

GUIDANCE ON CONTROL OF EXPOSURES RELATED TO USE OF CARBON TETRACHLORIDE SOLVENT SUBSTITUTES IN METAL DEGREASING APPLICATIONS



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.



November 2009

**GUIDANCE ON CONTROL OF EXPOSURES RELATED TO USE OF
CARBON TETRACHLORIDE SOLVENT SUBSTITUTES IN
METAL DEGREASING APPLICATIONS**

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 substance 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 requires 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 (CO₂), 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 few ***Metal Degreasing*** 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 Brakes India Private Limited, Polambakkam and Wheels India Private limited Chennai 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

| | |
|--|-----------|
| 1. INTRODUCTION | 9 |
| 2. WORK PRACTICES RELATED TO USE OF SOLVENTS IN THE METAL DEGREASING SECTOR | 11 |
| 2.1. Immersion | 11 |
| 2.2. Spraying..... | 11 |
| 2.3. Vapour degreasing..... | 11 |
| 2.4. Wiping..... | 12 |
| 3. HAZARD IDENTIFICATION AND RISK ASSESSMENT..... | 13 |
| 4. EXPOSURE ASSESSMENT AND RISK CHARACTERIZATION | 15 |
| 5. CONTROL GUIDANCE..... | 16 |
| 5.1. General Work Practice Guidelines..... | 16 |
| 5.2. Process Specific Guidelines | 19 |

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 |
| 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

FIGURES

- Figure 1 Cleaning of component by immersion method
Figure 2 Cleaning of components by spraying method
Figure 3 Typical vapour degreaser
Figure 4 Cleaning of components by vapour degreasing method

TABLES

- Table 1 Job-hazard-risk profile
Table 2 General guidelines for managers and supervisors
Table 3 General guidelines for workers
Table 4 Job specific control guidance sheet
Table 5 Codes and types of personal protective equipments
Table 6 Data sheet for Isopropyl alcohol
Table 7 Data sheet for Acetone
Table 8 Data sheet for n-Hexane
Table 9 Data sheet for Trichloroethylene
Table 10 Data sheet for Perchloroethylene
Table 11 Data sheet for Toluene

BOXES

- Box 1 Optimum use of solvent and percentage reduction in exposure concentration
Box 2 Instruction for reading the guidance sheet

1. INTRODUCTION

Metal degreasing is a widespread process performed in many manufacturing industries. Metal components often contain lubricating oils, dirt, grease, fluxes, rust and this has to be cleaned before surface treatment for subsequent manufacturing process. Generally, metal degreasing process is employed in industries where production process includes fabrication, manufacture and assembling of metal parts such as those involved in automobile, aviation, rail and road industries. Metal degreasing is considered as a vital activity and hence, the contaminants must be effectively cleaned or degreased.

There are various processes being used by many industries for the cleaning operation. Some use mechanical means like sand blasting and high pressure jets to flush out insoluble soils. For soluble contaminants, either cold cleaning processes like spraying, wiping, rinsing and immersion cleaning, or hot cleaning processes like vapour degreasing are used. It is also possible to combine two processes, as in case of ultrasonic cleaning, where a solvent is used along with mechanical agitation of parts to do precision cleaning.

Industries use different methods of degreasing; acid, alkaline, neutral, emulsion, ultrasonication, mechanical (e.g. wire brushing, grinding and sanding, abrasive blasting) and solvent cleaning depending on the metal components, type of contaminant, cost and cleaning efficiency. Though different methods are practiced, use of chemicals in each of the processes is inevitable.

Acid degreasing is based on the removal of contaminants by using sulfuric, hydrochloric, nitric, phosphoric, hydrofluoric, fluorboric and chromic acids. This method is less commonly used because of the acids' inherent corrosive property, difficulty in handling and less efficiency than other methods. Since acids can cause metal embrittlement and can form insoluble byproducts, their use is very limited.

Alkaline degreasing is the most commonly used for removal of soils in metal preparation prior to other processes. Sodium hydroxide based cleaners are generally used because of their economic value. However, their use is limited for cleaning non-ferrous metal due to the formation of over etching surfaces and also due to the difficulty in rinsing of residues. Though, alkali silicate is good to clean non-ferrous metals, it is expensive as well as difficult to rinse. Synthetic detergents and surfactants have widely been preferred for their good performance, easy handling and disposal, in spite of the longer bath time.

Solvent degreasing process use solvents such as Acetone, n-Hexane, Isopropyl alcohol, Toluene, Methyl ethyl ketone (MEK), Methylene dichloride (MDC), 1,1,1-Trichloroethane, Trichloroethylene (TCE), Perchloroethylene (PCE) etc. Two common methods of degreasing used are liquid solvent cleaning (cold cleaning) and vapor degreasing.

Although new cleaning products have been developed and marketed in the form of pure substances and mixtures, chlorinated solvents are extensively used because of their cleaning efficiency and hence, it has been the best option. These solvents are expensive, can cause environmental pollution as well as degradation of the earth's ozone layer and hazardous effects on human health. In view of these drawbacks, many attempts have been made to replace chlorinated solvents with aqueous based cleaning composition.

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 METAL DEGREASING SECTOR

Different cleaning methods are employed in metal degreasing sector and selection of solvents also varies depending on the cleaning method. In most of the cases, cleaning methods such as spraying, vapour degreasing, immersion and wiping are routinely carried out in industries as briefed in this section.

2.1. Immersion

Metal components such as smaller machine or automobile parts, gauges, bolts and nuts are generally cleaned by immersion method. A few components at a time are cleaned in a small wide mouthed open tray (**Figure 1**), followed by agitation and rinsing in the solvent.



Figure 1: Cleaning of component by immersion

2.2. Spraying

Here, metal parts are hanged over a tray or a container (**Figure 2**) or placed on a chemical fume hood followed by spraying the solvent under high pressure over the components. After the contaminants are dissolved in the solvent, the metal parts are removed and the solvent is filtered for reuse.



Figure 2: Cleaning of components by spraying method

2.3. Vapour degreasing

Vapor degreasers consist of a tank (**Figure 3**) containing solvent-based cleaning solution, usually TCE, at elevated temperatures resulting in higher volatilization. A condenser is placed above the vaporization zone to condense much of the vapor

back to the solution. In this method of cleaning the metal parts are degreased by placing the components in the vapour zone with varying resident time depending on the components and taken out after the cleaning is completed. Vapor degreasing is technically effective but economically and environmentally disadvantageous.

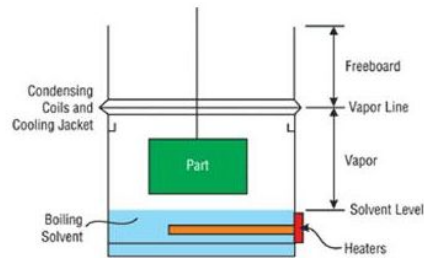


Figure 3: Typical vapour degreaser



Figure 4: Cleaning of components by vapour degreasing method

2.4. Wiping

This method of cleaning is perhaps one of the most frequently used for equipment cleanings. A rag or sponge is dipped into the solvent and then wiped to remove oily or greasy dirt that has been accumulated on the components being cleaned. It should be noted that there is no real equipment cost for this method of cleaning except for labour and materials. Big components are cleaned by this method, usually for surface cleaning. During maintenance activities, the machine surface or the machine parts are also cleaned by using this process.

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 metal degreasing sector.

Table 1: Job-hazard-risk profile

| Job | Process/Hazard | Risk |
|---|---|--|
| <p>Metal degreasing Immersion method</p>  | <ul style="list-style-type: none"> • Removal of contamination by immersion Or • Cleaning by rinsing and agitation • Spillage and vaporization during filling of solvent in to the tray. | <ul style="list-style-type: none"> • Exposure via lungs, skin and eyes. • Additional lung exposure through evaporation from open container • Contamination of water and soil through spilled and disposed solvent wastes. |
| <p>Spraying method</p>  | <ul style="list-style-type: none"> • Cleaning of components by spraying. • Solvent mist from high pressure spray. | <ul style="list-style-type: none"> • Exposure via lungs, skin and eyes due to solvent splashing and vaporization. • Enhanced skin absorption by not using gloves and whole body exposure to vapour mists. |
| <p>Vapour degreasing method</p>  | <ul style="list-style-type: none"> • Cleaning by vapour degreasing. • Condensed vapours on the components and at the mouth of the degreasing bath. | <ul style="list-style-type: none"> • Exposure via lungs, skin and eyes. • Inhalation risk from use of improper respirator and gloves. • Contamination of water and soil through disposal of solvent waste. |

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 while Toluene, PCE, TCE, n-Hexane and Acetone levels consistently exceed the permissible exposure limits in most of the cleaning processes, IPA levels are relatively lower than the other solvents but marginally above the ACGIH guideline. By using required quantity of solvents for specific cleaning applications, exposure concentrations are reduced significantly. **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 oxygen manufacturing and refilling 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 | | |
|---|---|--|
| <ul style="list-style-type: none"> • 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 | Cleanup | Personal hygiene |
| <ul style="list-style-type: none"> • 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. | <ul style="list-style-type: none"> • 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. | <ul style="list-style-type: none"> • 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 | | |
| <ul style="list-style-type: none"> • 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 | | |
|--|--|--|
| <ul style="list-style-type: none"> • 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 |
| <ul style="list-style-type: none"> • 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. | <ul style="list-style-type: none"> • 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. | <ul style="list-style-type: none"> • 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 | | |
| <ul style="list-style-type: none"> • 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** 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**.


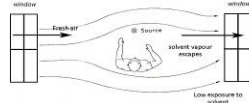
Box 2: Instruction for reading the guidance sheet


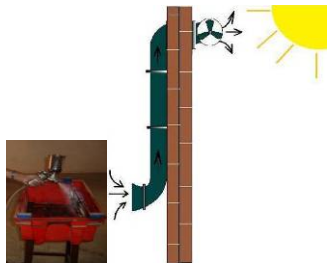
For identifying job specific hazard, risk and control measures, read the guidance sheet from left to right across the row.


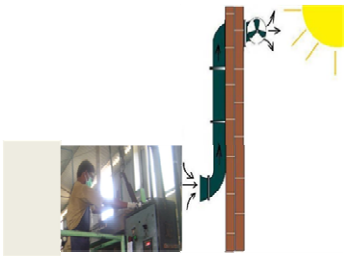
It must be emphasized that the guidance sheets only provide information on “safe use” of specific solvents being used in each process. Selection amongst solvent substitutes is governed by considerations that often go beyond occupational exposures. On the basis of a limited set of exposure measurements, it has been observed that PCE concentrations are higher, in spite of its higher boiling point and high specific gravity boiling point. In non-ventilated spaces, PCE concentrations may build up over time in continuous cleaning process, creating more risks of exposure. The concentrations of PCE and TCE consistently 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 **11**.

Table 4: Job Specific Control Guidance Sheet

| Job | Hazard/Solvents | Risk/ Exposure Situation | Control Measures | | |
|---|---|---|--|--|---|
| | | | Engineering | Administrative | PPEs |
| <p>Metal cleaning by immersion method</p>  | <ul style="list-style-type: none"> Isopropyl Alcohol (IPA) Acetone n-Hexane Trichloroethylene (TCE) Perchloroethylene (PCE) Toluene | <ul style="list-style-type: none"> Inhalation, dermal (skin) and eye exposure due to immersion with bare hand, naked eyes; evaporation from spills during transferring and agitation of tray. Additional Inhalation from open solvent container and tray. | <ul style="list-style-type: none"> Cleaning area should be well ventilated. Select the work location near a window in accordance to the wind direction.  <ul style="list-style-type: none"> Use mechanical ventilation like industrial or exhaust fan to dilute the vapours. | <ul style="list-style-type: none"> Close the container after transferring the solvent. Use optimum quantity of solvent. Do not dip the components directly into the container to avoid skin contact and solvent contamination. Use narrow mouthed containers or trays for immersion and rinsing. Remove the spills immediately. Keep solvents away from ignition sources. Prohibit smoking and place visual sign boards in the workplace to avoid fire hazard | <p>Gloves: IPA: GL 1 Acetone: GL 2 n-Hexane: GL 3 PCE: GL 4 TCE: GL 5 Toluene: GL 5</p> <p>Spectacles/goggles: GG 1</p> <ul style="list-style-type: none"> Use solvent resistant spectacles and power corrected if necessary. Not required if respirator (R1 or R2) is used. |

| Job | Hazard/Solvents | Risk/ Exposure Situation | Control Measures | | |
|--|---|--|---|--|---|
| | | | Engineering | Administrative | PPEs |
| <p>Metal cleaning by spraying method</p>  | <ul style="list-style-type: none"> • Isopropyl Alcohol (IPA) • Acetone • n-Hexane • Trichloroethylene (TCE) • Perchloroethylene (PCE) • Toluene | <ul style="list-style-type: none"> • Exposure through lungs, skin and eyes due to solvent splashing and vaporization. • Enhanced skin absorption by not using gloves and whole body exposure to vapour clouds. • Contamination of water and soil through disposal of solvent waste. | <ul style="list-style-type: none"> • Cleaning should be carried out in well ventilated environment. • Use Local exhaust system and make sure that the exhaust system is working.  | <ul style="list-style-type: none"> • Isolate the spraying from other process to minimize the solvent exposure of other workers. • Reduce the workers' exposure time by job rotation. • Use soap oil solution for cast iron cleaning. • Use alkaline degreasing method for cleaning steel. • Use spraying in combination with immersion method. • Use electrode degreasing wherever feasible. (The contaminants are charged in an electrical field and deposited at the respective electrodes) • Use ultrasonication method wherever feasible. | <p>Gloves and CPC: IPA: GL 1 Acetone: GL 2 n-Hexane: GL 3 PCE: GL 4 TCE: GL 5 Toluene: GL 5</p> <p>Use CPC 1 together with gloves for this process.</p> <p>Spectacles/Goggles: GG 2</p> <ul style="list-style-type: none"> • Use solvent resistant goggle and power corrected if necessary. • Not required if respirator (R1 or R2) is used. <p>Respirators:</p> <ul style="list-style-type: none"> • R 1 in absence of LES/LEV and intermittent process. • R 2 for continuous spraying process. |

| Job | Hazard/Solvents | Risk/ Exposure Situation | Control Measures | | |
|--|--|---|---|---|--|
| | | | Engineering | Administrative | PPEs |
| <p>Metal cleaning by vapour degreasing method.</p>  | <ul style="list-style-type: none"> Perchloroethylene (PCE) Trichloroethylene (TCE) | <ul style="list-style-type: none"> Inhalation, dermal (skin) and eye contact due to solvent vapourization at the mouth of degreasing bath and condensed solvent on the components. Additional Inhalation and dermal risk by using improper respirator and gloves. | <ul style="list-style-type: none"> Cleaning should be carried out in well ventilated environment. Use local exhaust system.  | <ul style="list-style-type: none"> Isolation of work process. Hold the component in the vapour condensing zone for few seconds followed by holding near the local exhaust system in case of manual component holding. One hour interval required before subsequent exposure; not more than 4 cycles of 15 minutes cleaning per day per worker for vapour degreasing process. | <p>Gloves: PCE: GL 4 TCE: GL 5</p> <p>Spectacles/Goggles: GG 2</p> <ul style="list-style-type: none"> Use solvent resistant goggle and power corrected if necessary. Not required if respirator (R1 or R2) is used. <p>Respirators:</p> <p>R 1 in the absence of LES/LEV and for intermittent process.</p> <p>R 2 for continuous vapour degreasing process.</p> |



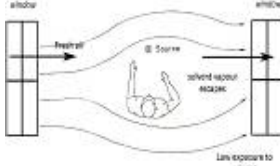


| Job | Hazard/Solvents | Risk/ Exposure Situation | Control Measures | | |
|---|---|--|--|---|---|
| | | | Engineering | Administrative | PPEs |
| <p>Cleaning of Oil by wiping method</p>  | <ul style="list-style-type: none"> Isopropyl Alcohol (IPA) Acetone n-Hexane Trichloroethylene (TCE) Perchloroethylene (PCE) Toluene | <ul style="list-style-type: none"> Inhalation, dermal (skin) and eye contact due to cleaning with bare hand, naked eyes, spills. Additional Inhalation and dermal risk by using inappropriate respirator, gloves. Additional Inhalation risk due to solvent evaporation from open or partially closed containers.  | <ul style="list-style-type: none"> Transfer the solvent into small container using funnel to avoid spillage and splash. Cleaning area should be well ventilated (natural ventilation). Select the work location near a window in accordance to the wind direction  | <ul style="list-style-type: none"> Use optimum quantity of solvent. Close the container after use. Restrict the presence of coworkers nearby, during the cleaning process. Prohibit dipping the cotton directly into the container to avoid skin contact and solvent contamination. 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. | <p>Gloves and CPC: IPA: GL 1 Acetone: GL 2 n-Hexane: GL 3 PCE: GL 4 TCE: GL 5 Toluene: GL 5</p> <p>Spectacles/goggles: GG 1</p> <ul style="list-style-type: none"> Use solvent resistant spectacles and power corrected if necessary. Not required if respirator (R1 or R2) is used. |

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 | <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">Butyl </div> <div style="text-align: center;">Nitrile </div> <div style="text-align: center;">Viton </div> </div> |
| 2 | GL 2 | 8 hr: Butyl/ latex or rubber gloves | <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">Butyl </div> <div style="text-align: center;">Latex or Rubber </div> </div> |
| 3 | GL 3 | 8 hr: Nitrile, PVA, Viton, | <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">Nitrile </div> <div style="text-align: center;">PVA </div> <div style="text-align: center;">Viton </div> </div> |
| 4 | GL 4 | Nitrile latex gloves |  |
| 5 | GL 5 | 8 hr: PVA, Viton | <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">PVA </div> <div style="text-align: center;">Viton </div> </div> |
| 6 | 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 | Supplied air respirator (Air line 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 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°C | 33 mm Hg | 0.79 g/cm ³ | 12 °C | Highly flammable | 1.7 Debye | 23.5 |
| Health guidance | | | | | | | | | |
| Acute (Immediate) effects | Chronic (Delayed) effects | Target organ affected | Permissible limits of exposure | | First aid | Medical Surveillance | | | |
| | | | STEL | TWA | | | | | |
| The substance irritates the eyes and the respiratory tract. The substance may cause effects on the central nervous system, resulting in depression. Exposure far above the OEL may result in unconsciousness | The liquid defats the skin | Eyes, skin, respiratory system | 500*** 200**** | 400** 400*** 400**** | Eye: Irrigate immediately Skin: Water flush Breathing: Respiratory support Swallow: Medical attention immediately | Testing whole blood, expired air and urine for IPA or for the metabolites | | | |
| Safety and environmental guidance | | | | | | | | | |
| Incompatible chemicals | Storage condition | Type of fire extinguisher | Spill control | | | Waste disposal | | | |
| Strong oxidizers, acetaldehyde, chlorine, ethylene oxide, acids, isocyanates | Fireproof Separate from strong oxidants Keep the storage area 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° C | 124 mm Hg | 0.69 g/cm ³ | -23 °C | Highly flammable | 0 Debye | 14.9 |
| Health guidance | | | | | | | | | |
| Acute (Immediate) effects | Chronic (Delayed) effects | Target organ affected | Permissible limits of exposure | | First aid | Medical Surveillance | | | |
| | | | STEL | TWA | | | | | |
| The substance irritates the skin. Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. Exposure at high levels could cause lowering of consciousness | Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the central nervous system peripheral nervous system, resulting in polyneuropathy. Animal tests show that this substance possibly causes toxic effects upon human reproduction | Eyes, skin, respiratory system, central nervous system, peripheral nervous system | - | 500** 50*** 50**** | Eye: Irrigate immediately Skin: Soap wash immediately Breathing: Respiratory support Swallow: Medical attention immediately | Testing urine for 2,5-hexanedion in the end of shift at end of workweek | | | |
| Safety and environmental guidance | | | | | | | | | |
| Incompatible chemicals | Storage condition | Type of fire extinguisher | Spill control | | | Waste disposal | | | |
| Strong oxidizers | Fireproof Separate from strong oxidants Keep the storage area and container well 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 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/m ³ - 8 hours [Rat]. 44000 mg/m ³ - 4 hours [Mouse]. | 56 °C | 180 mm Hg | 0.79 g/cm ³ | -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 end at the 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 Trichloroethylene (TCE)

| 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 | (79-01-6) | ORAL (LD50): Acute: 5650 mg/kg [Rat]. 2402 mg/kg [Mouse]. DERMAL (LD50): Acute: 20001 mg/kg [Rabbit]. | 87°C | 58 mm Hg | 1.47 g/cm ³ | None | None | 0.8 Debye | 19.0 |
| Health guidance | | | | | | | | | |
| Acute (Immediate) effects | Chronic (Delayed) effects | Target organ affected | Permissible limits of exposure | | First aid | Medical Surveillance | | | |
| | | | STEL | TWA | | | | | |
| The substance irritates the eyes and the skin. Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. The substance may cause effects on the central nervous system, resulting in respiratory failure. Exposure could cause lowering of consciousness | Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the central nervous system, resulting in loss of memory. The substance may have effects on the liver kidneys (see notes). This substance is probably carcinogenic to humans | Eyes, skin, respiratory system, heart, liver, kidneys, central nervous system | 200* 25**** | 50* 100** 10**** | Eye: Irrigate immediately Skin: Water flush promptly Breathing: Respiratory support Swallow: Medical attention immediately | Testing Trichloroacetic acid in urine in end of the shift at end of workweek Testing Trichlorethanol in blood in end of the shift at end of workweek Testing Trichloroethylene in blood in end of the shift at end of workweek Testing Trichloroethylene in end-exhaled air in end of the shift at end of workweek Pulmonary Function Tests Blood Plasma | | | |
| Safety and environmental guidance | | | | | | | | | |
| Incompatible chemicals | Storage condition | Type of fire extinguisher | Spill control | | | | Waste disposal | | |
| Strong caustics & alkalis; chemically-active metals (such as barium, lithium, sodium, magnesium, titanium & beryllium) | Separate from metals See chemical dangers 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. (Extra personal protection: filter respirator for organic gases and vapours). Do NOT let this chemical enter the environment | | | | Waste must be disposed of in accordance with federal, state and local environmental control regulations | | |

Table 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°C | 14mm 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 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 11: 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°C | 21 mm Hg | 0.87 g/cm 3 | 4-7°C | Highly flammable | 0.3 Debye | 18.2 |
| Health guidance | | | | | | | | | |
| Acute (Immediate) effects | Chronic (Delayed) effects | Target organ affected | Permissible limits of exposure | | First aid | Medical Surveillance | | | |
| | | | STEL | TWA | | | | | |
| The substance irritates the eyes and the respiratory tract. Exposure could cause central nervous system depression. Exposure at high levels may result in cardiac dysrhythmia, unconsciousness and death | Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the central nervous system, resulting in decreased learning ability and psychological disorders. Animal tests show that this substance possibly causes toxic effects upon human reproduction | Eyes, skin, respiratory system, central nervous system, liver, kidneys | 150* 150*** | 100* 100** 100*** 20**** | Eye: Irrigate immediately Skin: Water flush promptly Breathing: Respiratory support Swallow: Medical attention immediately | Testing O-cresol content in urine or (Hippuric acid in urine) in end of the shift Testing toluene content in blood in prior to last shift to workweek | | | |
| Safety and environmental guidance | | | | | | | | | |
| Incompatible chemicals | Storage condition | Type of fire extinguisher | Spill control | | | | Waste disposal | | |
| Strong oxidizers | Fireproof Separate from strong oxidants | Powder, AFFF, foam, carbon dioxide | Collect leaking liquid in sealable containers. Absorb remaining liquid in sand or inert absorbent and remove to safe place. Do NOT wash away into sewer (extra personal protection: self-contained breathing apparatus). | | | | Waste must be disposed of in accordance with federal, state and local environmental control regulations | | |

* 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