Commitment to the Human Element
Working safely while protecting people and the environment is a vital part of everything we do at Dow. Our success is not complete without the most essential component of our scorecard—the Human Element. We are committed to eliminating injuries, safeguarding the environment, human health, reducing waste, reducing emissions and promoting resource conservation.

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Introduction

The Dow Chemical Company has a fundamental concern for all who make, distribute and use its products, and for the environment in which we live. This concern is the basis for our Product Stewardship philosophy, by which we assess the safety, health and environmental information on our products, and then take appropriate steps to protect employee and public health and the environment. The success of this Product Stewardship program rests with each and every individual involved with Dow products—from the initial concept and research to the manufacture, sale, distribution, use, disposal and recycling of each product.

As a Responsible Care® company, Dow is fully committed to Product Stewardship as a way of approaching every task, and we encourage you to make the same commitment.

Purpose of This Manual

This manual is designed to help you safeguard the health of your employees, encourage safe working practices, maintain chlorinated solvent exposure levels below the current industrial health limits, and protect the environment. It is essential that everyone who comes into contact with chlorinated solvents is thoroughly trained in safe work practices and the proper use of equipment. All personnel should be aware of potential hazards, understand how to use personal protective equipment, and know how to seek medical assistance and/or administer first aid.

Further, Dow recommends that every individual who handles, stores or is regularly exposed to chlorinated solvents read and familiarize themselves with the contents of this manual and the appropriate Safety Data Sheets (SDS). Every individual who may use these solvents is required to understand how to access and understand the information contained in the SDS.

Safety Data Sheets

Each SDS contains information for handling specific Dow chlorinated solvents. Always consult the appropriate SDS or contact Dow to make sure you have the proper chlorinated solvent for your application. The most current SDS can be found at www.dow.com in the Safety Data Sheet finder.

Solvents Covered in This Manual

While this manual outlines general safety information for methylene chloride, perchloroethylene and trichloroethylene products, the same principles apply to other chlorinated organic products produced by Dow.

Some grades of chlorinated solvents are designed for particular applications and may contain stabilizers that have been developed with specific end uses in mind; therefore, they may not be suitable for other applications. Consult the relevant SDS or contact Dow to decide on the right product for your end-use requirements. Also, be aware of changing marketplace conditions and government regulations that may restrict the products available to you.

KEEP THIS MANUAL AND THE CURRENT SDS NEARBY IN CASE OF EMERGENCY AND AS A VALUED REFERENCE.
Product Stewardship

A Commitment to Health, Safety and the Environment
This section discusses Dow’s Product Stewardship philosophy, including:
• The role of the end user
• Guidelines for using chlorinated solvents
• Special considerations for methylene chloride, perchloroethylene and trichloroethylene
• Information about Safety Data Sheets

Chlorinated solvents have been widely used for metal cleaning, urethane foam blowing, pharmaceutical manufacturing, paint stripping, cleaning printed circuit board components and dry cleaning for more than 50 years. They are also used as feedstocks for the manufacture of fluorocarbons, refrigerants and blowing agents (HCFCs and HFCs), and other industrial products.

As the world’s largest manufacturer of chlorinated solvents, Dow is committed to assessing safety, health and environmental information on our products, and then taking appropriate steps to protect employee and public health, and the environment. Dow has devoted considerable resources to promoting the safe and effective use of chlorinated solvents, as well as their proper storage and disposal.

Hazard vs. Risk
It is important to properly define the words “hazard” and “risk.” Hazard refers to the intrinsic toxicological and ecotoxicological properties of a substance that can cause harm to humans and/or the environment. Risk is an estimate of the potential exposure to these hazards. Whether a hazardous substance poses a risk depends on the circumstances under which the substance is used or handled. For example, the likelihood of exposure to humans or the environment is reduced when a hazardous substance is used in a closed system, thereby reducing risk.
You Have a Role in Product Stewardship

In general, Product Stewardship is a way of assessing information on the health and environmental aspects of a product and then providing guidelines to protect the environment and those who use the product. At Dow, Product Stewardship is a process to make health, safety and environmental protection an integral part of designing, manufacturing, marketing, distributing, using, recycling and disposing of products.

Government regulations vary by location and are subject to change. It is ultimately your responsibility to ensure that your use of chlorinated solvents complies with all applicable regulations, and that the application of these solvents meets all national, regional and local regulations.

End-Use Guidelines

Always review how you plan to use chlorinated solvents before choosing one for your application.

Dow recommends you use the following end-use guidelines as part of the process of evaluating applications for chlorinated solvents. Dow's chlorinated solvents should not be used in applications in which:

- Soil or groundwater contamination is likely (direct application to the ground, sink drains, sewers or septic tanks)
- Overexposure is likely (small rooms or confined spaces where inadequate ventilation exists and no adequate personal protective equipment is available and in use)
- Skin contact is likely (such as removing adhesive tape from the skin, or as a hand cleaner to remove oils and greases)
- Direct contact with food is possible
- Vapor concentrations are used in the flammable range without appropriate control equipment
- Disposal of waste would pose an environmental or health risk
- Chemical reactivity poses a danger (contact with strong alkali or in areas where welding is done)
- Any applicable regulations would be violated

Chlorinated solvents have been used effectively in a variety of Dow-supported applications around the world for more than 50 years, including:

- Aerosol products formulation
- Chemical processing industry
- Coatings and adhesives formulation
- Dry cleaning
- Fluorocarbons
- Metal cleaning/degreasing
- Paint formulation and stripping
- Pharmaceuticals manufacturing
- Silicones
- Urethane foam blowing

Dow is continuously reviewing the applications in which chlorinated solvents are used, especially in light of new regulations and other potential restrictions that may be placed on the use of these solvents. Due to the established Dow Industrial Hygiene Guideline for atmospheric trichloroethylene (TCE) of 5 ppm maximum and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value of 10 ppm, Dow does not support the use of trichloroethylene in aerosol applications. The use of other chlorinated solvents in aerosol applications should be carefully scrutinized by the formulator to minimize the potential for human or environmental exposures in end-use applications.

There may be other applications that are not appropriate for these chlorinated solvents. Always consult the appropriate SDS or contact Dow to make sure you have the appropriate chlorinated solvent for your application.

Methylene chloride, perchloroethylene and trichloroethylene can be used safely in many applications. Exposure can be adequately controlled through ventilation, engineering controls, work practices and personal protective equipment (PPE). Review each application carefully to ensure that exposure is below established limits.
**Safety Data Sheets**

**Always review the SDS before handling chlorinated solvents.**

Never handle any chlorinated solvent before you have read the relevant SDS. Each SDS contains information for handling a specific Dow chlorinated solvent. SDSs are updated regularly and reflect the most current detailed information on health effects, handling precautions and first aid. They may also provide additional information that is not contained in this manual.

The SDS must be readily accessible to all persons where the product is being used. It is your responsibility to ensure that the most up-to-date SDS, provided by the supplier, is available to, and understood by, all employees who work with chlorinated solvents.

For details on the general physical properties of chlorinated solvents, the selection of solvents, equipment for specific end uses, and general use, refer to the back cover of this manual for the phone number, web address and mailing address of a Dow office in your region. Be sure to ask for literature or other materials appropriate to your specific application.

**Responsible Care®**

In addition to Product Stewardship, Dow is committed to implementing the guiding principles of the chemical industry’s Responsible Care initiatives. We respond to concerns about the impact of chemicals on people and the environment in order to continuously improve our performance in every aspect of our business.
Human Health Considerations

This section presents important information about keeping individuals safe when working with chlorinated solvents. In this section, you will find general safety information, along with specific recommendations for:

- Personal protective equipment (PPE)
- Monitoring solvent vapor levels
- Entry guidelines for tanks, pits and other confined areas
- Vapor degreaser safety

Toxicity and Risk

Essentially all substances, both natural and man-made, are toxic to some degree. Toxicity is defined as the ability of a substance to produce any harmful effect to a living organism, at some level or frequency of exposure, by inhalation, ingestion, or direct skin or eye contact.

The potential risk of a hazardous substance can be considerably reduced with proper handling, such as the use of engineering controls, fume hoods, respirators, chemical goggles and other safety equipment. At recommended occupational exposure levels (see appropriate SDS), it is unlikely that chlorinated solvents would produce adverse effects, even from repeated exposure. Used properly by trained personnel and stored carefully in accordance with applicable laws and regulations, chlorinated solvents can be used safely and provide effective solutions for your solvent needs.

Experience has shown that overexposure to chlorinated solvents is most likely to arise during storage, filling, handling and maintenance operations. Please read these sections carefully, as they will provide you with the proper guidelines for working with chlorinated solvents.

Table 1: Odor Thresholds

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Odor Threshold</th>
<th>Slight (not unpleasant)</th>
<th>Strong (unpleasant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylene chloride</td>
<td>150–160 ppm</td>
<td>250–1,000 ppm</td>
<td>&gt; 1,000 ppm</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>20–50 ppm</td>
<td>100–400 ppm</td>
<td>&gt; 1,000 ppm</td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td>5–70 ppm</td>
<td>100–200 ppm</td>
<td>&gt; 280 ppm</td>
</tr>
</tbody>
</table>

General Safety Guidelines

- Always consult the appropriate SDS before beginning work and keep it nearby so you can refer to it in case of an accident or exposure.
- Know which type of solvent and grade you are handling, and be aware of its properties and hazards.
- Always use the appropriate PPE and safety equipment for the application. Wear protective garments and eye protection at all times.
- Be alert. When working with chlorinated solvents, avoid situations that can result in overexposure.
- Monitor the air regularly for the presence of chlorinated solvents. Do not rely on smell alone as an indicator of hazardous exposure levels (see Table 1).
- Trained personnel should regularly monitor solvent concentrations in the air to ensure safety and to comply with all applicable regulations.
- Immediately seek fresh air and assistance if you become light-headed while working with chlorinated solvents; dizziness and loss of coordination can lead to more serious accidents.
- Avoid contact with your skin. Prolonged or repeated contact of chlorinated solvents with the skin may cause irritation. Certain inhibitors in some products may cause skin sensitization.
- Do not drink alcohol before working with chlorinated solvents or after possible overexposure. Alcohol consumption in an industrial workplace is unwise, dangerous and often illegal. Alcohol consumption may accentuate the central nervous system symptoms associated with exposure to chlorinated solvents, and may lower your tolerance to adverse effects caused by inhaling solvent vapor.

To find more information about chlorinated solvents, or to download the most current version of the Chlorinated Solvents Product Stewardship Manual, visit www.chlorinatedsolvents.com or www.dow.com
Routes of Exposure
When considering the toxicity of chlorinated solvents, the route of exposure is important. The likely routes of exposure are inhalation, ingestion or direct contact with the skin or eyes.

See Table 2 for a summary of the health effects of methylene chloride, perchloroethylene and trichloroethylene. For specific safety information, refer to the appropriate SDS.

**Inhalation**
Inhalation of solvent vapor is the most likely route of exposure to chlorinated solvents. Therefore, it is essential to keep ambient levels in the workplace below the regulated or recommended occupational exposure standards. Groups such as the German Maximum Allowable Concentration (MAK) Commission and American Conference of Governmental Industrial Hygienists (ACGIH) are independent, non-regulatory organizations. These groups have developed MAK and Threshold Limit Value (TLV) guidelines to assist professionals in the control of health hazards in the workplace. Industrial hygiene professionals around the world refer to these guidelines.

**Odor Threshold**
Solvent vapors in the air produce various intensities of odor. The characteristic smell of chlorinated solvents has been described as “sweetish,” “aromatic” or “ether-like.” The odor threshold is different for the three solvents (see Table 1) covered in this manual. Although smell by itself is not a reliable measure of vapor concentrations, it is an important warning of a condition that needs further investigation.

The intensity of solvent odors can be related to the vapor concentration in the air. With time, however, individuals can become accustomed or insensitive to the odor. Therefore, the perception of odor is not sufficient warning of excessive exposure. To ensure employee safety, a trained individual should monitor the work area regularly.

**Ingestion**
Swallowing small amounts of chlorinated solvents incidental to normal handling operations is not likely to cause injury. Swallowing larger amounts, either accidentally or intentionally, could result in serious injury or death. Do not eat, drink or smoke in areas where chlorinated solvents are stored or used.

<table>
<thead>
<tr>
<th></th>
<th>Central Nervous System Effects (a)</th>
<th>Eye Irritation (b)</th>
<th>Skin Irritation (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylene chloride</td>
<td>&gt; 500 ppm</td>
<td>&gt; 500 ppm</td>
<td>moderate</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>&gt; 400 ppm</td>
<td>&gt; 400 ppm</td>
<td>moderate</td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td>&gt; 100 ppm</td>
<td>&gt; 100 ppm</td>
<td>slight</td>
</tr>
</tbody>
</table>

(a) For example: headache, dizziness, sleepiness. Usually these effects are reversible if the person is removed from the area and given fresh air.
(b) Painful
(c) Effects become more severe upon repeated exposure. All chlorinated solvents can cause defatting of the skin with repeated exposure.
One way to compare the acute oral toxicity of substances is to determine their LD50. The LD50 is the single dose, expressed in grams per kilogram of body weight, which results in a 50-percent mortality rate in laboratory animals. The oral LD50s of the chlorinated solvents are relatively high, which generally indicates a low degree of acute toxicity (see Table 3).

If ingestion occurs, do not induce vomiting. Call a physician and/or take the employee to an emergency medical facility. If the solvent liquid enters the lungs, it may be rapidly absorbed by the lung tissue, leading to injury of other body systems.

**Skin Contact**
Occasional brief skin contact with chlorinated solvents is unlikely to cause any significant adverse effects, and a single prolonged exposure is not likely to result in the absorption of harmful amounts.

If contact does occur, wash the skin immediately and thoroughly with water.

Chemical-resistant gloves should be worn. Chlorinated solvents can defat the skin. This may allow infection and dermatitis to develop, especially where there is substantial daily contact. Chlorinated solvents can also cause irritation if the affected skin is prone to rubbing against shoes, clothing or gloves. Methylene chloride and trichloroethylene may cause more significant skin irritation than perchloroethylene (see Table 2).

**Eye Contact**
Because liquid solvents and very high levels of their vapors can cause eye pain and discomfort, you should wear suitable eye protection at all times (see Personal Protective Equipment, page 9).

Methylene chloride may cause moderate eye irritation that may be slow to heal, and may cause slight corneal injury. If methylene chloride comes in contact with the eyes, immediately flush eyes with water for five minutes, remove contact lenses (if present), and continue flushing for an additional 15 minutes. Obtain medical attention without delay, preferably from an ophthalmologist.

Trichloroethylene and perchloroethylene may cause slight eye irritation. If either of these chemicals comes in contact with the eyes, flush thoroughly with water for one to two minutes, remove contact lenses (if present), and continue flushing for several additional minutes. If effects occur, consult a physician, preferably an ophthalmologist.

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**Exposure**
It is important to distinguish between short-term exposure (acute effects) and long-term exposure (chronic effects).

**Short-Term Exposure**
Acute (short-term) exposure to chlorinated solvents above the recommended exposure guidelines can have effects on the central nervous system (light-headedness, drowsiness, headache, giddiness). These effects are reversible, and behavioral and neurological studies have not shown any significant adverse effects in humans. Higher concentrations can cause anesthetic or narcotic effects.

Continued exposure to high concentrations may lead to unconsciousness or, in extreme circumstances, prove fatal. At very high exposure levels, chlorinated solvents (in particular, trichloroethylene) can sensitize the heart to the effects of adrenaline and similar agents, which may lead to sudden cardiac arrest. Chlorinated solvents may irritate the respiratory tract (at very high concentrations).

Acute exposure to high concentrations of trichloroethylene or perchloroethylene can also lead to irreversible alterations in human liver function or to effects on the kidneys, although the latter is less well documented in humans than in laboratory animals.

**Long-Term Exposure**
A number of studies on the long-term effects of chlorinated solvents in animals have been conducted. The results of these studies, together with studies on the mechanism of tumor induction and human epidemiology, suggest that workers exposed to these solvents in the workplace are unlikely to develop cancer as long as recommended occupational exposure standards are maintained. Animal studies also indicate that exposure to chlorinated solvents will not likely cause birth defects or permanent damage to the central nervous system at exposure concentrations within workplace standards.
**Human Health Considerations**

**Methylene Chloride**
When an individual inhales methylene chloride, the body converts a portion of it to carbon monoxide, which results in increased carboxyhemoglobin (carbon monoxide bound to hemoglobin) levels in the blood. High levels of carboxyhemoglobin can reduce the ability of the blood to carry oxygen, and may also contribute to central nervous system effects. Smoking also results in high levels of carboxyhemoglobin. Avoid smoking when working with methylene chloride, as adverse effects can be intensified.

**Solvent Vapor Degreasers**
Because solvent vapors are heavier than air, high concentrations of vapor can accumulate readily in tanks, pits, degreasers, small rooms and other confined or poorly ventilated areas. These concentrations can cause unconsciousness and, at very high levels, death. Employees who work with vapor degreasers and/or in confined spaces should read and understand the precautions described in Entry Guidelines for Tanks, Pits and Other Confined Areas (page 10) and Vapor Degreaser Safety (page 11).

If you or a fellow employee experience symptoms of dizziness, loss of coordination, or eye irritation—or if breathing becomes difficult—leave the area immediately and seek fresh air. Call a physician and/or take the employee to an emergency medical facility. If a colleague stops breathing, perform mouth-to-mouth resuscitation and seek medical assistance immediately.

**DOWPER™ MC, DOWPER™ LM, Perchloroethylene SVG Double Stabilized**
Vapor-degreasing grades of perchloroethylene contain an inhibitor that is a skin sensitizer and, therefore, should not be used in applications where skin contact could occur.

These special perchloroethylene formulations have been developed solely for the vapor degreasing of metals. They are intended for this use only. The stabilizers that contribute to their superior performance may cause skin sensitization, so they should not be used in operations such as dry cleaning or cold cleaning where skin contact could occur. Always consult the SDS for specific information about the products you are using.

**Trichloroethylene**
A Dow Industrial Hygiene Guideline (Dow IHG) has been established for trichloroethylene at 5 ppm for an eight-hour exposure. A Dow IHG is an internal standard that must be met by all Dow operations where the potential for employee exposure may exist. Consult the current SDS for more information on the Dow IHG and the regulated exposure standards in your country.

### Table 3: LD50s (Ingestion) and LC50s (Inhalation) for Chlorinated Solvents in Rats

<table>
<thead>
<tr>
<th>Solvent</th>
<th>LD50 (g/kg of body weight)</th>
<th>LC50 (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylene chloride</td>
<td>2</td>
<td>15,000</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>5</td>
<td>3,000</td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td>2.6</td>
<td>5,000</td>
</tr>
</tbody>
</table>

*™Trademark of The Dow Chemical Company (“Dow”) or an affiliated company of Dow*
Personal Protective Equipment

Do not work in areas contaminated by solvent vapor unless you are properly equipped and trained. You must have protective equipment and use it in accordance with the manufacturer’s instructions and all applicable regulations. Protect yourself and safeguard the health and safety of operators, maintenance employees and all others who work with chlorinated solvents.

Eye Baths and Showers

Ensure that eye baths and showers are readily available for emergency use and that access routes to these facilities are free of obstructions. Regularly test eye baths and showers for proper operation, including temperature and adequate water flow.

What to Wear

When handling chlorinated solvents, wear:

- An apron made from polyvinyl alcohol (PVA) or neoprene rubber
- Safety glasses with side shields (or their equivalent), or chemical goggles, when working in situations where the solvent may splash
- Respiratory protection (or have appropriate ventilation)
- Impervious gloves made from resistant materials. When determining which type of gloves to use, it is important to verify what type of solvent you are handling and how long the gloves will be exposed (see Appendix B).

The following additional protective equipment may be indicated for maintenance personnel:

- Chemical goggles or face shield
- Rescue harness and lifeline for entering tanks and other enclosed or confined spaces
- Positive-pressure air-line masks with proper reduction valves and filters, or self-contained, positive-pressure breathing apparatus. **NOTE: Never use an industrial cartridge respirator for entry into tanks or other confined spaces.** Approved industrial respirators should only be used for temporary emergency use, such as escaping from contaminated areas. They also should not be used as a substitute for adequate ventilation or proper equipment operation.

Protective Equipment Maintenance

It is important to maintain and service all equipment according to manufacturers’ recommendations. Conduct regular practice drills using personal protective equipment (PPE) to make sure equipment fits properly, hoses are secure, etc. All respiratory protection programs must conform to applicable occupational safety and health requirements.

To find more information about chlorinated solvents, or to download the most current version of the Chlorinated Solvents Product Stewardship Manual, visit www.chlorinatedsolvents.com or www.dow.com.
**Human Health Considerations**

**Monitoring Solvent Vapor Levels**
There are several ways of measuring the concentration of chlorinated solvents in the air; however, special training is needed to ensure that the measurements are reliable and meaningful. Therefore, make sure that solvent vapor levels are checked regularly by trained specialists.

**Direct Exposure Measurements**
The simplest method for performing spot measurements is to use a commercially available colorimetric device, such as a Draeger tube or an MSA/Auer tube. These devices give only spot measurements, and can be affected at times by humidity or by other chemicals present in the air, making results difficult to interpret. Sophisticated instruments for continuous measurement of solvent vapors—such as infrared spectrometers, flame ionization detectors or photo ionization detectors—are also available; however special training is required to become proficient with their use. Always read the instructions carefully before using any detection device.

**Indirect Exposure Measurements**
Indirect exposure measurements are more accurate than direct methods. The most common indirect devices (vapor monitoring badges and personal monitoring pumps) sample a known quantity of air either by diffusion or drawing through a tube containing activated carbon. A laboratory analyzes the carbon to determine the contaminants present and measure their concentrations.

This method also tends to be the most accurate, and is valid in the range of German MAK Commission, ACGIH or TLV concentration values (National Institute of Occupational Safety and Health—NIOSH method 1003).

**Entry Guidelines for Tanks, Pits and Other Confined Areas**
Confined-area entry is the most hazardous operation involving chlorinated solvents. Chlorinated solvent vapors are heavier than air, and high concentrations can collect in low, confined and unventilated spaces such as tanks or pits. It is therefore important to keep the tank ventilated and use appropriate respiratory protection during the entire cleaning or repair operation.

The tank should be ventilated through openings at the bottom and top of the tank, or exhausted mechanically from the lowest point in the confined area. Additionally, the oxygen level in the tank should be measured by oxygen meter before and during any entry into the confined area. **Oxygen levels should never fall below 19.5 percent.**

A common industrial respirator does not provide sufficient protection if oxygen levels are too low. Failure to use full respiratory protection when entering confined or unventilated areas where solvent vapors could be present is dangerous. Very high vapor concentrations combined with insufficient oxygen levels can cause dizziness, loss of coordination, unconsciousness, even death (see page 8).

Individuals who are familiar with the hazards, appropriate safety precautions, equipment, and rescue and first-aid guidelines associated with the use of chlorinated solvents should supervise tank and pit cleaning operations (see the sections on The Supervisor’s Role and Observers, page 11).

**General Tank-Entry Guidelines**
1. Obtain written permission to enter the tank.
2. Lock out power feeds.
3. Shut off heating systems.
4. Drain solvent.
5. Disconnect all pipelines, including vents into or out of the tank; cap pipe ends; or install a blank in the pipeline.
6. Air-dry the tank.
7. Vent solvent vapors properly.
8. Monitor the air in the area/vessel to ensure that the oxygen concentration is sufficient.
9. Display “Employee in Tank” signs at all entry points.
10. Have a person wearing proper PPE stationed outside the tank as an observer.
11. Follow all applicable regulations for confined-area entry.
The Supervisor’s Role

The crew supervisor should carefully inspect the tank before cleaning or repair operations begin. Make certain that manholes are easily accessible, brightly illuminated and large enough to accommodate safety gear. Steps and ladders must be rigid and well secured. If possible, provide mechanical hoisting equipment in the event it becomes necessary to evacuate injured or disabled employees.

The supervisor should also make sure that all employees entering the tank or serving as observers have the necessary, chemical-resistant protective equipment. Check the fit, operation and suitability of all safety equipment, clothing and breathing equipment.

Observers

Station a fully equipped observer outside the tank at all times. He or she must be capable of performing rescue guidelines.

If you are the observer outside the tank, stay alert. Watch for signs of overexposure (nausea, dizziness, loss of inhibitions, giddiness or loss of coordination) in both the employee in the tank and yourself. Make sure that other employees are within calling distance, and that a notification guideline is in place.

Additional Information

More information on confined-area entry is available from the American Society for Testing Materials (ASTM):
ASTM Standard Practice for Confined Area Entry, D-4276.

Contact ASTM at www.astm.org or:
ASTM International
100 Barr Harbor Drive
PO Box C700
West Conshohocken, PA 19428-2959

Vapor Degreaser Safety

- Make sure you understand what you want the solvent to do, and know how your equipment works. Familiarize yourself with the basic principles of solvent degreasing. Be sure you are thoroughly acquainted with all aspects of your degreaser: its operation, the cleaning cycles and its control and maintenance. Always refer to instruction manuals or contact the manufacturer if you are unsure about any aspect of your equipment or its operation.

- Be aware of all applicable laws regulating the operation and cleaning of degreasers. You may require a special permit to operate the machinery.

- Follow the manufacturer’s recommended start-up guidelines.

- Always keep the area around the degreaser clean and free from obstruction.

- Do not overload the degreaser. Maintain an appropriate load and speed to avoid losing solvent from the degreaser.

- Use only approved baskets, racks or hangers. Wooden baskets, racks or hangers are porous, resulting in loss of solvent through absorption, and should not be used.

- Never clean textiles or gloves in the degreaser. These or other absorbent materials will remove solvent from the machine.

- Do not allow a fan to blow across the degreaser opening. Air currents will draw vapor from the degreaser and carry it into the workplace.
This section presents important information on how to prevent environmental contamination when working with chlorinated solvents. Specific recommendations are presented for:

- Preventing and reducing contamination to air, soil and water
- Recycling chlorinated solvents

In addition, specific discussions of these solvents related to issues such as ozone depletion, climate change and acid rain can be found at the end of this section.

Chlorinated solvents may damage the environment if they are released into the air, water or soil. You should be aware of the potential effects of chlorinated solvents on the environment before beginning to use them for any application. The following guidelines are a checklist for both health and environmental safety. Wherever possible, you should employ engineering controls and management practices to ensure that the solvent is utilized in the most environmentally responsible manner possible. In applications such as metal cleaning and dry cleaning, releases into the atmosphere can be dramatically reduced by using modern, closed machines or vent recovery systems that utilize activated carbon.

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**Environmental Considerations**

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**General Safety Guidelines to Prevent Water, Soil and Air Contamination**

- Cover chlorinated solvent containers when not in use.
- Minimize the number of transfer processes.
- Use nozzles, hoses and couplings whenever transferring solvent.
- Connect hoses securely before performing filling operations.
- When moving drums from one location to another, use a mobile trough that is large enough to hold the contents of the drum in the event of a leak.
- Be aware of residual amounts of solvent in pipes and hoses. If possible, purge all lines and hoses with air or nitrogen before disassembling or disconnecting.
- Utilize a proven dry-disconnect coupling, or purge and cap lines and hoses to prevent contamination. Capping hoses that contain residual liquid solvent is not recommended, as the hose may rupture if the solvent heats up and expands.
- Whenever possible, install permanent piping for applications that involve frequent filling and emptying.
- Conduct all solvent operations in containment areas that are coated with solvent-resistant materials and can accommodate the volumes being handled and isolated from drains to the sewer or ground (see Secondary Containment, page 21).
Prevent and Reduce Air Contamination

Chlorinated solvents have a relatively short lifetime in the atmosphere. Their atmospheric lifetimes vary from a few days (trichloroethylene) to a few months (methylene chloride and perchloroethylene) (see Table 4 on page 15).

When they are not in use, cover openings in equipment and vessels (tanks, drums, etc.) that contain chlorinated solvents to minimize release of solvent vapors into the workplace. Most facilities that use chlorinated solvents are equipped with exhaust systems that reduce human exposure to solvent vapors. However, the exhaust should be treated to remove the solvent vapors before they are released into the atmosphere.

Several exhaust purification methods are available. Carbon adsorption is the traditional method to capture solvent vapors. The exhaust gasses are passed through a bed of activated carbon, which adsorbs the solvent vapors. Studies show that polymeric beds are also very effective at this.

Desorption and recovery processes are critical parts of the overall process. The traditional use of steam to recover solvents from carbon can strip stabilizers from the solvent and generate a considerable amount of water that needs to be treated or decontaminated.

Alternative processes use heat and condensation to recover the solvent, with less stabilizer loss and no additional waste stream to treat.

Prevent and Reduce Water and Soil Contamination

Chlorinated solvents are not “readily biodegradable,” according to the definition by the Organization for Economic Cooperation and Development (OECD). While methylene chloride is biodegradable under both aerobic and anaerobic conditions, trichloroethylene and perchloroethylene biodegrade very slowly. Thus, contamination of groundwater and soil by chlorinated solvents can be a serious problem.

Chlorinated solvents are not very soluble in water, but they can still cause contamination of surface or groundwater. Additionally, because chlorinated solvents are heavier than water, large spills will tend to collect at low points, creating a concentrated source for continuing contamination. Even process water that has come in contact with chlorinated solvents will contain some chlorinated solvent, and should be handled as a hazardous waste stream.

The main causes of groundwater and soil contamination are negligence and improper storage, handling and disposal guidelines. Contaminated soil and water are difficult and costly to clean. Therefore, avoiding leaks and spills that can cause groundwater and soil contamination is imperative. Do not dispose of contaminated water in the sewer or septic system, or pour it on the ground.

Furthermore, those responsible for handling chlorinated solvents and solvent wastes must understand and follow approved guidelines and relevant government regulations for the handling and disposal of chlorinated solvents and their waste. Laws dictating how a user may treat hazardous waste vary. Dow recommends that you contact a licensed disposal contractor to handle any waste, contamination or disposal situations. If you intend to treat any contaminated material on-site, Dow recommends that you contact a qualified environmental engineering company to assist with the permitting and design of any such system.

To find more information about chlorinated solvents, or to download the most current version of the Chlorinated Solvents Product Stewardship Manual, visit www.chlorinatedsolvents.com or www.dow.com
Avoid High-Risk Situations
Practical experience has shown that the risk of soil or groundwater contamination is particularly high in the following situations:

- Transferring or pumping chlorinated solvents to and from drums and small containers when leaks and spills are not properly prevented and/or contained
- Disregarding the amounts of residual solvent in containers assumed to be empty
- Overfilling storage containers and not containing excess liquid
- Disregarding the amounts of residual solvent left in hoses, and allowing it to drip onto unprotected ground
- Failing to notice or repair minor leaks in pumps, pipes, hoses, couplings or other equipment
- Carrying chlorinated solvents in open containers, and disregarding minor spills
- Carelessness when storing or handling wastes contaminated with chlorinated solvents
- Not immediately cleaning up leaks and spills when they occur

Reduce, Reuse, Recycle
It is not acceptable to dispose of chlorinated solvent wastes in landfills. Dow encourages users to reduce, reuse and recycle chlorinated solvents as much as possible in any operation. Many countries have established pollution management standards based on the following principles:

- Reduce the use of chlorinated solvents at the source by choosing process equipment that minimizes fugitive emissions, or use control systems that capture emissions for recovery.
- Reuse/recycle chlorinated solvents by recovering and purifying solvent through filtration and distillation.
- Contact a reputable recycling company in your area to reclaim spent chlorinated solvents.
Environmental Considerations

Issues Discussion

Stratospheric Ozone Depletion

Methylene chloride, perchloroethylene and trichloroethylene have not been implicated in stratospheric ozone depletion. Their relatively short atmospheric lifetime indicates they are destroyed in the troposphere and have negligible effect on the stratospheric chlorine load.

Tropospheric Ozone Formation (Photochemical Smog)

United States

Methylene chloride, perchloroethylene and trichloroethylene do not contribute significantly to tropospheric ozone formation. Methylene chloride and perchloroethylene are both exempt under the U.S. EPA Regulations for Volatile Organic Compounds (VOCs).* Trichloroethylene is regulated as a VOC.

Europe

Methylene chloride, trichloroethylene and perchloroethylene have a vapor pressure above 0.01 kPa at 20°C, and are therefore considered VOC substances according to the definition of the European VOC Directive (1999/13/EU). For applications defined in the European VOC Directive, the rules laid out in national adoptions of this directive have to be followed. The national rules can be more stringent than minimum requirements given in the European VOC Directive.

Climate Change

Greenhouse gasses like carbon dioxide contribute to global warming by absorbing thermal radiation emitted by the earth. Methylene chloride, perchloroethylene and trichloroethylene have short atmospheric lifetimes, and exist at extremely low concentrations. As a result, their contribution to global warming is very low (see Table 4).

Acid Rain

Human contribution to acid rain includes the burning of fossil fuels, which release oxides of sulfur and nitrogen. The quantities of chlorinated solvents released into the atmosphere are insignificant compared with the amounts of these oxides produced. Chlorinated solvents are estimated to contribute significantly less than one percent of the acid rain produced through human activities (see Table 4).

Additional Information

For more information on these issues, see:

www.hisia.org
www.eurochlor.org
www.dow.com

Table 4: Environmental Properties of Chlorinated Solvents

<table>
<thead>
<tr>
<th>Chlorinated Solvent</th>
<th>Ozone Depletion Potential (ODP)</th>
<th>Global Warming Potential (GWP)</th>
<th>Maximum Incremental Reactivity (MIR)</th>
<th>Contribution to Acid Rain</th>
<th>Atmospheric Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylene chloride</td>
<td>~0</td>
<td>~0</td>
<td>0.07</td>
<td>&lt;&lt; 1%</td>
<td>5–6 months</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>~0</td>
<td>Not available</td>
<td>0.60</td>
<td>&lt;&lt; 1%</td>
<td>6–8 days</td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td>~0</td>
<td>Not available</td>
<td>0.04</td>
<td>&lt;&lt; 1%</td>
<td>5–6 months</td>
</tr>
</tbody>
</table>


To find more information about chlorinated solvents, or to download the most current version of the Chlorinated Solvents Product Stewardship Manual, visit www.chlorinatedsolvents.com or www.dow.com
This section provides important information on proper storage guidelines for chlorinated solvents. Specific recommendations are presented for:

- Drum storage
- Bulk storage
- Tank specifications
- Underground storage
- Tank cleaning, repair and maintenance
- Solvent sampling
- Unloading bulk solvent
- Secondary containment
- Storage of spent solvents
- Location of pipes, elbows and fittings
- Related equipment

Experience has shown that overexposure to chlorinated solvents is most likely to arise during storage, filling, handling and maintenance operations. Please read this section carefully, as it will provide you with the proper guidelines for working with chlorinated solvents.

Drum Storage

Chlorinated solvents are often delivered in drums. On arrival, store these drums in an area equipped for spill and leakage containment, or over a sump that is isolated from sewer/septic or groundwater releases. The system should be large enough to contain the full potential volume of material in primary storage. Such containment areas should not have bottom outlets, and should be made of solvent-resistant material. Cover storage sites for holding containers of chlorinated solvents to protect them from direct exposure to sunlight and rain.

There are specific national and local regulations governing the use of solvent-resistant materials and solvent-tight containers for storage facilities. You should review and follow all applicable laws and regulations. Never use concrete alone when constructing drum storage areas, because chlorinated solvents can permeate concrete. Instead, painted steel is recommended to allow observers to verify the integrity of the storage area.

Drums containing chlorinated solvents should be stored upright. However, you may place drums fitted with a bung valve in a horizontal drum cradle to allow easy transfer of solvents to smaller containers.

Treat any liquid found in retention basins as contaminated solvent waste, unless it is proven to be solvent-free.
Bulk Storage
Carbon-steel tanks are usually adequate for storing chlorinated solvents, although you should note that the build-up of moisture inside these tanks may lead to corrosion problems. If you require exceptional solvent purity, stainless steel may be used, or tanks may be coated with a solvent-resistant lining.

Figure 1: Bulk Storage Arrangement for Transferring Solvent by Pump
Shown: Horizontal Tank With Bottom Connections

Equipment used in handling, storing or processing chlorinated solvents—including tanks, pumps, piping, valves, meters and other instrumentation—must not contain aluminum or other white metals, such as magnesium or zinc (see Figure 1). A reaction between these metals and the solvent may cause corrosion, and could ultimately cause equipment failure (see Related Equipment, page 21).
Tank Specifications
Tank specifications should be in accordance with all applicable laws and regulations. The chlorinated solvents discussed in this manual have a specific gravity greater than 1 (water=1), which should be reflected in tank design.

- Ensure tanks are clean, dry and free from rust.
- Ensure tanks have appropriate pressure-vacuum relief valves, a vent dryer or inert gas pad, and optimal vapor return lines for transfer operations.
- Use closed-loop filling systems with a vapor return line between delivery and storage vessels. Vapor return is also advised for in-process filling operations.
- Ensure tanks are grounded to prevent the build-up of static electricity.
- If the tank is located in a containment area, you should follow the applicable laws and regulations for solvent-resistant materials and solvent-tight containers. See Drum Storage (page 16) for more information.

Underground Storage
Locating single-walled storage tanks without adequate leakage control systems underground is not recommended, and may be specifically prohibited in some areas. The escape of chlorinated solvents through unobserved leaks may pollute soil and groundwater, and may lead to high costs for removing contaminated wastes.

If underground storage is already in place, install a tank testing and monitoring system, and inspect it regularly.

Tank Cleaning, Repair and Maintenance
Practice continuous maintenance on your tanks to prevent loss of solvent.

Tank cleaning should be directed by thoroughly trained personnel who are familiar with the hazards, appropriate safety precautions, equipment and first-aid guidelines applicable to working with chlorinated solvents.

In some areas, applicable laws and regulations may require that cleaning, repair and maintenance work be performed by certified companies only. All equipment should be maintained and serviced according to the manufacturer’s recommendations.

Because solvents can evaporate rapidly, a small leak under pressure can result in the loss of solvent without the warning of a pool of liquid. A simple halide leak detector can be used to check connections, valves, pump packing and any other accessible parts of the system. Be sure that all connections are made with a material that will not react with the solvent: polytetrafluoroethylene (PTFE) or TEFLO tape is recommended to wrap screwed fitting threads before assembly.

Solvent Sampling
Visual inspection does not always detect moisture and other contaminants. Consider these recommended guidelines when sampling chlorinated solvents:

- Dry bottles before taking samples.
- Sample bottles should be made of narrow-mouthed glass (preferably amber-colored), with a maximum fill just below the shoulder of the bottle. Completely filling sample bottles can result in broken containers due to thermal expansion.
- Label bottles.
- Bottle caps should be of a type that will seal against the neck of the bottle. Conical cap liners made of polyethylene work well, as do flat liners made of soft TEFLO or foamed polyethylene.
- Store samples in tightly sealed secondary containers, in a cool place and away from direct sunlight, or properly dispose of samples after testing.
- Transport and store samples in appropriately sized secondary containers.

The best method of obtaining samples from delivered tank cars and tank trucks is to take them from a sample point on the unloading line. Take the sample when the line is full of liquid, and before off-loading the product into a storage vessel.

When sampling from storage tanks, withdraw samples from the center of the tank, away from the bottom or sides of the tank. To do this, insert the sampling device into the top of the tank, or collect the sample from a drain on piping to or from an operating recirculation pump.
Unloading Bulk Solvent

Properly trained and equipped personnel, who are present at all times, should carry out unloading operations in areas that are contained with a solvent-resistant material. Whenever a container is unloaded by gravity or a pump, a vapor piping system should connect between the shipping container and the receiving tank to reduce solvent losses.

The preferred method, and that with the greatest control, is unloading from the bottom of the shipping container with a pump, rather than by gravity. If pumping facilities are not available, and the tank relief devices have a sufficiently high rating (check the maximum allowable pressure), the contents may be unloaded through a dip tube, with gas pressure applied into the top of the tank. Connect the inert gas line to the top of the tank using a pressure control valve and a pressure relief device set at 50 percent of the tank relief valve set pressure. Clean, dry nitrogen at a pressure of 20–30 psig (1034–1551 mmHg gauge) is suitable for this purpose. **Do not use air pressure, because moisture in the air could contaminate the solvent.**

Other important information:

- Verify that the receiving tank is correct, and ensure it has adequate capacity.
- Set air valves and vapor return lines prior to beginning pumping operations.
- The use of dedicated unloading hoses is preferred. If these are not available, the transfer hose must be cleaned before use.
  - At the beginning of the transfer, flush the hoses with a small amount of solvent for cleaning purposes, and collect it for waste disposal.
  - After the flush, a sample of the solvent may be taken into a glass container (see Solvent Sampling, page 18) for analysis.
  - Repeat flushing as necessary until the hose is clean and you obtain an uncontaminated solvent sample.
- When unloading is complete, collect all solvent drained from hoses, valves, etc. for use or disposal.

Customers who receive bulk quantities of chlorinated solvents and repackage them into 55-gallon drums or other small volume containers should first unload the solvent from the delivery vessel into a stationary bulk storage tank, and then drum from the storage tank. To provide adequate ventilation and to prevent spills and solvent contamination, make sure that all fittings and transfer operations take place in an area protected with safety and environmental controls.

When it is not possible to use a stationary bulk tank, appropriate equipment, including pump and valves, must be in place between the truck and the drumming station. Provide secondary containment for both the truck and the drumming station, and follow all other general unloading procedures (see Figure 2, page 20).

**Transfer From Storage to Point of Use**

The simplest and most economical method of transfer is to pipe the solvent directly to the point of use, using gravity flow. If the point of use is far away, or higher than the storage tank, then use an appropriate pump with permanently installed pipe.

When delivering solvent to the bottom of a receiving vessel, make sure it is at a point below the fluid surface to minimize turbulence and unnecessary evaporation. Regularly inspect and properly maintain all piping, valves and pumps.

Do not transfer even small amounts of chlorinated solvent in open containers. If permanently installed piping is not available, use a mobile tank with covered openings and pressure relief to move the solvent to the application that needs filling. Always use proper nozzles and approved fluid flow lines to connect the mobile tank to the machine. Vapor return lines from the point of use back to the storage tank will minimize solvent vapor emissions during transfer.

**The Importance of Labeling**

When you transfer a chlorinated solvent from its original container, properly label the new container. The contents of the new container should be identified, and the safety and environmental information shown on the original label should be visible. If the containers will be exported, the language on the label should be understandable by the receiving party.

To find more information about chlorinated solvents, or to download the most current version of the Chlorinated Solvents Product Stewardship Manual, visit www.chlorinatedsolvents.com or www.dow.com
Figure 2: Semiautomatic Drumming Station Using a Scale for Drumming Solvents From Tank Trucks

THIS IS A CONCEPTUAL DRAWING TO SHOW EQUIPMENT ONLY—not a suggested physical layout for actual operating purposes.

NOTE: CONTROLS FOR PUMP, FAN, DRUM FILLER, ETC., MUST BE LOCATED WITH OPERATOR CONVENIENCE AND SAFETY IN MIND.

Legend

- Static Electricity Ground
- Clamps and Ground Wires for Piping, Pumping and Filling System
- Customer’s Manual Valve—Note: Do not open until pipe connections and filling equipment have been checked.
- Truck Valve and Operator
- Posted Operation Instructions
- Pump Switches Controlling Centrifugal Pump and Fan Switch
- Filling Station—Dial Scale with Automatic Shut-off, Filling Drums Using a Bottom-Filling Drum Lance (Max. Cap. 60 GPM)
- Exhaust Fan—Pickup at Drum Bunghole and Floor Level
- Eye Wash/Safety Shower Station(s)
- Emergency Stops—Locations at Pump, Filling Station, and Others If Required
- Fire Blanket/Protective Equipment Cabinet
- Spill/Leak Drainage to Sump¹
- Wheel Chocks
- Vent Scrubber
- Pressure Switch—Shuts Off Pump When Valve Closes
- Operator Emergency Escape Routes
- Sample Valve
- Line Drain/Cleanout Connection²

¹ The sump should be contained, not drained into the sewer.
² Drainings must be collected from the line drain.
Secondary Containment
To help prevent soil and groundwater contamination, a secondary containment system is strongly recommended, and is a legal requirement in many countries. Always consult local regulations for requirements which may be more detailed or restrictive than the following general information.

Secondary containment systems may take the form of a dual-walled container, a dike around the tank area or a sump below the tank area. The system should be designed specifically for the chemicals being handled, and it should be constructed from solvent-resistant material. In addition, the system should be large enough to contain the full potential volume of material in the primary storage vessel/container. Drains to a collection point must be installed, and must be independent of the sewage/drainage system for external discharge already located at the site.

Storage of Spent Solvents
The storage of spent solvents demands the same precautions as the storage of fresh solvents. It is very important that spent solvents and solvent-laden waste materials are not put in hermetically sealed containers due to the risk of pressure building from potential uncontrolled reactions, such as the reaction of small particles of metal with trichloroethylene after inhibitors have been depleted.

Location of Pipes, Elbows and Fittings
Do not bury pipelines, elbows and fittings. The pipelines should be readily accessible for frequent inspection, and for immediate detection and repair of leaks. Piping may also be placed in an appropriately sized and solvent-resistant trough to collect any leaking solvent. If buried pipes are unavoidable, they must be jacketed, and a leakage alarm system must be provided for the void between the jacket and the pipe.

Related Equipment
Pipes
Pipes may be made of carbon steel, hot-dip galvanized steel or stainless steel. To prevent joint failure and the release of solvent, be sure that all piping connections are made with solvent-resistant materials. Recommended pipe connections are first welded, then flanged, and lastly screwed to ensure a leak-free system. Slip-on sockets and soldered connections are not acceptable for service with chlorinated solvents.

Schedule 40 carbon steel pipe is usually sufficient, unless purity requires stainless steel. If you must use screwed fittings, wrap the threads of the fittings with tape made from polytetrafluoroethylene (PTFE) or Teflon to prevent leaks. Do not use “pipe dope.” Remove cutting oils and other dirt before placing the pipe in service. Pipe sections that can be closed off by valves should be protected with relief valves if pressures can exceed the burst pressure of the pipe.

Unloading Hose
A two-inch-diameter, seamless, flexible metal hose, preferably stainless steel, can be used to unload tank cars. PTFE-lined hose sheathed in a metal braid (such as stainless steel or bronze) or in neoprene rubber is also satisfactory. Interlocked, spiral-type hose should never be used, as it will allow solvent to leak through the packing. Order hose in the required length, with fittings already installed by the manufacturer.

Use of dedicated transfer hoses for each solvent is preferred over common-use unloading hoses found on transport equipment or unloading stations. Develop hose-inspection and pressure-testing programs to ensure that the integrity of hoses is maintained and that replacement occurs when needed.
**Pumps**
When selecting a pump, it is important to consider the high vapor pressure of the product when the lifting capability of the pump is calculated. This is especially true for methylene chloride. Centrifugal pumps or positive displacement pumps of ductile iron or carbon steel casing are satisfactory for transferring chlorinated solvents. Pumps should be equipped with a stainless steel shaft and double mechanical seals. Cast iron is not recommended for pumps.\(^1\)

**Valves**
Steel ball, gate or globe valves are satisfactory. Ball valves should have a PTFE seat, and globe valves should have a metal seat. Rings of PTFE, or of asbestos impregnated with PTFE, may be used as stem packing. Where full-line flow is desired, ball or gate valves are recommended. Where throttling is necessary, globe or needle valves may be used. Swing and lift valves are both satisfactory as backflow prevention (check) valves. Cast iron is not recommended for valves.**

**Seals and Gaskets**
These materials must be solvent-resistant, flexible enough to conform to the flange, and resilient enough to recover from compression. Impregnated cellulose fiber, cork-base materials, and PTFE-impregnated asbestos are representative materials. VITON resin is acceptable, except for use with methylene chloride, since the VITON will swell in liquid contact with the solvent. Either CHEMREZ or KALREZ are recommended for use with methylene chloride. Gaskets of rubber or synthetic rubber, such as neoprene rubber or BUNA N, should not be used with any of the chlorinated solvents.

**Meters**
Meters for measuring flow, pressure and/or temperature should be suitable for use with the particular solvent you are handling. Obtain information on suitability directly from the manufacturer. Meters should not have any aluminum, magnesium or zinc components, or any alloys of these materials.

**Additional Information**
The European Chlorinated Solvent Association (ECSA) provides more information about the selection of pumps, gaskets, valves and piping that are intended for use with chlorinated solvents.

For a copy of Storage and Handling Chlorinated Solvents, you can download the PDF at www.eurochlor.org/upload/documents/document130.pdf or send your request to:

ECSA
Avenue E Van Nieuwenhuyse 4
Box 2 B-1160
Brussels, Belgium
www.eurochlor.org

\(^{**}\)Cast iron is not recommended. Cast iron pumps or valves are susceptible to breaking or cracking due to mechanical strain and temperature changes. This may lead to leaking of the chlorinated solvents.
Handling

This section presents important information on proper handling guidelines for chlorinated solvents. Specific recommendations are presented for:

- Proper handling and storage related to heat
- Leaks and spills
- Disposal of spent solvents, waste and used drums

Experience has shown that overexposure to chlorinated solvents is most likely to arise during storage, filling, handling and maintenance operations. Please read this section carefully, as it will provide you with the proper guidelines for working with chlorinated solvents.

Figure 3: Hydrogen Chloride, Chlorine and Phosgene Releases Produced in Glove-Box Welding Studies

<table>
<thead>
<tr>
<th>Methylene Chloride (585–906 ppm)</th>
<th>Trichloroethylene (98–106 ppm)</th>
<th>Perchloroethylene (81–103 ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>140</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>88</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>68</td>
</tr>
</tbody>
</table>

Hydrogen chloride, chlorine and phosgene are classified as toxic inhalation hazards. Conduct a job safety assessment to identify tasks, potential hazards, recommended guidelines, personal protective equipment and training necessary for situations where these substances may be present or formed.

Keep Solvents Away From Flames and Heat

Do not use or store chlorinated solvents near open flames or excessive heat (such as ovens, furnaces, space heaters, welding operations and pilot lights). When solvent vapors are exposed to extreme heat, they can decompose, yielding highly corrosive or toxic products such as hydrogen chloride, carbon dioxide, carbon monoxide and chlorine, which can create greater hazards than the solvent itself, including metal corrosion in the workplace and toxicity to employees. Under certain conditions such as welding, very low levels of phosgene may form (see Figure 3).
Detecting Decomposition Products
If methylene chloride, perchloroethylene or trichloroethylene decomposes, dangerous concentrations of phosgene can sometimes build up before the hydrogen chloride or chlorine level is high enough for individuals to notice.

Do not rely on smell alone. Hydrogen chloride and chlorine are strong respiratory irritants. If you are experiencing eye, nose or throat irritation, leave the area immediately.

If processes involving extreme heat, such as welding operations, must be conducted in an area where chlorinated solvents may be present, ensure that there will be adequate ventilation, and test regularly for phosgene. If acceptable levels can not be achieved, any employees in that area should wear a positive-pressure breathing apparatus.

Do not smoke while handling chlorinated solvents or in areas where they are present.

Proper Ventilation
If hot processes are unavoidable in areas where solvent vapors are present, the products of combustion should be vented outside the building through corrosion-resistant ducts. The air supply for space heaters, ovens or furnaces should never be drawn from areas containing solvent vapor. For example, they should not have their intakes located near exhaust vents that carry solvent vapor.

Welding and Torch-Cutting
Do not weld in any area where chlorinated solvent vapors may exist. Avoid arc welding near equipment containing these solvents, because air currents may direct vapors toward the welding operation. Furthermore, do not weld any drum that has previously contained chlorinated solvents. The concentration of residual vapors in the drum might be in a flammable range and could cause an explosion (see Table 5).

The special precautions that apply to welding also apply to torch-cutting. Do not torch-cut any drum that has previously contained chlorinated solvents. Do not torch-cut in an area where solvent vapors may be present, because of flammability and solvent decomposition.

Table 5: Flammable Limits in Air

<table>
<thead>
<tr>
<th>Volume % of Solvent in Air at 25°C (77°F)</th>
<th>Upper Flammable Limit (UFL)</th>
<th>Lower Flammable Limit (LFL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylene chloride</td>
<td>22</td>
<td>14</td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Trichloroethylene (at 100°C, 212°F)</td>
<td>45</td>
<td>8</td>
</tr>
</tbody>
</table>

NOTES: (1) See the Safety Data Sheets for product-specific information.
(2) Mixtures of chlorinated solvents with other substances, or in different atmospheres, may alter the flammability limits given above.
What to Do When Spills or Leaks Occur
Spilled solvent and solvent-contaminated water should never be allowed to drain off into sewers or any body of water, or onto the ground. It is important to inspect and maintain your process equipment, holding tanks and spill-control devices continually, and to know what to do ahead of time if a spill or leak occurs. Be prepared by having proper protective equipment identified and available for personnel cleaning up any spills.

If you or a fellow employee experience symptoms of dizziness, loss of coordination, or eye irritation—or if breathing becomes difficult—leave the area immediately, and seek fresh air. Call a physician and/or take the employee to an emergency medical facility. If a colleague stops breathing, perform mouth-to-mouth resuscitation and seek medical assistance immediately.

Guidelines for Small Spills and Leaks
1. Maintain proper protective equipment, and keep it available for personnel cleaning up the spill.
2. Contain the spill.
3. Stop the leak using proper protective equipment and ventilation.
4. Clean up small spills and leaks immediately using mops, rags, cloths, sawdust or compatible chemical binders such as bentonite, vermiculite or sawdust.
5. Place solvent-laden materials and/or binders in a covered, solvent-resistant metal container.
6. Arrange for proper waste disposal according to applicable laws and regulations.
7. Contact the supervisor, even for small spills and leaks.

Guidelines for Large Spills
1. Evacuate the area and call for help immediately.
2. Ventilate the area.
3. Notify the supervisor.
4. Protect yourself. Do not approach the spill area without wearing self-contained, positive-pressure respiratory equipment and suitable protective clothing.
5. Contain the spill.
6. Block floor drains, if present, to prevent the spill from spreading further.
7. Pump spilled solvent into a solvent-resistant container. Close and label the container.
8. Absorb residual spilled solvent with compatible chemical binders such as bentonite, vermiculite or sawdust, and then transfer to a closed container for proper disposal.
9. Spills may have to be reported to the proper authorities if quantities exceed reportable volumes.

After a spill, if the product is reusable, refer to the “Reduce, Reuse, Recycle” section (page 14). The preferred method for disposing of chlorinated solvents and the materials used for cleanup is to send the waste, via an authorized waste hauler, to a licensed reclaimer or to a government-approved incinerator. Perform repairs and/or take corrective action to prevent recurrence.

Disposal of Spent Solvents, Waste and Used Drums
Use an authorized processor or a special waste treatment plant to dispose of distillation residues and water contaminated with chlorinated solvents.

Never dispose of chlorinated solvent waste by pouring it on the ground, down a sewer, or into a septic system. Do not dispose of chlorinated solvent wastes in landfills. This practice is illegal in most countries. In addition, the wastes from different solvents should never be mixed, even in disposal. Doing so would make reclamation and recycling impractical, and, in some countries, such mixing is illegal. Be sure to review all applicable laws and regulations before disposing of chlorinated solvent wastes.

Containers must be disposed of in accordance with all applicable federal, state and local regulations. Offer the empty container to a qualified reconditioner, or crush and dispose of the container in accordance with procedures approved by federal, state and local authorities. All drum labels should be defaced or removed, and all other drum markings are to be removed prior to disposal or transfer to a qualified reconditioner.

The reuse of appropriately cleaned drums should be limited to industrial purposes only; these drums are not suitable for use with substances intended for human or animal consumption or contact.
### Table 6: Physical Properties of Chlorinated Solvents

<table>
<thead>
<tr>
<th>Properties</th>
<th>Methylene Chloride</th>
<th>Trichloroethylene</th>
<th>Perchloroethylene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Formula</td>
<td>CH₂Cl₂</td>
<td>C₂HCl₃</td>
<td>C₂Cl₄</td>
</tr>
<tr>
<td>Molecular Weight</td>
<td>84.9</td>
<td>131.4</td>
<td>165.8</td>
</tr>
<tr>
<td>Boiling Point @ 760 mmHg</td>
<td>103.6°F (39.8°C)</td>
<td>189°F (87°C)</td>
<td>250°F (121°C)</td>
</tr>
<tr>
<td>Freezing Point</td>
<td>142°F (97°C)</td>
<td>-125°F (-87°C)</td>
<td>-8°F (-22°C)</td>
</tr>
<tr>
<td>Specific Gravity @ 25°C/25°C</td>
<td>1.32</td>
<td>1.46</td>
<td>1.62</td>
</tr>
<tr>
<td>Pounds per Gallon @ 25°C</td>
<td>10.98</td>
<td>12.11</td>
<td>13.47</td>
</tr>
<tr>
<td>Vapor Density (air=1.00)</td>
<td>2.93</td>
<td>4.53</td>
<td>5.76</td>
</tr>
<tr>
<td>Specific Heat @ 25°C cal/g°C</td>
<td>0.283</td>
<td>0.226</td>
<td>0.209</td>
</tr>
<tr>
<td>Heat of Vaporization @ Boiling Point cal/g</td>
<td>78.9</td>
<td>56.4</td>
<td>50.1</td>
</tr>
<tr>
<td>Heat of Vaporization @ Boiling Point BTU/lb.</td>
<td>142.0</td>
<td>101.6</td>
<td>90.2</td>
</tr>
<tr>
<td>Refractive Index @ 25°C</td>
<td>1.421</td>
<td>1.474</td>
<td>1.503</td>
</tr>
<tr>
<td>Viscosity @ 25°C Centipoise</td>
<td>0.41</td>
<td>0.58</td>
<td>0.84</td>
</tr>
<tr>
<td>Flash Point Tag Open Cup ASTM, Method D-1310</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Flash Point Tag Closed Cup ASTM, Method D-56</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Solubility (g/100g) @ 25°C H₂O in Solvent</td>
<td>0.17</td>
<td>0.04</td>
<td>0.011</td>
</tr>
<tr>
<td>Solubility (g/100g) @ 25°C Solvent in H₂O</td>
<td>1.3</td>
<td>0.10</td>
<td>0.015</td>
</tr>
<tr>
<td>Surface Tension (dynes/cm @ 25°C)</td>
<td>27.1</td>
<td>28.7</td>
<td>31.8</td>
</tr>
<tr>
<td>Kauri Butanol Value</td>
<td>136</td>
<td>129</td>
<td>90</td>
</tr>
<tr>
<td>Solvent-Water Azeotropic Boiling Point</td>
<td>100.6°F (38.1°C)</td>
<td>164°F (73.3°C)</td>
<td>190°F (87.8°C)</td>
</tr>
<tr>
<td>Flammable Limits (Volume% of Solvent in Air) @ 25°C Lower Limit</td>
<td>14</td>
<td>8/45 (saturation)</td>
<td>None</td>
</tr>
<tr>
<td>Flammable Limits (Volume% of Solvent in Air) @ 25°C Upper Limit</td>
<td>22</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Autoignition Temperature</td>
<td>1033°F (556°C)</td>
<td>788°F (420°C)</td>
<td>Noncombustible</td>
</tr>
<tr>
<td>Vapor Pressure @ 20°C</td>
<td>355 mmHg</td>
<td>54.25 mmHg</td>
<td>14 mmHg</td>
</tr>
<tr>
<td>Octenol/Water Partition</td>
<td>1.25</td>
<td>2.42</td>
<td>3.4</td>
</tr>
<tr>
<td>Kinematic Viscosity @ 25°C</td>
<td>0.31 mm²/s</td>
<td>0.391 cSt</td>
<td>0.52 cSt</td>
</tr>
</tbody>
</table>

Disclaimer: The data above represents physical properties only, and should not be construed as Product Specifications.
Gloves for Use With Chlorinated Solvents

To help avoid skin contact with chlorinated solvents, it is important to select the right type of gloves. Glove selection also depends on the length of exposure to the chlorinated solvent (see Table 7).

To develop the criteria for proper glove selection, Dow has conducted permeation tests on available glove materials, resulting in three categories of use conditions:

- **Heavy duty** means continual use, or use where prolonged solvent contact is likely. This may include frequent immersion in dip, wipe or spray applications.
- **Medium duty** means intermittent use, or use where brief solvent contact is likely. Examples include handling wet parts or those that contain chlorinated solvent.
- **Light duty** means one-time use of disposable gloves. This is common where frequent light contact may be encountered, such as cleaning electrical equipment like office copy machines.

Glove materials include many different polymer materials, most of which are commercially available. When choosing a glove material that is appropriate for the chlorinated solvent you are handling, consider the following:

- **Thickness.** Permeation of similar material varies according to the thickness. The thicker the glove, the longer the breakthrough time (the time it takes the solvent to reach the opposite side of the material) and the less permeation.
- **Amount of contact.** Tests conducted by Dow show that the worst case of contact is continuous immersion in the chlorinated solvent.
- **Mixtures.** The permeation behavior of mixtures can be very different from that of pure components. The test data was obtained with commercially available, inhibited solvents, and cannot be duplicated with mixtures containing more than five percent of another component. In many cases, the permeation behavior of solvent mixtures is intermediate to that of the pure components; however this is not always the case. As a general rule, the higher the proportion of the component, and the smaller and more volatile its molecule, the more important it is to determine the permeation characteristics of the mixture before handling.
- **Temperatures.** Permeation test data was obtained at room temperature of 73°F (23°C). An increase in temperature of 18°F (10°C) generally cuts the breakthrough time in half and doubles the permeation rate.

Dow does not, however, advise selecting gloves on the basis of their generic material alone. You should also consider other characteristics, such as dexterity and comfort, cut and abrasion protection, thermal insulation, and disposable and reusable features. For example, you might be able to achieve superior solvent resistance and comfort by using two different types of gloves—a thin inner glove with a high breakthrough time, and a tighter-fitting outer glove with less solvent resistance.

A summary of information on the use of gloves with chlorinated solvents can be found in Table 7.

### Table 7: Permeation Resistance of Common Glove Materials

(Breakthrough Time in Minutes: Permeation rate in mg/sec/m²)

<table>
<thead>
<tr>
<th>Duty</th>
<th>Material</th>
<th>Thickness (mm)</th>
<th>Methylene Chloride</th>
<th>Trichloroethylene</th>
<th>Perchloroethylene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy</td>
<td>VITON® Fluoroelastomer</td>
<td>0.15</td>
<td>83 (3.8)</td>
<td>&gt; 480</td>
<td>&gt; 480</td>
</tr>
<tr>
<td></td>
<td>Polyvinyl Alcoholb</td>
<td>0.45</td>
<td>&gt; 480</td>
<td>&gt; 480</td>
<td>&gt; 480</td>
</tr>
<tr>
<td></td>
<td>EVAL Laminatec</td>
<td>0.07</td>
<td>&gt; 480d</td>
<td>&gt; 480d</td>
<td>&gt; 480d</td>
</tr>
<tr>
<td>Medium</td>
<td>Butyl Rubber</td>
<td>0.40</td>
<td>10 (116)</td>
<td>4.7 (340)</td>
<td>80 (149)</td>
</tr>
<tr>
<td></td>
<td>NBR (nitrile)</td>
<td>0.34</td>
<td>&lt; 1 (938)</td>
<td>9.4 (274)h</td>
<td>211 (4.7)</td>
</tr>
<tr>
<td></td>
<td>Neoprene</td>
<td>0.48</td>
<td>&lt; 1 (447)</td>
<td>4.7 (365)</td>
<td>12 (163)</td>
</tr>
<tr>
<td>Light</td>
<td>Polyethylene</td>
<td>0.07</td>
<td>&lt; 1 (70)</td>
<td>&lt; 1 (232)</td>
<td>&lt; 1 (128)</td>
</tr>
<tr>
<td></td>
<td>PVC (Vinyl)</td>
<td>0.10</td>
<td>&lt; 1f</td>
<td>&lt; 1 (169)h</td>
<td>&lt; 1 (124)h</td>
</tr>
</tbody>
</table>

*Trademark of E.I. DuPont de Nemours, Inc.

*Water soluble, glove can soften.

*Three-layer laminate: polyethylene (PE)/polyethylene vinyl alcohol (EVAL)/PE.


*Tear resistance significantly reduced after testing.

*Disintegrates.

*Stiffened after test.

To find more information about chlorinated solvents, or to download the most current version of the Chlorinated Solvents Product Stewardship Manual, visit [www.chlorinatedsolvents.com](http://www.chlorinatedsolvents.com) or [www.dow.com](http://www.dow.com).
Appendix C

Methylene Chloride
Epidemiological studies conducted over 35 years with more than 6,000 people exposed to methylene chloride in their workplace showed no increase in deaths from cancer or any other disease. Although repeated exposure to high levels of methylene chloride is known to cause transient central nervous system disturbance, neurological studies have shown that there is virtually no chance of permanent damage.

A long-term inhalation study of mice exposed to high doses of methylene chloride showed an increased incidence of lung and liver tumors (National Toxicology Program, 1986). However, similar studies in rats and hamsters did not show an increased incidence of these tumors.

The results of recent research on methylene chloride indicate that the mouse may not be a representative model for humans. This new research has identified the mechanistic basis of tumor formation, which is due to the metabolism of methylene chloride by a specific form of the enzyme glutathione-S-transferase. High levels of this enzyme are found in specific lung and liver cells of the mouse. The glutathione-S-transferase pathway is by far more important in the mouse than it is in the rat or hamster, and seems to be of least importance in human tissue. The conclusion of the new research is that the mouse is unique in its response to methylene chloride, and that it might be inappropriate to use data on mouse tumors for assessing the risk from methylene chloride in humans.

Cancer Classification
The International Agency for Research on Cancer (IARC) has classified methylene chloride in group 2B, as a substance considered to be “possibly” carcinogenic to humans.

According to ACGIH, methylene chloride is an “animal carcinogen” (category A3).

The German MAK Commission has classified methylene chloride as a “possible carcinogen” (category IIIA). In the European Union, methylene chloride is currently classified in category 3, as a “possible carcinogen,” based on evidence of carcinogenicity in animals (with risk phase R-40).

The U.S. Environmental Protection Agency (EPA) has classified methylene chloride as probably carcinogenic to humans (B2) under the 1986 Guidelines for Carcinogen Risk Assessment. The EPA’s Science Advisory Board stated, however, that the level of uncertainty is greater, and that the hazard may be less than that expressed by the EPA classification.

According to the National Toxicology Program (NTP), methylene chloride is reasonably anticipated to be a human carcinogen, based on sufficient evidence of carcinogenicity in experimental animals (NTP, 1986).
Perchloroethylene

There is no evidence of permanent damage to the central nervous system by perchloroethylene exposure at the recommended exposure standards. Data from reproductive and developmental toxicity studies suggest that perchloroethylene has no adverse effects on the offspring of rats and mice.

Several studies to investigate the carcinogenic potential of perchloroethylene in laboratory animals have been conducted. Some of these studies showed that perchloroethylene can cause liver tumors in mice and kidney tumors in male rats.

Extensive research into the mechanisms of tumor formation has been conducted to determine whether these findings in rodents have any relevance for humans. This research has shown that liver tumors in mice result from an increase in peroxisome levels, which is itself caused by a metabolite of perchloroethylene, trichloroacetic acid (TCA). This mechanism is not thought to be relevant to humans exposed to perchloroethylene (see Appendix E—Trichloroethylene). Three possible mechanisms have been suggested to explain the presence of kidney tumors in male rats. They are:

(a) Chronic high exposure-related toxicity
(b) Protein droplet accumulation
(c) Conjugation with glutathione, which may lead to the formation of a DNA-damaging metabolite of perchloroethylene

The accumulation of a particular type of protein (alpha-2U globulin) is associated with the kidney tumors in male rats only. Importantly, a similar mechanism of tumor formation does not occur in humans. It also appears that the rat is far more likely to conjugate perchloroethylene with glutathione than any other species, particularly humans.

A number of epidemiology studies have investigated the cancer mortality and mortality patterns of other diseases among dry cleaning employees exposed to perchloroethylene and a variety of other drycleaning solvents. Overall, these studies show no exposure-related increases in terms of death rates from specific diseases.

Some of these studies show slight increases in certain cancer types. However, a study in a subgroup of dry cleaning employees exposed to perchloroethylene only did not show an overall increase in the risk of cancer, although the incidence of esophageal cancer was slightly elevated in males of African descent. These findings are thought not to be related to perchloroethylene exposure.

Cancer Classification

The IARC has classified perchloroethylene in group 2A, as a substance considered “probably” carcinogenic to humans. The IARC concluded that there is “limited” evidence of carcinogenicity in humans on the basis of the results of some of the available epidemiological studies.

The German MAK Commission has classified perchloroethylene as a “possible carcinogen” (category IIIIB). In the European Union, perchloroethylene is currently classified in category 3, as a “possible carcinogen,” based on evidence of carcinogenicity in animals (with risk phase R-40).

ACGIH classifies perchloroethylene in its category A3—animal carcinogen. ACGIH goes on to say that the agent is carcinogenic in experimental animals at a relatively high dose, by route(s) of administration, at site(s), of histologic type(s), or by mechanism(s) that may not be considered relevant to worker exposure. Available epidemiological studies do not confirm an increased risk of cancer in exposed humans. Available evidence does not suggest that the agent is likely to cause cancer in humans except under uncommon or unlikely routes or levels of exposure.

In the United States, the EPA’s Scientific Advisory Board has stated that the weight of evidence for perchloroethylene does not support the classification as a probable carcinogen (B2) under the 1986 Guidelines for Carcinogen Risk Assessment. It is expected that perchloroethylene will be reassessed in the near future under the revised EPA Cancer Guidelines.

According to the National Toxicology Program (NTP), perchloroethylene is reasonably anticipated to be a human carcinogen, based on sufficient evidence of carcinogenicity in experimental animals (NTP 1986, IARC 1979, 1987, 1995).
Trichloroethylene

With the exception of hearing loss observed in rats at very high exposure levels, there is no evidence of permanent damage to the central nervous system by trichloroethylene exposure. Data from reproductive and developmental toxicity studies suggest that trichloroethylene has no adverse effects on the offspring of rats and mice at exposure levels that had no adverse effects on the parents.

The carcinogenic potential of trichloroethylene in laboratory animals and humans (through epidemiological studies) has been well investigated. In long-term animal studies, tumors were observed in mice and, to a lesser degree, in rats. In mice, liver and lung tumors were found. Extensive research into the induction of mouse liver tumors has shown that the solvent is metabolized to trichloroacetic acid (TCA), which, in turn, increases the number of certain intracellular organelles (peroxisomes) in the mouse liver. The formation of peroxisomes is associated with the formation of liver tumors in animals, but it is generally accepted that the mechanism is “promotional” in nature. Based on scientific data presently available, this mechanism is not thought to be relevant to humans exposed to trichloroethylene for two reasons:

- TCA levels in humans are low because the human body has a limited ability to metabolize trichloroethylene to TCA.
- TCA does not induce increased levels of peroxisomes in human liver cells.

The studies have concluded that these mouse liver tumors are unlikely to have relevance for humans. Accumulating evidence indicates that the probable mechanism underlying the increase in mouse lung tumors is not relevant to humans. Enzymes present in a specific cell type (the Clara cell) in the mouse lung metabolize trichloroethylene to chloral, which is genotoxic and highly cytotoxic to the Clara cell, and which—in contrast to other species—cannot be detoxified in the mouse lung.

In addition, recent research has indicated that the increase in mouse lung tumors may result from the repeated cycle of damage and repair in the Clara cells that occurs during the dosing regimen of the cancer study. A borderline increase of kidney tumors in rats is only seen at doses that are highly toxic, and is probably related to a high-dose phenomenon. It appears to be due to renal toxicity, a specific metabolite of trichloroethylene, or a combination of both. More research is being conducted to experimentally explore the hypothesized mechanisms of tumor formation.

There have been several large epidemiological studies in humans (all combined up to 20,000 subjects) exposed in the workplace to trichloroethylene, none of which consistently indicated an overall increase in cancer risk. Some recent epidemiological studies in Germany and France have shown small increases in kidney cancer associated with exposure to trichloroethylene. These small excesses of kidney cancer were restricted to those workers who had experienced high cumulative exposures to trichloroethylene.

Cancer Classification

The IARC has classified trichloroethylene in group 2A, as a substance considered “probably” carcinogenic to humans. The IARC, following its own restrictive classification scheme, concluded that there is “limited” evidence of carcinogenicity in humans on the basis of a combination of the results of some of the available epidemiological studies, and there is sufficient evidence of carcinogenicity in experimental animals.

According to the ACGIH, trichloroethylene is “Suspected as a Human Carcinogen” (Category A2). Human data are accepted as adequate in quality, but are conflicting or insufficient to classify the agent as a confirmed human carcinogen; or the agent is carcinogenic in experimental animals at dose(s), by route(s) of exposure, at site(s), of histologic type(s), or by mechanism(s) considered relevant to human exposure. The A2 category is used primarily when there is limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals with relevance to humans.

Trichloroethylene is currently being reassessed under the revised (1996) EPA Guidelines.

The German MAK Commission recently reclassified trichloroethylene as a “proven human carcinogen” based on epidemiological (case control) studies conducted in Germany.

In the European Union, under the EU Dangerous Substances Directive, trichloroethylene is a category 2, probable human carcinogen (with risk phase R-45).

The National Toxicology Program (NTP) listed trichloroethylene in the Ninth Report on Carcinogens (RoC) as reasonably anticipated to be a human carcinogen based on limited evidence of carcinogenicity from studies in humans, sufficient evidence of malignant tumor formation in experimental animals, and convincing relevant information that TCE acts through mechanisms indicating that it would likely cause cancer in humans (NTP, 2000a).
Appendix F

Table 8: Relative Evaporation Rates†

<table>
<thead>
<tr>
<th>Compound</th>
<th>Relative Evaporation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-Butyl acetate</td>
<td>1.0</td>
</tr>
<tr>
<td>Ethanol§</td>
<td>1.4</td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td>1.5</td>
</tr>
<tr>
<td>Methyl alcohol</td>
<td>2.1</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>3.0</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>3.9</td>
</tr>
<tr>
<td>Acetone</td>
<td>5.7</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>7.0</td>
</tr>
</tbody>
</table>

†Evaporation rates measured with respect to n-butyl acetate. Larger numbers reflect faster evaporation. As measured by ASTM D3539-76.

§95% Et OH, 5% H2O

Figure 4: Boiling Temperatures of Chlorinated Solvents and Oil
Figure 5: Vapor Pressure of Chlorinated Solvents

Figure 6: Density of Chlorinated Solvents as a Function of Temperature
Figure 7: Specific Gravity Data

Methylene Chloride and Mineral Oil

Specific Gravity 25°C/25°C

Mineral Oil Volume %

Trichloroethylene and Mineral Oil

Specific Gravity 25°C/25°C

Perchloroethylene and Mineral Oil

Specific Gravity 25°C/25°C

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