels to be prepared in local language in accordance to MSDS.</li> <li>Label must contain key information (such as Flammability, Health Risks, etc.)</li> <li>Hazard symbols must be provided on the label.</li> <li>Caution words and statements (Danger, Toxic, Irritant, Corrosive etc.) for hazardous chemicals need to be provided.</li> <li>Damaged or worn out labels must be replaced.</li> <li>Embossed labels can be requested from the manufacturer.</li> </ul>	<ul style="list-style-type: none"> <li>Routine implementation of clean up schedule and procedures.</li> <li>Identification of a responsible and trained person for cleanup activities.</li> <li>Planning and implementation of periodical maintenance of equipments and accessories.</li> <li>Deployment of spill control procedures to prevent health and environmental risks.</li> <li>Provision of appropriate PPEs during cleanup of spills.</li> <li>Provisions of proper waste disposal protocols.</li> </ul>	<ul style="list-style-type: none"> <li>Practice of good hygiene practice amongst the workers.</li> <li>Provision of hand washing facility with adequate soaps and detergents.</li> <li>Provision of a separate lunch room.</li> <li>Provision of adequate work cloths.</li> <li>Provision of shower stations.</li> </ul>
<b>Provision of training on</b>		
<ul style="list-style-type: none"> <li>The availability and importance of MSDS.</li> <li>Obtaining MSDS from the manufacturer or competent sources (Government or Safety Agencies) in case of non availability.</li> <li>Informing the workers on the importance of MSDS.</li> <li>Procedures and protocol development for safe handling of chemicals.</li> <li>Managing emergency situations.</li> <li>Risk assessment and implementing control measures.</li> <li>Evaluation of the training programs conducted for workers.</li> <li>Selection of appropriate PPEs.</li> <li>Importance of medical fitness for wearing PPEs and selecting workers for providing PPE.</li> </ul>		



**Table 3: General Guidelines for Workers**

<b>Storage and Handling</b>		
<ul style="list-style-type: none"> <li>• Follow storage and handling procedures.</li> <li>• If safe handling procedures are not available, request your supervisor.</li> <li>• Observe safety sign boards for recognizing the hazards.</li> <li>• Handle any new chemicals in the presence of Manager/Supervisor at initial stage.</li> <li>• Learn to use safety equipments.</li> <li>• Use protective device while handling hazardous chemicals.</li> <li>• Request for PPE if not available.</li> <li>• Report any damage or inconsistency of safety equipments to the Manager/supervisor.</li> <li>• Report if chemicals are used beyond expiry dates.</li> <li>• Place back containers at designated location after use.</li> <li>• Transport the containers in closed condition.</li> <li>• Close the containers with air tight fittings to prevent spoiling of chemicals.</li> <li>• Store drinking water separately away from the chemical store.</li> </ul>		
<b>Labeling</b>	<b>Cleanup</b>	<b>Personal hygiene</b>
<ul style="list-style-type: none"> <li>• Request for label and label information in local language</li> <li>• Read the label before using the chemicals.</li> <li>• Care should be taken to prevent label damage while transferring, transporting and handling.</li> <li>• Request to your manager/ supervisor for replacing the damaged label.</li> </ul>	<ul style="list-style-type: none"> <li>• Remove dust, oils and dirt regularly from the machines and floors.</li> <li>• Regularly clean up at end of the shift or end of the day.</li> <li>• Report immediately about the spills to managers/supervisors.</li> <li>• Request for MSDS/instructions in local language for spill cleanup.</li> <li>• Immediately clean the spills according to the instructions and protocol.</li> <li>• Wear appropriate PPEs during cleaning the spills.</li> </ul>	<ul style="list-style-type: none"> <li>• Wash hands before eating.</li> <li>• Use soap for washing the hands.</li> <li>• Avoid smoking and eating at workplaces.</li> <li>• Avoid placing your fingers into mouth, ears and nose while handling chemicals.</li> <li>• Trim the nails periodically to prevent chemical accumulation.</li> <li>• Dress open wounds before handling the chemicals.</li> <li>• Wear clean work clothes.</li> <li>• Change work clothes before leaving the workplace.</li> <li>• Have a shower at the end of the shift (to reduce the dermal exposures and minimize the transportation of the contaminants to home)</li> <li>• Clearly mark the drinking water bottles and always keep them a clean place.</li> </ul>
<b>Provision of training on</b>		
<ul style="list-style-type: none"> <li>• Recognizing and understanding the hazardous nature and risk of using chemicals.</li> <li>• Importance of material safety data sheet (MSDS)</li> <li>• Good housekeeping procedures (Storage, handling, labeling and cleanup of chemicals).</li> <li>• Handling the chemical spills and proper disposal methods.</li> <li>• Managing emergency situations – using first-aid, handling fire extinguishers, communications (persons to be contacted, contact phone number) etc.</li> <li>• Checking the functioning of pollution control systems.</li> <li>• Incident or failure reporting systems.</li> <li>• PPE - use, storage, cleaning and maintenance.</li> </ul>		

## 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 **Tables 4** and **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**.





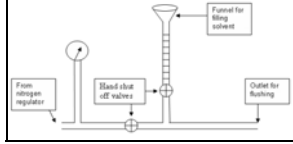
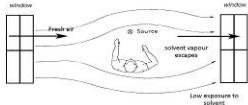


### Box 2: Instruction for reading the guidance sheet

**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 Acetone concentrations are always lower than all other solvents followed by n-Hexane, Perchloroethylene (PCE), Trichloroethylene (TCE) and MEK. The concentrations of PCE and TCE usually exceed the prescribed exposure limits. However, these two are reported as suspected carcinogens while the health effects of TCE are more evident than the effects of PCE.

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 **10**.

**Table 4: Job Specific Control Guidance Sheet**

Job	Hazards/ Solvents	Risk/ Exposure Situation	Control Measures		
			Engineering	Administrative	PPEs
<p><b>Cleaning of circuitry:</b></p> <p>Filling of solvent</p>  <p>Flushing with dry nitrogen</p> 	<ul style="list-style-type: none"> <li>• Acetone</li> <li>• n-Hexane</li> <li>• PCE</li> <li>• TCE</li> <li>• MEK</li> </ul>	<p>Inhalation, dermal (skin) and eye contact due to spills, inadequate ventilation, handling with bare hands and naked eyes.</p>  <p>Inhalation and eye contact due to open or partially closed containers.</p> 	<ul style="list-style-type: none"> <li>• Use funnel for transferring solvent to avoid spillage.</li> </ul>  <ul style="list-style-type: none"> <li>• Cleaning area should be well ventilated.</li> <li>• Select the work location near a window in accordance to the wind direction.</li> </ul>  <ul style="list-style-type: none"> <li>• Local Exhaust System must be installed near the drain if solvent used is more than 40ml per circuitry cleaning and more than 4 cleaning continuously even with good ventilation.</li> </ul> 	<ul style="list-style-type: none"> <li>• Use optimum quantity of solvent.</li> <li>• Close the container after use.</li> </ul>  <ul style="list-style-type: none"> <li>• Restrict co-workers' presence nearby during the cleaning process.</li> <li>• Keep solvents away from ignition sources.</li> <li>• Prohibit smoking and place visual signboards in the workplace to avoid fire hazard.</li> <li>• Dispose the solvent waste in proper drain and treat according to standard protocol.</li> <li>• Provide eye washing bottles or eye cup (E1 or E2) to deal with splash.</li> </ul> <div style="background-color: #d4edda; padding: 10px; border: 1px solid #c3e6cb; margin-top: 10px;"> <p><b>Acetone and n-Hexane are highly flammable and it is suggested for use under good or open ventilation condition.</b></p> </div>	<p><b>Gloves:</b></p> <p>Acetone: GL 1 n-hexane: GL2 PCE: GL3 TCE: GL4 MEK: GL5</p> <p><b>Spectacles:</b></p> <p>GG1</p> <p>Use power corrected goggle if necessary</p> <p>Not required if R1 is used</p> <p><b>Respirator:</b></p> <p>Use R1 in the absence of ventilation system</p>

**Table 5: Codes and types of personal protective equipments**

Sl. No	Code	Recommended protection	PPEs (Gloves/Goggles/Respirator)
1	GL 1	8 hr: Butyl/ latex or rubber gloves	<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>Butyl</p>  </div> <div style="text-align: center;"> <p>Latex or Rubber</p>  </div> </div>
2	GL 2	8 hr: Nitrile, PVA, Viton,	<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>Nitrile</p>  </div> <div style="text-align: center;"> <p>PVA</p>  </div> <div style="text-align: center;"> <p>Viton</p>  </div> </div>
3	GL 3	Nitrile latex gloves	
4	GL 4	8 hr: PVA, Viton	<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>PVA</p>  </div> <div style="text-align: center;"> <p>Viton</p>  </div> </div>
5	GL 5	Butyl gloves	
Sl. No	Code	Recommended protection	Spectacles / Goggles
2	GG1	Solvent resistant goggle	
Sl. No	Code	Recommended protection	Respirator
1	R1	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 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 7: Data Sheet for n-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)	<b>LD50 - Skin</b> >2 gm/kg rabbit; <b>LD50 -oral</b> >5 gm/kg rat <b>LC50 - inhalation</b> >3367 ppm - rat;	63.70° C	124mm Hg	0.69 g/cm <sup>3</sup>	-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 room and container 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 8: 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): Acute:</b> >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	14mm 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 (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 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 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 Trichloroethanol 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, food and feedstuffs dry. 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. (Extra personal protection: filter respirator for organic gases and vapours). Do NOT let this chemical enter the environment				-		



**Table 10: 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	78mm Hg	0.81 g/cm <sup>3</sup>	-9°C	Highly flammable	208Debye	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. Cool. Keep the storage room and container 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.			

\* 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