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**TRICHLOROETHANE,
A SUMMARY OF THE TOXICOLOGICAL DATA**

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RESEARCH DIRECTORATE**

March 1989

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PREFACE

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TRICHLOROETHANE, A SUMMARY OF THE TOXICOLOGICAL DATA

1. INTRODUCTION

The U.S. Army Research, Development and Engineering Center (CRDEC), Smoke Division, Munitions Directorate, requested the Toxicology Division, Research Directorate, to conduct a literature search on the toxicological and environmental hazards of trichloroethane. The 1,1,1-isomer of trichloroethane has a high vapor pressure, is essentially nonflammable, and has been selected as the solvent for the safe smoke grenade. The 1,1,1-isomer will be used to form a slurry with titanium dioxide, the prime smoke candidate, in order to compact it. Residual trichloroethane will then be vaporized prior to loading the grenade. The following databases were searched: TOXLIT, RTECS, MEDLINE, MED83, and HSDB.

There are two isomers of trichloroethane, 1,1,1-trichloroethane and 1,1,2-trichloroethane. The physical properties of the isomers are somewhat different. The toxicological properties are decidedly different. Several toxicological references¹⁻⁶ contain a serious mistake as they do not differentiate between the isomers or erroneously list 1,1,2-trichloroethane as the least toxic compound.⁷ It should be noted that 1,1,1-trichloroethane is considerably less toxic than 1,1,2-trichloroethane.

2. 1,1,1-TRICHLOROETHANE

1,1,1-Trichloroethane, CAS 71-55-6, RCRA u226, commonly called "methyl chloroform," is most frequently used as a solvent. The projected consumption for 1987 was 680,000,000 lb.⁸ There are abundant animal and human data on the material. This discussion will focus primarily on the properties relevant to its proposed use and the data most pertinent to humans.

2.1 Physical and Chemical Properties.

1,1,1-Trichloroethane has the following physical and chemical characteristics.

physical state	colorless liquid
molecular weight	133.42
specific gravity	1.3249 (26/4 °C)
boiling point	74.1 °C
vapor pressure	127 torr (25 °C)
refractive index	1.43765 (21 °C)
percentage in "saturated air"	16.7 (25 °C)

solubility	0.09 g/100 mL water at 20 °C; soluble in ethanol, ethyl ether
flammability	no flash point or fire point; will not sustain combustion
1 mg/L = 183 ppm, and 1 ppm = 5.46 mg/cm at 25 °C, 760 torr. ⁹	
octanol/water partition coefficient	2.49. ¹⁰

Vapors can be collected for sampling with an adsorption tube. Analysis is done through gas chromatography following desorption with carbon disulfide.

Hydrogen chloride, chlorine, phosgene, and carbon monoxide may be released in a fire involving 1,1,1-trichloroethane.^{7,11,12} It reacts slowly with water, releasing hydrochloric acid.¹³ The compound reacts with aluminum and its alloys producing hydrogen chloride; considerable pressure can build up in a closed container.¹¹ Mixtures with potassium or its alloys are sensitive to shock and may explode on light impact.¹⁴ Methyl chloroform also undergoes a decomposition reaction with magnesium and zinc.¹⁵ To prevent these reactions, 1,1,1-trichloroethane is often stabilized (inhibited) with various compounds including: perchloroethylene, petroleum solvents, toluene, ethylene dichloride, *o*-dichlorobenzene, and xylene. The presence of appreciable quantities of some of these inhibitors, notably xylene, toluene, or *o*-dichlorobenzene, increases the toxicity of 1,1,1-trichloroethane.¹⁶

2.2 Toxicity.

1,1,1-Trichloroethane is probably the least toxic of the chlorinated solvents.⁹ The estimated lethal dose for a 150-lb man is 0.5 to 1.0 pt.¹⁵ The threshold limit value (TLV) is 350 ppm (National Institute for Occupational Safety and Health (NIOSH), 1978; American Conference of Governmental Industrial Hygienists (ACGIH), 1980). Methyl chloroform has been used as an anesthetic and is a central nervous system (CNS) depressant. Death can occur at anesthetic concentrations and is usually attributable to respiratory arrest or cardiovascular collapse. The concentration range over which anesthesia can be expected ranges from 1 to 3%¹⁸ or approximately 10,000 to 30,000 ppm.¹¹ However, Torkelson et al.⁷ reported incoordination and beginning anesthetic effects in humans at concentrations ranging from 200 to 1000 ppm.¹⁹ Gamberale and Hultengren have reported impairment of psychophysiological function at concentrations ranging from 250 to 550 ppm.¹⁹

Note that methyl chloroform, like other chlorinated solvents, sensitizes the heart to circulating catecholamines and can produce fatal ventricular fibrillation. Aviado and Belej²⁰ studied these phenomena in mice and observed that methyl chloroform produced fibrillation independent of and in addition to catecholamine sensitization. In dogs, arrhythmias have been produced with concentrations as low as 0.5%.²¹ There are numerous deaths annually from "solvent sniffing," and they are often attributed to this phenomenon. One report described casualties as being under "light plane anesthesia;" none of them lost consciousness until they collapsed and died.²²

Torkelson and Rowe⁹ state that 1,1,1-trichloroethane has little capacity to produce organ injury from either single or repeated exposures.

No abnormalities were observed in rats, guinea pigs, rabbits, and monkeys after 6 mo of repeated exposures to 500 ppm for 7 hr/day, 5 days/week.⁷ Klassen and Plaa²³⁻²⁵ have demonstrated in rats, mice, and dogs that hepatic and/or renal dysfunction, if present, does not occur until near-lethal doses are reached and is reversible. Prendergast et al.²⁶ exposed rats, guinea pigs, rabbits, dogs, and monkeys to 12,060 ppm (30 exposures, 8 hr/day, 5 days/week) or 2,059 ppm or 754 ppm (continuous, 90-day exposure) of 1,1,1-trichloroethane. No toxic signs were observed. A few lethalties occurred in the low-dose animals but were not directly attributed to methyl chloroform. Human exposures ranging from 500 ppm for 7 hr to 1900 ppm for 5 min produced no evidence of systemic injury.⁷ Similarly, human exposures to 500 ppm for 6.5 - 7.0 hr/day for 5 days did not produce any abnormalities in clinical laboratory tests.²⁷ A study of neurophysiological parameters in 22 women, exposed for 6.5 years to concentrations of 1,1,1-trichloroethane ranging from 110 to 990 ppm, demonstrated no differences in nerve conduction velocity, clinical symptoms, or psychometric function as compared to 7 controls.²⁸ Kramer et al.²⁹ studied a population of 151 industrial workers with up to 6 years exposure to methyl chloroform and found no exposure effects as compared to 151 pair-matched controls. However, a study in which mice were exposed to 1000 ppm for up to 14 weeks reported moderate liver damage.³⁰ With intraperitoneal administration of the solvent to mice, Paa et al.³¹ estimated the ED50 for hepatotoxicity to be 70% of the LD50. NIOSH guidelines¹² state that high concentrations of methyl chloroform cause liver changes in animals and suggest that the possible consequences be considered before exposing persons with impaired liver function. Data from studies using mice indicate that there may be an interaction between 1,1,1-trichloroethane and ethanol, and a significant acute toxicity may occur with joint administration of the two compounds.³² Carlson³³ reported phenobarbital potentiated, to some extent, the hepatotoxic effects observed in rats following a 2-hr exposure to 890 ppm of 1,1,1-trichloroethane. However, Klassen and Plaa²⁴ had difficulty demonstrating a potentiation by alcohol of methyl chloroform-induced liver dysfunction in dogs.

NIOSH guidelines state that "reproductive abnormalities have been noted in studies of animals exposed to high concentrations of methyl chloroform," "workers should be provided with information advising them of studies in which congenital abnormalities were found following exposure of animals to high concentrations of methyl chloroform," and "the physician should be made aware of any reproductive abnormalities in workers." It is not entirely clear if the above refers to reproduction, as well as teratogenicity; nor is it clear as to which studies these statements refer. A study of mice that covered multiple generations where 1,1,1-trichloroethane was administered in drinking water in effective daily doses of up to 1000 mg/kg failed to show effects on fertility, gestation, viability, or lactation indices. Pup survival and weight gain were not adversely affected, and no dominant lethal mutations or teratogenic effects were demonstrated.³⁴ Exposure of mice and rats to 875 ppm methyl chloroform for 7 hr/day during days 6-15 of gestation did not cause significant maternal, embryonal, or fetal toxicity; no teratogenicity was observed.³⁵ Exposure of Long-Evans rats to 2100 ppm of 1,1,1-trichloroethane before mating and/or during pregnancy reduced fetal body weight, delayed ossification, and retarded kidney development in fetuses. However, the effects were reversible and had no influence on postnatal outcome.³⁶ Injecting 50 or 100 mg of methyl chloroform into the air space of fertile chicken eggs on days 2, 3, and 6 of incubation produced multiple malformations.³⁷

Methyl chloroform showed mutagenic effects per the salmonella/microsome test, a drosophila test, and the micronucleus test on mouse bone marrow.³⁸ However, Torkelson and Rowe⁹ pointed out many of the stabilizers that are added to 1,1,1-trichloroethane are electrophilic and may be "responsible for the weakly positive findings in the Ames test reported sporadically." Dominant lethal effects were not demonstrated, even with daily doses as high as 8500 mg/kg discussed above.^{34,39}

There is no clear evidence that methyl chloroform is carcinogenic. A bioassay for carcinogenicity was negative for tumors, but significantly increased mortality was observed in the exposed animals, and the data were regarded as being inconclusive.⁴⁰ Torkelson and Rowe⁹ state that the increased mortality was possibly related to respiratory involvement secondary to the gavage dosing technique. No vehicle-control animals were used. Torkelson and Rowe⁹ also state that no adverse effects (tumors, mortality, gross and histopathology, hematology, or clinical chemistry) have been demonstrated in rats exposed to methyl chloroform concentrations as high as 1750 ppm for 1 hr/day for 1 year and then kept for their lifetimes. However, Price et al.⁴¹ reported that cell transformation tests, using rat embryo cultures, were positive following exposure to methyl chloroform and that injection of transformed cells into Fischer rats produced local fibrosarcomas. Torkelson and Rowe⁹ think that it is unlikely that carcinogenicity is of concern if exposure to 1,1,1-trichloroethane is kept below levels causing frank anesthesia.

1,1,1-Trichloroethane undergoes very little metabolism and 90-98% of the dose is excreted unchanged in the expired air, regardless of the route of administration.^{27,42,43} The low systemic toxicity of methyl chloroform has been attributed to this fact. The primary metabolites are trichloroacetic acid and trichloroethanol.⁹

Methyl chloroform is absorbed through the skin to some extent. The amount of absorption is proportional to the duration of the exposure and the amount of area and type of skin exposed. Gas chromatographic analysis of expired air following immersion of the hand in 1,1,1-trichloroethane for 30 min indicated a peak alveolar air concentration of only 21.5 ppm. It was concluded that methyl chloroform was unlikely to be absorbed in toxic quantities when in contact with the skin of the hands and forearms.⁴⁴ Similarly, a study of vapor penetration, as measured by urinary metabolites and concentration in expired air following a 3.5-hr exposure to 600 ppm methyl chloroform, indicated that percutaneous absorption was slow. It was concluded that in the work environment, dermal absorption of vapors through undamaged skin was likely to be insignificant.⁴⁵

Methyl chloroform is a dermal irritant following prolonged or repeated skin contact.¹² Torkelson and Rowe⁹ attribute the bulk of the effects to the defatting action of the solvent. In one study, the hand of a subject was immersed in 1,1,1-trichloroethane for 30 min. Although an uncomfortable burning sensation was reported during part of the exposure period, the findings were only a "chalky-white scale" that was "readily removed by rinsing the hands in water" and a mild erythema that subsided within 1 hr.⁴⁴

1,1,1-Trichloroethane is considered to be an eye irritant.¹² Torkelson et al.⁷ reported that eye application in rabbits was painful, but

conjunctival irritation was slight, and there was essentially no ocular damage. In a collaborative evaluation of the Draize test, methyl chloroform was generally named as a nonirritant in all parameters.⁴⁶ In a report of splash contact with a human eye, the injury was classified as mild, transient with recovery in 48 hr.⁴⁷

2. Environmental Fate and Ecotoxicity.

With regard to environmental fate, land spills of methyl chloroform dissipate through evaporation into the atmosphere and percolation into the ground water.⁴⁸ Schwarzenbach⁴⁸ states that given the fact it is not retained in soil during bank infiltration and is frequently found in groundwater in high concentrations, one can conclude that 1,1,1-trichloroethane is not strongly adsorbed by soils, especially subsurface soils. Slow degradation has been reported in loamy sand under acclimated conditions; no or very slow degradation has been reported in other soils.^{49,50} Volatilization from water is rapid because of the high vapor pressure and low water solubility of the compound.⁵⁰ The half-life in water ranges from several hours to several weeks, depending upon wind and mixing conditions.⁵¹ Some degradation to vinylidene chloride has been observed in sea water; none has been observed in river water.^{52,53} The half-life of methyl chloroform in the atmosphere is from 6 mo to 2 years. About 15% of the atmospheric methyl chloroform drifts into the stratosphere where it is rapidly degraded by photodissociation.^{55,56} Because of its stability, methyl chloroform is carried long distances and has been found as far away as the South Pole.^{54,56,59} 1,1,1-Trichloroethane released into the atmosphere can return, in part, in rain.⁵⁸ There is little or no tendency for bioconcentration.⁵⁹ Human exposure is most likely from contaminated air or drinking water.

Verschueren⁶⁰ reports the following ecotoxicity values: LC₅₀ Fathead minnow--52.8 mg/L/96 hr (flow-through test), LC₅₀ Fathead minnow--105 mg/L/96 hr (static test), and LC₅₀ Guppy (*Poecilia reticulata*)--133 ppm/7 days.

3. 1,1,2-TRICHLOROETHANE

1,1,2-Trichloroethane is known as vinyl trichloride. It is discussed primarily within the context of its significant differences from 1,1,1-trichloroethane and relevant toxicological data.

3.1 Physical and Chemical Properties.

The physical and chemical properties of 1,1,2-trichloroethane are as follows.

physical state	colorless liquid
molecular weight	133.42
specific gravity	1.442 (20/4 °C)
melting point	-36.7 °C
boiling point	113.5 °C

vapor pressure	25 torr (25 °C)
refractive index	1.4711 (20 °C)
percentage in "saturated air"	3.3 (25 °C)
solubility	0.44 g/100 g water at 20 °C; soluble in ethanol and ethyl ether
flammability	not flammable by standard test in air

1 mg/L = 183 ppm and ppm = 5.46 mg/m at 25 °C, 760 torr.⁹

The vapor pressure of 1,1,2-trichloroethane is approximately five-fold that of 1,1,1-trichloroethane.

As with methyl chloroform, the decomposition products that may be released in a fire involving vinyl trichloride include hydrogen chloride, hydrogen cyanide, and carbon monoxide.⁵¹ 1,1,2-Trichloroethane is incompatible with strong oxidizers and strong caustics. Its reaction with aluminum, magnesium, sodium, and potassium may cause fires and explosions.⁵¹

Vinyl trichloride is used primarily as a chemical intermediate and, secondarily, as a specialty solvent. Its use is quite restrictive because of its toxicity and the availability of other less toxic solvents.⁹

4.1.2. Toxicity.

Muskelin et al.⁶² rate 1,1,2-trichloroethane as very toxic and estimate the lethal oral dose for humans to be 50-500 mg/kg or between 1 tsp and 1 cup for a 150-lb (71-kg) person. In a study of the effects of halogenated hydrocarbons in mice, Pao et al.³¹ rated 1,1,1-trichloroethane at 1 for lethality and 1,1,2-trichloroethane was rated 71. The TLV for 1,1,2-trichloroethane is 100 ppm.⁶³ However, ACGIH⁶³ stated that based upon comparison with chloroform, the TLV should be lower than 10 ppm might be in order.

Like methyl chloroform, 1,1,2-trichloroethane is a CNS depressant. It may result secondary to respiratory arrest or cardiovascular collapse. It may also be associated with the sensitization to catecholamines.⁶⁴

Like 1,1,1-trichloroethane, vapor exposure or injection causes hepatic and renal damage by a variety of species, including man.^{23,24,44,65} Compared to a rat, the LD₅₀ attributed to the hepatotoxic effects of 1,1,1-trichloroethane in mice was 1.5 times higher and was rated 40.³¹ Hepatic injury is enhanced by compounds that induce the microsomal enzymes.^{24,32,66} Vinyl trichloride is considered hepatotoxic, however, while two studies demonstrated this potential in mice (LD₅₀ 1.5 g/kg body weight of the compound), an LD₅₀ in rats was not demonstrated (LD₅₀ > 5).³¹ The compound has been shown to be mutagenic following injection of the yolk sac of fertilized chicken eggs. Surprisingly, the study indicated that 1,1,2-trichloroethane has less hepatogenic potential than did 1,1,1-trichloroethane.²⁷ 1,1,2-Trichloroethane concentrations of 20, 40 and

60 µmol/plate were not mutagenic in a plate assay with Salmonella typhimurium strain TA1535 with or without microsomal activation.⁶⁹

The metabolism and excretion of 1,1,2-trichloroethane are different from that of the 1,1,1-isomer. Yllner⁷⁰ observed, following intraperitoneal injection in mice, that only 16-22% was expired, while 73-87% was excreted in urine. The urinary metabolites were chloroacetic acid, S-carboxymethyl-cysteine, and thiodoacetic acid.

Data do not indicate that the dermal or ocular irritant properties of 1,1,2-trichloroethane are markedly different from those of the 1,1,1-isomer.^{9,64} However, experimental findings in guinea pigs indicate dermal absorption can be fatal.⁷¹

3.3 Environmental Fate and Ecotoxicity.

The environmental fate of 1,1,2-trichloroethane is similar to that for the 1,1,1-isomer. However, it is photodegraded in the atmosphere by reaction with hydroxyl radicals.⁷² The half-life in polluted atmospheres is a few days, and in unpolluted atmospheres, it is 24 days.⁷³ As with 1,1,1-trichloroethane, the 1,1,2-isomer is lost from water primarily by evaporation, but owing to its lower vapor pressure, the half-life in water is longer (days to weeks).⁷⁴

The U.S. Environmental Protection Agency (EPA)⁷⁵ has reported an LC₅₀ of 15 mg/L/48 hr for *Daphnia* (static test).

4. CONCLUSIONS AND RECOMMENDATIONS

1,1,1-Trichloroethane is markedly less toxic than 1,1,2-trichloroethane and is widely used in industry. As noted in Section 2.2, 1,1,1-trichloroethane has low systemic and dermal toxicity and is not a frank carcinogen. It is considered to be among the safest of the chlorinated solvents.

Given the high vapor pressure and relatively low toxicity of 1,1,1-trichloroethane, it is not anticipated that solvent residual from the slurry would present a toxicological hazard for the safe smoke grenade. However, methyl chloroform sensitizes the heart to circulating catecholamines, producing ventricular fibrillation (Section 2.2), and the situation in which the smoke grenade would be employed is relatively stressful. Therefore, it is suggested the concentration of grenade-disseminated residual vapor be determined to rule out the likelihood of such an occurrence.

1,1,1-Trichloroethane does cause reversible ocular irritation, and as with most solvents, repeated skin exposure produces dermal irritation (Section 2.2). Appropriate protective clothing such as gloves and goggles should be worn per the Material Safety Data Data (MSDS) (Appendix). Inhalation of vapors should be avoided. Also note that trichloroethane is a Resource Conservation and Recovery Act (RCRA) chemical and should be handled in accordance with CRDEC, State, and Federal regulations for hazardous wastes.

Consideration should be given to the types of metal with which trichloroethane comes into contact. Uninhibited trichloroethane is known to

react with various metals, and the decomposition products can be hazardous or explosive (Section 2.1).

Additional toxicological and environmental studies should be conducted on collected particulates from grenade-disseminated titanium dioxide. These include acute and repeated inhalation, mutagenicity, and aquatic tests.

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APPENDIX

MATERIAL SAFETY DATA SHEET FOR 1,1,1-TRICHLOROETHANE



MATERIAL SAFETY DATA SHEET

DOW CHEMICAL U.S.A. MIDLAND, MICHIGAN 48674 EMERGENCY (517) • 636 • 4400

Product Code: 08592

Page: 1

PRODUCT NAME: 1,1,1-TRICHLOROETHANE, INHIBITED

Effective Date: 03/20/88 Date Printed: 06/07/88

MSDS:001111

1. INGREDIENTS:

1,1,1-Trichloroethane	CAS# 000071-55-6	96.5% (wt.)
Diethylene Ether	CAS# 000123-91-1	2.5
1,2-Butylene oxide	CAS# 000106-88-7	0.47
Nitromethane	CAS# 000075-52-5	0.34

The hazard information presented is based on tests conducted on this or similar mixtures. Therefore, pursuant to the OSHA Hazard Communication Standard (see 29 CFR Part 1910.1200 (g) (2) (b)), the information is based on the tested mixture and not individual ingredients.

2. PHYSICAL DATA:

BOILING POINT: 165F (74C)
VAP PRESS: 100 mmHg @ 20C
VAP DENSITY: 4.55
SOL. IN WATER: 0.07 g/100g @ 25C
SP. GRAVITY: 1.321 @ 25/25C
APPEARANCE: Colorless liquid.
ODOR: Irritating odor at high concentrations.

3. FIRE AND EXPLOSION HAZARD DATA:

FLASH POINT: None
METHOD USED: TOC, TCC, COC

FLAMMABLE LIMITS
LFL: 7.5% @ 25C
UFL: 15% @ 25C

EXTINGUISHING MEDIA: Water fog.

FIRE & EXPLOSION HAZARDS: Vapors of this solvent may develop a

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MATERIAL SAFETY DATA SHEET

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

Product Code: 08592

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PRODUCT NAME: 1,1,1-TRICHLOROETHANE, INHIBITED

Effective Date: 03/20/88 Date Printed: 06/07/88

MSDS:001111

3. FIRE AND EXPLOSION HAZARD DATA: (CONTINUED)

flammable atmosphere in confined areas.

FIRE-FIGHTING EQUIPMENT: Self-contained, positive pressure respiratory equipment.

4. REACTIVITY DATA:

STABILITY: (CONDITIONS TO AVOID) Avoid open flames, welding arcs or other high temperature sources which induce thermal decomposition.

INCOMPATIBILITY: (SPECIFIC MATERIALS TO AVOID) Water - long term contact can deplete stabilizers followed by slow hydrolysis producing corrosive acid. Avoid prolonged contact with, or storage in, aluminum or its alloys. Metallic aluminum and zinc powders should be avoided.

HAZARDOUS DECOMPOSITION PRODUCTS: Hydrogen chloride and very small amounts of phosgene and chlorine.

HAZARDOUS POLYMERIZATION: Will not occur.

5. ENVIRONMENTAL AND DISPOSAL INFORMATION:

ACTION TO TAKE FOR SPILLS/LEAKS: Small leaks: Mop up, wipe up, or soak up immediately. Remove to out-of-doors.
Large spills: Evacuate area. Contain liquid; transfer to closed metal containers. Keep out of water supplies.

DISPOSAL METHOD: When disposing of the unused contents, the preferred options are to send to licensed reclaimer, or to permitted incinerators. Any disposal practice must be in compliance with federal, state, and local regulations. Do not

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M A T E R I A L S A F E T Y D A T A S H E E T

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

Product Code: 08592

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PRODUCT NAME: 1,1,1-TRICHLOROETHANE, INHIBITED

Effective Date: 03/20/88 Date Printed: 06/07/88

MSDS:001111

5. ENVIRONMENTAL AND DISPOSAL INFORMATION: (CONTINUED)

dump into sewers, on the ground, or into any body of water.

6. HEALTH HAZARD DATA:

EYE: May cause pain. May cause slight transient (temporary) irritation with slight transient corneal injury. Vapors may irritate eyes.

SKIN CONTACT: Prolonged or repeated exposure may cause skin irritation. Repeated contact may cause drying or flaking of skin.

SKIN ABSORPTION: A single prolonged skin exposure is not likely to result in absorption of harmful amounts. The LD50 for rabbits is about 15,000 mg/kg.

INGESTION: Single dose oral toxicity is low. The LD50 for rats is >10,000 mg/kg. If aspirated (liquid enters the lung), may be rapidly absorbed through the lungs and result in injury to other body systems.

INHALATION: Minimal anesthetic or narcotic effects may be seen in the range of 500-1000 ppm trichloroethane. Progressively higher levels over 1000 ppm may cause dizziness, drunkenness; concentrations as low as 10,000 ppm can cause unconsciousness and death. These high levels may also cause cardiac arrhythmias (irregular heartbeats). In confined or poorly ventilated areas, vapors which readily accumulate can cause unconsciousness and death.

SYSTEMIC & OTHER EFFECTS: Based on available data, repeated exposures are not anticipated to cause any significant adverse effects. Similar formulations did not cause cancer in long-term animal studies. Birth defects are unlikely. Exposures having

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M A T E R I A L S A F E T Y D A T A S H E E T

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

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PRODUCT NAME: 1,1,1-TRICHLOROETHANE, INHIBITED

Effective Date: 03/20/88 Date Printed: 06/07/88

MSDS:001111

6. HEALTH HAZARD DATA: (CONTINUED)

no adverse effects on the mother should have no effect on the fetus. In animal studies, has been shown not to interfere with reproduction. Results of in vitro ("test tube") mutagenicity tests have been negative. Results of mutagenicity tests in animals have been negative.

7. FIRST AID:

EYES: Irrigate immediately with water for at least 5 minutes.

SKIN: Wash off in flowing water or shower.

INGESTION: Do not induce vomiting. Call a physician and/or transport to emergency facility immediately.

INHALATION: Remove to fresh air. If not breathing, give mouth-to-mouth resuscitation. If breathing is difficult, give oxygen. Call a physician.

NOTE TO PHYSICIAN: Because rapid absorption may occur through lungs if aspirated and cause systemic effects, the decision of whether to induce vomiting or not should be made by an attending physician. If lavage is performed, suggest endotracheal and/or esophageal control. Danger from lung aspiration must be weighed against toxicity when considering emptying the stomach. Exposure may increase "myocardial irritability." Do not administer sympathomimetic drugs unless absolutely necessary. No specific antidote. Supportive care. Treatment based on judgment of the physician in response to reactions of the patient.

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M A T E R I A L S A F E T Y D A T A S H E E T

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

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PRODUCT NAME: 1,1,1-TRICHLOROETHANE, INHIBITED

Effective Date: 03/20/88 Date Printed: 06/07/88

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8. HANDLING PRECAUTIONS:

EXPOSURE GUIDELINE(S): 1,1,1-Trichloroethane - OSHA standard is 350 ppm and current ACGIH TLV is 350 ppm (450 ppm STEL).

ACGIH TLV is 25 ppm (skin) for diethylene ether. OSHA PEL is 100 ppm (skin) for diethylene ether. Dow Industrial Hygiene Guide for 1,2-butylene oxide is 40 ppm (excursion 100 ppm). ACGIH TLV for nitromethane is 100 ppm.

VENTILATION: Control airborne concentrations below the exposure guideline. Use only with adequate ventilation. Local exhaust ventilation may be necessary for some operations. Lethal concentrations may exist in areas with poor ventilation.

RESPIRATORY PROTECTION: Atmospheric levels should be maintained below the exposure guideline. When respiratory protection is required for certain operations, use an approved air-purifying respirator. For emergency and other conditions where the exposure guideline may be greatly exceeded, use an approved positive pressure self-contained breathing apparatus. In confined or poorly ventilated areas, use an approved positive pressure self-contained breathing apparatus.

SKIN PROTECTION: For brief contact, no precautions other than clean body-covering clothing should be needed. When prolonged or frequently repeated contact could occur, use protective clothing impervious to this material. Selection of specific items such as gloves, boots, apron, or full body suit will depend on operation.

EYE PROTECTION: Use safety glasses. Where contact with liquid is likely, chemical goggles are recommended because eye contact with this material may cause pain, even though it is unlikely to cause injury.

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M A T E R I A L S A F E T Y D A T A S H E E T

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

Product Code: 08592 Page: 6

PRODUCT NAME: 1,1,1-TRICHLOROETHANE, INHIBITED

Effective Date: 03/20/88 Date Printed: 06/07/88 MSDS:001111

9. ADDITIONAL INFORMATION:

REGULATORY REQUIREMENTS:

SARA HAZARD CATEGORY: This product has been reviewed according to the EPA 'Hazard Categories' promulgated under Sections 311 and 312 of the Superfund Amendment and Reauthorization Act of 1986 (SARA Title III) and is considered, under applicable definitions, to meet the following categories:

An immediate health hazard

SPECIAL PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Handle with reasonable care. Avoid breathing vapors. Store in a cool dry place. Concentrated vapors of this product are heavier than air and will collect in low areas such as pits, degreasers, storage tanks, and other confined areas. Do not enter areas where vapors of this product are suspected unless special breathing apparatus is used and an observer is present for assistance.

1,1,1-Trichloroethane products should not be packaged in aluminum aerosol cans or with finely divided aluminum or its alloys in an aerosol can.

Aluminum is not an acceptable material of construction for pumps, mixers, fittings, storage tanks for 1,1,1-trichloroethane products or formulations. Metallic aluminum and zinc powders should be avoided. For additional information on toxicity, handling precautions, and first aid, refer to chlorinated solvents literature form no. 100-6170-87.

MSDS STATUS: Revised Section 9.

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M A T E R I A L S A F E T Y D A T A S H E E T

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

Product Code: 08592

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PRODUCT NAME: 1,1,1-TRICHLOROETHANE, INHIBITED

Effective Date: 03/20/88 Date Printed: 06/07/88

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MATERIAL SAFETY DATA SHEET

DOW CHEMICAL U.S.A. MIDLAND, MICHIGAN 48674 EMERGENCY (517) • 636 • 4400

Product Code: 87375

Page: 1

PRODUCT NAME: 1,1,1-TRICHLOROETHANE, FILM CLEANING GRADE

Effective Date: 03/20/88 Date Printed: 06/07/88

MSDS:000699

1. INGREDIENTS:

1,1,1-Trichloroethane CAS# 000071-55-6 99.9%

This document is prepared pursuant to the OSHA Hazard Communication Standard (29 CFR 1910.1200). In addition, other substances not 'Hazardous' per this OSHA Standard may be listed. Where proprietary ingredient shows, the identity may be made available as provided in this standard.

2. PHYSICAL DATA:

BOILING POINT: 165F (74C)
VAP PRESS: 100 mmHg @ 20C
VAP DENSITY: 4.55
SOL. IN WATER: 0.07 g/100 g @ 25C
SP. GRAVITY: 1.330-1.335 @ 25/25C
APPEARANCE: Colorless liquid.
ODOR: Irritating odor at high concentrations.

3. FIRE AND EXPLOSION HAZARD DATA:

FLASH POINT: None
METHOD USED: TOC, TCC, COC

FLAMMABLE LIMITS
LFL: 7.5% @ 25C
UFL: 15% @ 25C

EXTINGUISHING MEDIA: Water fog.

FIRE & EXPLOSION HAZARDS: Vapors of this solvent may develop a flammable atmosphere in confined areas.

FIRE-FIGHTING EQUIPMENT: Wear positive-pressure, self-contained

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M A T E R I A L S A F E T Y D A T A S H E E T

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

Product Code: 87375 Page: 2

PRODUCT NAME: 1,1,1-TRICHLOROETHANE, FILM CLEANING GRADE

Effective Date: 03/20/88 Date Printed: 06/07/88 MSDS:000699

3. FIRE AND EXPLOSION HAZARD DATA: (CONTINUED)

respiratory equipment.

4. REACTIVITY DATA:

STABILITY: (CONDITIONS TO AVOID) Autoignition temperature 998F (537C). Avoid open flames, welding arcs, or other high temperature sources which induce thermal decomposition.

INCOMPATIBILITY: (SPECIFIC MATERIALS TO AVOID) Water - slow hydrolysis produces corrosive acid. Avoid contact with or storage in aluminum and its alloys. Definitely avoid contact with metallic aluminum and zinc powders.

HAZARDOUS DECOMPOSITION PRODUCTS: Hydrogen chloride and very small amounts of phosgene and chlorine.

HAZARDOUS POLYMERIZATION: Will not occur.

5. ENVIRONMENTAL AND DISPOSAL INFORMATION:

ACTION TO TAKE FOR SPILLS/LEAKS: Small leaks: Mop up, wipe up, or soak up immediately. Remove to out-of-doors. Large spills: Evacuate area. Contain liquid; transfer to closed metal containers. Keep out of water supply.

DISPOSAL METHOD: When disposing of the unused contents, the preferred options are to send to licensed reclaimer, or to permitted incinerators. Any disposal practice must be in compliance with federal, state, and local regulations. Do not dump into sewers, on the ground, or into any body of water.

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M A T E R I A L S A F E T Y D A T A S H E E T

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

Product Code: 87375

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PRODUCT NAME: 1,1,1-TRICHLOROETHANE, FILM CLEANING GRADE

Effective Date: 03/20/88 Date Printed: 06/07/88

MSDS:000699

6. HEALTH HAZARD DATA:

EYE: May cause pain. May cause slight transient (temporary) irritation with slight transient corneal injury. Vapors may irritate eyes.

SKIN CONTACT: Prolonged or repeated exposure may cause skin irritation. Repeated contact may cause drying or flaking of skin.

SKIN ABSORPTION: A single prolonged skin exposure is not likely to result in absorption of harmful amounts. The LD50 for rabbits is about 15,000 mg/kg.

INGESTION: Single dose oral toxicity is low. The LD50 for rats is >10,000 mg/kg. If aspirated (liquid enters the lung), may be rapidly absorbed through the lungs and result in injury to other body systems.

INHALATION: In confined or poorly ventilated areas, vapors which readily accumulate can cause unconsciousness and death. Minimal anesthetic or narcotic effects may be seen in the range of 500-1000 ppm trichloroethane. Progressively higher levels over 1000 ppm may cause dizziness, drunkenness; concentrations as low as 10,000 ppm may cause unconsciousness and death. These high levels may also cause cardiac arrhythmias (irregular heartbeats).

SYSTEMIC & OTHER EFFECTS: Based on available data, repeated exposures are not anticipated to cause any significant adverse effects. 1,1,1-Trichloroethane and similar mixtures did not cause cancer in long-term animal studies. Birth defects are unlikely. Exposures having no adverse effects on the mother should have no effect on the fetus. In animal studies, has been shown not to interfere with reproduction. Results of in vitro ('test tube') mutagenicity tests on 1,1,1-trichloroethane have been negative. Results of mutagenicity

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APPENDIX

M A T E R I A L S A F E T Y D A T A S H E E T

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

Product Code: 87375

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PRODUCT NAME: 111-TRICHLOROETHANE, FILM CLEANING GRADE

Effective Date: 03/20/88 Date Printed: 06/07/88

MSDS:000699

6. HEALTH HAZARD DATA: (CONTINUED)

tests in animals have been negative.

7. FIRST AID:

EYES: Irrigate immediately with water for at least 5 minutes.

SKIN: Wash off in flowing water or shower. Remove contaminated clothing and wash before reuse.

INGESTION: Do not induce vomiting. Call a physician and/or transport to emergency facility immediately.

INHALATION: Remove to fresh air. If not breathing, give mouth-to-mouth resuscitation. If breathing is difficult, give oxygen. Call a physician.

NOTE TO PHYSICIAN: Because rapid absorption may occur through lungs if aspirated and cause systemic effects, the decision of whether to induce vomiting or not should be made by an attending physician. If lavage is performed, suggest endotracheal and/or esophageal control. Danger from lung aspiration must be weighed against toxicity when considering emptying the stomach. Exposure may increase "myocardial irritability". Do not administer sympathomimetic drugs unless absolutely necessary. No specific antidote. Supportive care. Treatment based on judgment of the physician in response to reactions of the patient.

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APPENDIX

M A T E R I A L S A F E T Y D A T A S H E E T

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

Product Code: 87375

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PRODUCT NAME: 1,1,1-TRICHLOROETHANE, FILM CLEANING GRADE

Effective Date: 03/20/88 Date Printed: 06/07/88

MSDS:000699

8. HANDLING PRECAUTIONS:

EXPOSURE GUIDELINE(S): ACGIH TLV and OSHA PEL are 350 ppm for 1,1,1-trichloroethane. ACGIH STEL is 450 ppm for 1,1,1-trichloroethane.

VENTILATION: Control airborne concentrations below the exposure guideline. Use only with adequate ventilation. Local exhaust ventilation may be necessary for some operations. Lethal concentrations may exist in areas with poor ventilation.

RESPIRATORY PROTECTION: Atmospheric levels should be maintained below the exposure guideline. When respiratory protection is required for certain operations, use an approved air-purifying respirator. For emergency and other conditions where the exposure guideline may be greatly exceeded, use an approved positive pressure self-contained breathing apparatus. In confined or poorly ventilated areas, use an approved positive pressure self-contained breathing apparatus.

SKIN PROTECTION: For brief contact, no precautions other than clean body-covering clothing should be needed. When prolonged or frequently repeated contact could occur, use protective clothing impervious to this material. Selection of specific items such as gloves, boots, apron, or full body suit will depend on operation.

EYE PROTECTION: Use safety glasses. Where contact with liquid is likely, chemical goggles are recommended because eye contact with this material may cause discomfort, even though it is unlikely to cause injury.

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APPENDIX

M A T E R I A L S A F E T Y D A T A S H E E T

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

Product Code: 87375

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PRODUCT NAME: 1,1,1-TRICHLOROETHANE, FILM CLEANING GRADE

Effective Date: 03/20/88 Date Printed: 06/07/88

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9. ADDITIONAL INFORMATION:

REGULATORY REQUIREMENTS:

SARA HAZARD CATEGORY: This product has been reviewed according to the EPA 'Hazard Categories' promulgated under Sections 311 and 312 of the Superfund Amendment and Reauthorization Act of 1986 (SARA Title III) and is considered, under applicable definitions, to meet the following categories:

An immediate health hazard

SPECIAL PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Handle with reasonable care. Avoid breathing vapors. Store in a cool dry place. Concentrated vapors of methyl chloroform, low stabilized - are heavier than air and will collect in low areas such as pits, degreasers, storage tanks, and other confined areas. Do not enter these areas where vapors of this product are suspected unless positive pressure self-contained breathing apparatus is used and an observer is present for assistance.

1,1,1-Trichloroethane products should not be packaged in aluminum aerosol cans or with finely divided aluminum or its alloys in an aerosol can.

Aluminum is not an acceptable material of construction for pumps, mixers, fittings, storage tanks for 1,1,1-trichloroethane products or formulations. Metallic aluminum and zinc powders should be avoided.

For additional information on toxicity, handling precautions, and first aid, refer to chlorinated solvents literature form no. 100-5792.

MSDS STATUS: Revised Section 9.

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M A T E R I A L S A F E T Y D A T A S H E E T

Dow Chemical U.S.A.* Midland, MI 48674 Emergency Phone: 517-636-4400

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