GUIDANCE ON CONTROL OF EXPOSURES RELATED TO USE OF CARBON TETRACHLORIDE SOLVENT SUBSTITUTES IN INDUSTRIAL ELECTRICAL CONTACT CLEANING APPLICATIONS

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gtz PROKLIMA

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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 ***electrical applications across select 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.

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ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienist
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
MDC	Methylene dichloride
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
TCLo	Lowest Published Toxic Concentration
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

A nation's overall development is catalyzed by the optimum use of electric power and the proper usage of power is based upon the periodic maintenance of the source and allied components capable of utilizing the same. While several cleaning processes are involved in routine maintenance, electrical contact cleaning in particular plays a central role in maintaining electrical output by saving enormous wastages of electrical energy. With prolonged use, electrical contacts develop carbon deposits due to high voltage sparking at the point of contact. This deposit over electrical contact has been recognized as a known barrier against electrical supply and therefore needs to be cleaned for achieving better conductivity. A comprehensive approach towards cleaning multiple contaminants is often beneficial for the industry to enhance the efficiency of the process.

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 THE ELECTRICAL SECTOR

To achieve the desired cleaning efficacy, solvents which quickly dissolve and remove oil, grease, flux, condensation and other contaminants, do not leave any residue, restore electrical continuity of contacts and effectively clean surrounding areas of electrical circuitry while preserving the surrounding insulating materials are preferred by industries.

Most of the industries use Methylene dichloride (MDC), Mineral turpentine, Acetone, Isopropyl alcohol (IPA) and Perchloroethylene (PCE) as cleaning agents for electrical contact cleaning operations. Application of solvents is based on the quality and quantity of solvents and also depends upon the cleaning process. Following are the processes involved in contact cleaning in industrial electrical applications:

2.1. Brushing and wiping process

The brushing process (**Figure 1**) is carried out using solvents like MDC, acetone, IPA, etc. for cleaning the deposit over the contacts followed by wiping of the same area either by using rags or cotton clothes. This method is often used, as solvent use is minimal perhaps reducing accompanying exposure risks.

Figure 1: Cleaning of electrical contact by brushing method

2.2. Wiping process

This process is used for cleaning the electrical contact assembled within bigger components. This is most often done with bare fingers (**Figure 2**) or by using nose pliers (**Figure 3**) or forceps. Cleaning materials such as rags and cottons are dipped directly into solvents and used without selective PPEs can major health risks for the workers. Workers prefer using their hands to allow finer manipulation required for effective cleaning.

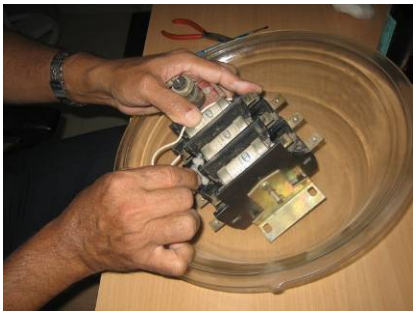


Figure 2: Cleaning of electrical contact by wiping with bare hands

Figure 3: Cleaning of electrical contact by wiping method using nose plier

2.3. Spraying process

This process is used for cleaning the electrical contacts that are directly on the installed panels as well for cleaning dismantled components (**Figure 4**) separately. Solvent volumes are high increasing exposure potentials considerably.

Figure 4: Cleaning of electrical contact by spraying method

2.4. Cleaning of panel contacts

This process is widely used using a combination of cleaning methods like spraying, brushing and wiping (**Figure 5 & 6**). Since often the components are set up in enclosed settings, the cleaning procedures are tough with significant potentials for high exposure.

Figure 5: Cleaning of electrical contact by spraying method

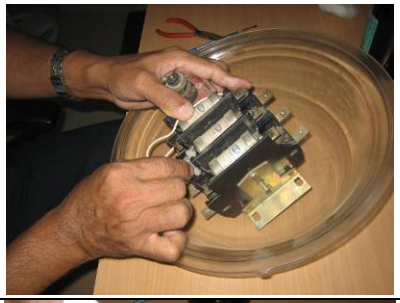
Figure 6: Cleaning of electrical contact by spraying followed by wiping method

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 related to industrial electrical applications.

Table 1: Job-hazard-risk profile

Job	Process/Hazard	Risk
Cleaning of contacts 	• Brushing followed by wiping	• Absorption through skin due to handling with bare hands
Cleaning of contacts 	• Wiping	• Absorption through skin due to handling with bare hands
Cleaning of dismantled contactor assembly 	• Wiping	• Absorption through skin due to handling with bare hands • Inhalation exposure during cleaning of assembly components due to high volume of solvent use
	• Spraying	• Absorption through skin, eye due to solvent splash and inhalation exposure due to solvent vapours
Cleaning of Panel contacts 	• Spraying	• Absorption through skin, eye due to solvent splash and inhalation exposure due to solvent vapours

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 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 while MDC levels consistently exceed the permissible exposure limits in most of the cleaning process, Acetone and IPA levels are usually lower than the permissible limits whereas, Mineral turpentine and PCE were found to be in intermediate levels. By using required quantity of solvents for specific cleaning applications, exposure concentration is reduced significantly. **Box 1** emphasizes the level of reduction that can be achieved in exposure concentration by optimizing 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 optimization of quantity of solvent use.

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 controls, administrative controls 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 electrical applications in industrial sectors.

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 fitness and performance.
- Safety sign boards specific to hazards must be provided and placed at appropriate 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

- 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.

Cleanup

- 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.

Personal hygiene

- 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 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 **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**.

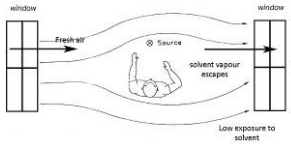
Box 2: Instruction for reading the guidance sheet

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 in general exposure concentration of acetone is lower than IPA, Mineral Turpentine and MDC in brushing and wiping process of cleaning operations. The same trends were seen during spraying process where exposure concentration of acetone is found to be below the permissible limit and in comparison to PCE, it's exposure concentration is always lower. On the other hand, owing to higher boiling point and higher specific gravity of PCE as compared to acetone, PCE concentration may build up over time creating new risks of exposure around the workplace (PCE is also being reported as a suspected carcinogen).

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
Wiping Process: a). Dismantled contact  b). Dismantled contact assembly 	• MDC • Mineral turpentine • Acetone • IPA	• Inhalation, dermal (skin) and eye contact due to cleaning with bare hands, naked eyes, spills, open containers, waste cotton used in wiping process of cleaning and inadequate ventilation	• Select a location near a window in downwind direction • Cleaning area should be well ventilated.  • Use nose pliers or forceps for cleaning  	• Use optimum quantity of solvent. • Transfer the solvent into small container using funnel to avoid spillage and splash • Close the solvent container after use. • Do not dip the cotton directly into the container to avoid skin contact • Treat solvent soaked cotton as hazardous waste • Remove the spills immediately • Keep solvents away from ignition sources • Prohibit smoking and place visual sign boards in the workplace to avoid fire hazard	**Gloves:** MDC: GL 1 Acetone: GL 2 IPA: GL 3 **Spectacles/ Goggles**: GG1 • Use solvent resistant spectacle and power corrected if necessary. • Not required if respirator (R2) is used. **Respirator:** Use R1 in the absence of LES

Job	Hazards/Solvents	Risk/ Exposure Situation	Control Measures		
			Engineering	Administrative	PPEs
Brushing process: a). Dismantled contact  b). Dismantled contactor assembly 	• MDC • Mineral turpentine • Acetone • IPA	Lung exposure to solvent vapours without adequate ventilation. Skin and eye contact due to solvent splash and vapour while working with bare hands, naked eyes respectively	• Process isolation along with good ventilation is essential • Cleaning of panel contacts and dismantled components should be done separately • Cleaning area should be well ventilated.	• Avoid spillage and overuse of solvent during the process using the brush • Optimize the solvent use during spraying process • Maintenance of electrical points and installations should be carried out periodically.	**Gloves:** MDC: GL 1 Acetone: GL 2 IPA: GL 3 In addition to gloves use **CPC1** during panel contact cleaning. **Spectacles/ Goggles**: GG2 • Use solvent resistant goggle and power corrected, if necessary, for dismantled component cleaning. • Not required if R2 is used. **Respirator:** Use R2 during panel cleaning in absence of LES

Job	Hazards/Solvents	Risk/ Exposure Situation	Control Measures		
			Engineering	Administrative	PPEs
Spraying process: Dismantled contact assembly 	• PCE • Acetone	Lungs, skin and eye exposure due to high concentration of solvents and vapours in the absence of adequate ventilation	• When a number of components are to be cleaned using large volumes of solvent, installation of Local Exhaust System (LES) is recommended. The mouth of the duct should be positioned near the emission source 	• Avoid spillage and overuse of solvent during the spraying process • Optimize the solvent use during spraying	**Gloves:** Acetone: GL 2 PCE: GL 4 **Spectacles/ Goggles**: GG2 • Use solvent resistant goggle and power corrected if necessary. • Not required if R2 is used. **Respirator:** Use R2 in the absence of LES

Table 5: Codes and types of personal protective equipments

Sl. No	Code	Recommended protection	PPEs (Gloves)
1	GL 1	8 hr: Poly Vinyl alcohol	
2	GL 2	8 hr: Butyl or latex/rubber gloves	Butyl Latex or Rubber 
3	GL 3	8 hr: Butyl, Nitrile, Viton,	Butyl Nitrile Viton 
4	GL 4	Nitrile latex gloves	
5	CPC1 (All solvents)	Chemical protective clothing (Refer GL1 to GL 5 for type of material)	
Sl. No	**Code**	**Recommended protection**	**Spectacles / Goggles**
1	GG 1	Solvent resistant spectacle	
2	GG2	Solvent resistant goggle	
Sl. No	**Code**	**Recommended protection**	**Respirator**
1	R1	Half face respirator	
2	R2	Full face respirator	

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 Methylene Chloride

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	(75-09-2)	**ORAL (LD50): Acute:** 1600 mg/kg [Rat].	40^0C	350mm Hg	1.33 g/cm 3	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, 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 and 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 (MDC) 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 chemical dangers. Keep away from food and feedstuffs. Keep the storage area cool. 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.)	Waste must be disposed of in accordance with federal, state and local environmental control regulations

Table 7: Data Sheet for Mineral Turpentine

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)**
Blend of aliphatic and aromatic hydrocarbons. Composition varies with manufacture.	(Not available)	**TCLo (inhaled, human)**: 600mg/m3/8H; **LC50 (inhaled, rat):** 3400ppm/4H; Eye (human): 880ppm/15min: irritant effect	146-197^{0}C (approx)	25 mm Hg	0.80-0.86 g/cm 3	36-38^{0}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 and kidney impairment. Exposure at high levels may result in tachycardia and 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 and remove to a 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 8: Data Sheet for Acetone

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)**
Ketone	(67-64-1)	**ORAL (LD50):** **Acute:** 5800 mg/kg [Rat]. 3000 mg/kg [Mouse]. 5340 mg/kg [Rabbit]. **VAPOR (LC50):** **Acute:** 50100 mg/m3 - 8 hours [Rat]. 44000 mg/m3 - 4 hours [Mouse].	56 ^{0}C	180 mm Hg	0.79 g/cm3	-20 ^{0}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 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 9: 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	33 mm 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 Separated from strong oxidants. Keep the storage area cool, ventilated 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 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].	121^0C	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.

* 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