OCCUPATIONAL SAFETY AND HEALTH GUIDELINES FOR CHEMICAL HAZARDS

Supplement III–OHG

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health
Cincinnati, Ohio

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NOTE TO THE READER

This document is the third in a series of supplements to the 1981 Publication *NIOSH/OSHA Occupational Health Guidelines for Chemical Hazards* (Washington, DC: U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, DHHS [NIOSH] Publication No. 81-123). The two previous supplements are as follows:

1. *Occupational Safety and Health Guidelines for Chemical Hazards* (DHHS [NIOSH] Publication No. 88-118, Supplement I-OHG). This document contains 35 guidelines.

2. *Occupational Safety and Health Guidelines for Chemical Hazards* (DHHS [NIOSH] Publication No. 89-104, Supplement II-OHG). This document contains 30 guidelines.

The 50 guidelines presented here in the third supplement include 33 revisions of previously issued guidelines and 17 new guidelines. Readers should replace the outdated guidelines in the original 1981 publication with the revised guidelines provided here.

The 50 occupational safety and health guidelines presented here are being published to disseminate technical information about chemical hazards to workers, employers, and occupational safety and health professionals. Each guideline includes (1) data on the chemical name and synonyms, chemical and physical properties, exposure limits, and signs and symptoms of exposure, and (2) recommendations for medical monitoring, personal protective equipment, and control procedures.. These recommendations reflect good industrial hygiene and medical monitoring practices, and their implementation should help employers to achieve sound occupational health programs.

The recommendations and information in these guidelines may be superseded as new information becomes available; readers should therefore regard these recommendations as general guidelines and should not rely on them for achieving compliance with occupational safety and health regulations.

The first two supplements to the original guidelines can be ordered from the Superintendent of Documents (U.S. Government Printing Office, Washington, DC 20402-9325) or from the National Technical Information Service (5285 Port Royal Road, Springfield, VA 22161 [telephone: 703-487-4650]). The original three-volume set of guidelines is available only from the National Technical Information Service (NTIS). The stock numbers for the U.S. Government Printing Office (GPO) and NTIS are as follows:

Publication	*GPO No.*	*NTIS No.*
Volumes I, II, III (DHHS [NIOSH] Publication No. 81-123)	——	PB 83-154609
Supplement I-OHG (DHHS [NIOSH] Publication No. 88-118)	017-033-00439-1	PB 89-203129
Supplement II-OHG (DHHS [NIOSH] Publication No. 89-104)	017-033-00441-2	PB 89-203137

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ACETALDEHYDE

INTRODUCTION

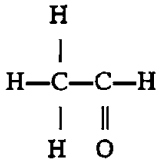
This guideline summarizes pertinent information about acetaldehyde for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

CH_3CHO

- **Structure**



- **Synonyms**

Acetic aldehyde, ethanal, acetylaldehyde, ethyl aldehyde

- **Identifiers**

1. CAS No.: 75-07-0
2. RTECS No.: AB1925000
3. DOT UN: 1089 26
4. DOT label: Flammable Liquid

- **Appearance and odor**

Acetaldehyde is a colorless, flammable, volatile liquid or gas (above 69°F) with a pungent, fruity odor detectable at low concentrations. The odor threshold is reported to be between 0.05 and 2.3 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 44.1
2. Boiling point (at 760 mm Hg): 21°C (69.8°F)
3. Specific gravity (water = 1): 0.79 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of acetaldehyde): 1.5
5. Melting point: -123.5°C (-190.3°F)
6. Vapor pressure at 20°C (68°F): 740 mm Hg
7. Solubility: Miscible with water, alcohol, ether, acetone, benzene, gasoline, solvent naphtha, toluene, turpentine, and xylene
8. Evaporation rate (ether = 1): 3

- **Reactivity**

1. Conditions contributing to instability: Contact of acetaldehyde with air may cause the formation of explosive peroxides, and contact of this substance with heat or flame may cause fires or explosions. Contact with trace metals or alkaline materials may cause acetaldehyde to undergo hazardous polymerization.

2. Incompatibilities: Fire and explosion may result from contact of acetaldehyde with strong oxidizers. Acetaldehyde reacts vigorously with acid anhydrides, alcohols, anhydrous ammonia, amines, ketones, phenols, hydrogen cyanide, hydrogen sulfide, halogens, phosphorus, isocyanates, and strong alkalies.

3. Hazardous decomposition products: Toxic gases (such as carbon monoxide and methane) may be released in a fire involving acetaldehyde.

4. Special precautions: Liquid acetaldehyde attacks some coatings and some forms of plastic and rubber.

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• **Flammability**

The National Fire Protection Association has assigned a flammability rating of 4 (extreme fire hazard) to acetaldehyde.

1. Flash point: -37.8°C (-36°F) (closed cup)

2. Autoignition temperature: 175°C (347°F)

3. Flammable limits in air (% by volume): Lower, 4.0; upper, 60.0

4. Extinguishant: Use dry chemical, carbon dioxide, or alcohol foam to fight fires involving acetaldehyde. Water may be ineffective, but it may be used to keep fire-exposed containers cool and to protect persons attempting to stop the leak. If a leak or spill of acetaldehyde has not ignited, water spray may be used to disperse vapors.

Fires involving acetaldehyde should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of acetaldehyde may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving acetaldehyde. Firefighters' protective clothing may provide limited protection against fires involving acetaldehyde.

EXPOSURE LIMITS

• **OSHA PEL**

The current Occupational Safety and Health Adminstration (OSHA) permissible exposure limit (PEL) for acetaldehyde is 100 ppm (180 mg/m^3) as an 8-hr TWA concentration and 150 ppm (270 mg/m^3) as a short-term exposure limit (STEL). A STEL is a 15-min TWA exposure which should not be exceeded at any time during the working day [29 CFR 1910.1000, Table Z-1-A].

• **NIOSH REL**

The National Institute for Occupational Safety and Health (NIOSH) considers acetaldehyde to be a potential occupational carcinogen and recommends exposures be controlled to the lowest feasible limit [NIOSH 1992].

• **ACGIH TLV®**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned an acetaldehyde threshold limit value (TLV) of 100 ppm (180 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek and a STEL of 150 ppm (270 mg/m^3) for periods not to exceed 15 min [ACGIH 1991b].

• **Rationale for limits**

The OSHA and ACGIH limits are based on the risk of conjunctivitis and sensory irritation of the respiratory tract associated with exposure to acetaldehyde. The NIOSH limit is based on positive carcinogenic results in animal studies.

HEALTH HAZARD INFORMATION

• **Routes of exposure**

Exposure to acetaldehyde can occur through inhalation, ingestion, or contact with the eyes, skin, or mucous membranes.

• **Summary of toxicology**

1. *Effects on Animals*: Acetaldehyde is an irritant of the eyes, mucous membranes, and upper respiratory tract in animals; at high concentrations, it is a central nervous system depressant. Acetaldehyde has caused squamous cell carcinomas and adenocarcinomas of the nasal cavity in rats and hamsters; it is also embryotoxic and teratogenic in several species of animals. Acetaldehyde causes severe irritation when applied to the eyes of rabbits; it causes mild irritation in contact with skin [NIOSH 1991]. In rats, the oral LD_{50} is 661 mg/kg, and the LC_{50} is 37 g/m^3 (20,550 ppm) for 30 min [NIOSH 1991]. Cats exposed to 380 ppm for 7 hr showed no effects; but increasing the concentration to 1,520 ppm caused signs of respiratory tract irritation [ACGIH 1991a]. Rats exposed to concentrations ranging from 400 to 5,000 ppm for 6 hr/day, 5 days/week for 4 weeks showed slight degeneration of the nasal epithelium at 400 ppm, and growth retardation, increased urinary output (in males only), and slight-to-moderate degeneration (with or without hyperplasia and metaplasia) of the nasal epithelium at 1,000 or 2,200 ppm [IARC 1985]. The rats exposed to 5,000 ppm showed severe growth retardation, increased neutrophil counts, reduced urine volumes, increased lung weights, and severe degenerative hyperplasia and metaplasia of the nasal, laryngeal, and tracheal epithelium [NLM 1992]. Hamsters were exposed to acetaldehyde concentrations ranging from 390 to 4,560 ppm for 6 hr/day, 5 days/week for 90 days. At the lowest concentration, these animals showed no toxic effects; at the highest concentration, however, they showed signs of eye and nose irritation, growth retardation, and erythrocytosis. At autopsy, these high-dose animals showed

increased kidney and heart weights and severe histopathologic changes of the respiratory epithelium [IARC 1985]. Fetal malformations (facial and cranial), digital anomalies, and embryonic deaths (resorptions) occurred in the offspring of rats and mice from dams treated with acetaldehyde during pregnancy [IARC 1985]. Acetaldehyde has been tested for carcinogenicity in rats by inhalation and in hamsters by inhalation and intratracheal administration. In rats, inhalation of acetaldehyde caused a statistically significant increase in the incidence of nasal adenocarcinomas and squamous cell carcinomas of the lungs. In hamsters, inhalation caused a significant increase in the incidence of laryngeal carcinoma, and intratracheal injections resulted in the induction of "peribronchiolar adenomated lesions," which were apparently not classified as tumors. The International Agency for Research on Cancer (IARC) has concluded that there is sufficient evidence for the carcinogenicity of acetaldehyde in animals [IARC 1987]. Acetaldehyde is mutagenic in bacterial and mammalian test systems with and without activation [NIOSH 1991].

2. *Effects on Humans*: Acetaldehyde is an irritant of the eyes, mucous membranes, skin, and upper respiratory tract, and it is a central nervous system depressant in humans. On the basis of effects seen in animals, acetaldehyde is a potential carcinogen in humans. Although sensitive individuals experienced irritation when exposed to 25 ppm for 15 min, most unacclimated human volunteers exposed to 50 ppm experienced mild eye irritation, and all subjects exposed to 200 ppm developed conjunctivitis [Proctor et al. 1988]. Upper respiratory tract irritation was reported at a vapor concentration of 134 ppm [Proctor et al. 1988]. Eye contact with liquid acetaldehyde causes a burning sensation and superficial corneal injury; exposure to concentrations above 50 ppm may cause persistent tearing, photophobia, and injury to the corneal epithelium [Grant 1986]. Acetaldehyde causes erythema when splashed on the skin; if contact is repeated or prolonged, this substance may cause dermatitis or skin burns [Proctor et al. 1988]. A study of East German workers exposed to acetaldehyde and other chemicals in a chemical factory showed an increase in the number of cancers of the bronchial tubes and oral cavity. However, IARC has concluded that the results of this study are inconclusive because the workers were exposed to other chemicals and only a small, poorly defined population was involved [IARC 1987].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to acetaldehyde can cause irritation of the eyes with burning, conjunctivitis, tearing, blurred vision, and photophobia; irritation and burning of the nose with rhinorrhea; and irritation of the upper respiratory tract with pain and coughing. Exposure to high levels of this substance may cause headache, drowsiness, dizziness, excitement, and agitation, followed by narcosis or stupor, pulmonary edema, and possibly death resulting from respiratory failure; however, ingestion can also induce nausea, vomiting, and diarrhea. Skin contact may cause dermatitis and burns of the exposed area.

2. *Chronic exposure*: Chronic exposure to acetaldehyde can cause conjunctivitis, coughing, difficult breathing, and dermatitis. On the basis of effects seen in animals, chronic exposure to acetaldehyde may cause heart and kidney damage, embryotoxicity, teratogenic effects, and possibly cancer in humans.

- **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of acetaldehyde. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of acetaldehyde are inhaled, move the victim to fresh air ***immediately.***

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if acetaldehyde or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve acetaldehyde and may result in worker exposures to this substance:

—Synthesis of acetic acid, acetic anhydride, acrolein, aldol, butanol, butylene glycol, chloral, crotonaldehyde, 2-ethylhexanol, metaldehyde, paraldehyde, pentaerythritol, peracetic acid, pyridines, and trimethylolpropane

—Manufacture of synthetic resins, aniline dyes, herbicides, fungicides, other pesticides, explosives, and pharmaceuticals

—Synthesis of rubber processing chemicals, disinfectants, cosmetics, and perfumes

—Use of acetaldehyde in silvering mirrors and as an alcohol denaturant

—Use of acetaldehyde as a hardening agent in photography and in the manufacture of gelatin, glue, lacquers, varnishes, and casein products

—Use of acetaldehyde as a flavoring agent and additive in milk products and candies and as a preservative for food and leather

The following methods are effective in controlling worker exposures to acetaldehyde, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

• Preplacement medical evaluation

Before a worker is placed in a job with a potential for exposure to acetaldehyde, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory tract. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to acetaldehyde at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with eye, skin, and respiratory tract diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to acetaldehyde exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of acetaldehyde on the eyes, skin, and respiratory tract. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissue or fluids to provide an index of exposure to a toxic substance or metabolite. Acetaldehyde can be detected in the blood, urine, and breath of exposed individuals. However, aldehyde concentrations in these biological specimens have not been correlated with airborne concentrations of this substance. Therefore, no biological monitoring method acceptable for routine use has yet been developed for acetaldehyde.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population. Because occupational exposure to acetaldehyde may cause diseases with prolonged latent periods, the need for medical monitoring may extend well beyond the termination of employment.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne acetaldehyde is determined by using a silane-treated glass tube that is packed with a 225-mg backup section and a 450-mg sampling section of pretreated XAD-2 adsorbent coated with 10% (by weight) 2-(hydroxymethyl)piperidine. Samples are collected at a maximum flow rate of 0.05 liter/min until a maximum air volume of 3 liters is collected (8-hr TWA), or they are collected at a maximum flow rate of 0.05 liter/min until a maximum air volume of 0.75 liter is collected (STEL). Analysis is conducted by gas chromatography using a nitrogen/phosphorus detector. The limit of detection for this procedure is 580 parts per billion. This method is described in the OSHA Computerized Information System [OSHA 1990]. A similar method for sampling and analyzing acetaldehyde is included in Method 2538 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If acetaldehyde contacts the skin, workers should immediately flush the affected areas with large amounts of water and then wash with soap and water.

Clothing and shoes contaminated with acetaldehyde should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of acetaldehyde, particularly its potential for causing skin or eye burns on prolonged contact.

A worker who handles acetaldehyde should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where acetaldehyde or a solution containing acetaldehyde is handled, processed, or stored.

STORAGE

Acetaldehyde should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Bulk quantities of acetaldehyde should be stored outside in detached, refrigerated tanks that conform to the requirements of the hazard communication standard. Storage in an inert gas atmosphere is recommended. Only nonsparking tools and equipment should be used to handle this OSHA Class IA flammable liquid. Containers of acetaldehyde should be protected from physical damage and should be stored separately from alkaline materials, acids, halogens, alcohols, ammonia, amines, ketones, hydrogen sulfide, hydrogen cyanide, acid anhydrides, phenols, oxidizing agents, and all ignition sources. All electrical service in storage areas should be of explosionproof design. To prevent static sparks, containers and equipment used to transfer acetaldehyde should be electrically grounded and bonded. Because empty containers may contain acetaldehyde residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving acetaldehyde, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete.

The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.

2. Notify safety personnel.

3. Remove all sources of heat and ignition.

4. Provide maximum explosionproof ventilation to ventilate area of leak or spill.

5. Use nonsparking tools during cleanup.

6. Use water spray to flush spills away from workers and to dilute the spill.

7. Absorb small liquid spills with paper towels, vermiculite, or sand and place the material in a covered container for later disposal.

8. For large liquid spills, build dikes far ahead of the spill to contain the acetaldehyde for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Acetaldehyde is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is above the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal authorities.

The reportable quantity for acetaldehyde is 1,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center *immediately* at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of acetaldehyde per calendar year are required by EPA [49 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of acetaldehyde emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Acetaldehyde is listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [42 USC 6901 et seq.] and has been assigned EPA Hazardous Waste No. U001. This substance has been banned from land disposal and may be treated by fuel substitution or incineration. Acetaldehyde may also be disposed of in an organometallic or organic lab pack that meets the requirements of 40 CFR 264.316 or 265.316.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of acetaldehyde are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of acetaldehyde exceeds

prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Gloves and protective clothing should be worn to prevent skin contact with acetaldehyde. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been tested against permeation by acetaldehyde and have demonstrated good-to-excellent resistance: Teflon®, butyl rubber, and polyethylene/ethylene vinyl alcohol. Butyl rubber may provide more than 8 hr of resistance to permeation by acetaldehyde. Natural rubber, neoprene, nitrile rubber, polyethylene, polyvinyl alcohol, polyvinyl chloride, and Viton® have demonstrated poor resistance to permeation by acetaldehyde.

If acetaldehyde is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Splashproof safety glasses, goggles, or face shields should be worn during operations in which there is any possibility of eye contact with acetaldehyde. Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with this substance. Contact lenses should not be worn if the potential exists for acetaldehyde exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ACETIC ACID

INTRODUCTION

This guideline summarizes pertinent information about acetic acid for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_2H_4O_2$

- **Structure**

CH_3COOH

- **Synonyms**

Ethanoic acid, ethylic acid, glacial acetic acid, methanecarboxylic acid, vinegar acid

- **Identifiers**

1. CAS No.: 64-19-7

2. RTECS No.: AF1225000

3. DOT UN: 2789 29 (glacial acetic acid or acetic acid solutions that are more than 80% acid); DOT UN: 2790 60 (aqueous solutions that are more than 10% but not more than 80% acid)

4. DOT labels: Corrosive, Flammable Liquid (glacial acetic acid or acetic acid solutions that are more than 80% acid); Corrosive (aqueous solutions that are more than 10% but not more than 80% acid)

- **Appearance and odor**

At temperatures above 16.7°C (62°F), acetic acid is a clear, colorless, combustible liquid with a pungent, vinegarlike odor. The odor threshold is reported to be between 0.21 and 1.0 parts per million (ppm) parts of air. This substance is available commercially in strengths ranging from 6% to more than 99% acid, by weight. Glacial acetic acid is 99.4% acid.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data (glacial acetic acid)**

1. Molecular weight: 60.1

2. Boiling point (at 760 mm Hg): 118°C (244.4°F)

3. Specific gravity (water = 1): 1.05 at 20°C (68°F)

4. Vapor density (air = 1 at boiling point of acetic acid): 2.1

5. Melting point: 16.7°C (62°F)

6. Vapor pressure at 20°C (68°F): 11 mm Hg

7. Solubility: Miscible with water, alcohol, glycerol, carbon tetrachloride, and ether; insoluble in carbon disulfide

8. Evaporation rate (butyl acetate = 1): 1.0

- **Reactivity**

1. Conditions contributing to instability: Heat and freezing temperatures. The vapor of acetic acid forms explosive mixtures with air.

2. Incompatibilities: Fires or explosions may result from contact of acetic acid with chromic acid, ammonium nitrate, sodium peroxide, nitric acid, phosphorus trichloride, or other oxidizers.

3. Hazardous decomposition products: Toxic gases (such as carbon dioxide and carbon monoxide) may be released when acetic acid is heated to decomposition.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

4. Special precautions: Acetic acid is highly corrosive in concentrated form; it corrodes metals, some coatings, and some forms of plastic and rubber.

- **Flammability (glacial acetic acid)**

The National Fire Protection Association has assigned a flammability rating of 2 (moderate fire hazard) to glacial acetic acid.

1. Flash point: 39°C (103°F) (closed cup). The flash point of concentrated solutions of acetic acid approaches that of glacial acetic acid; dilute acetic acid solutions are not combustible.

2. Autoignition temperature: 427°C (800°F). Dilute acetic acid solutions are not combustible.

3. Flammable limits in air (% by volume): Lower, 4.0; upper, 16.0

4. Extinguishant: Use water spray, dry chemical, alcohol foam, or carbon dioxide to fight fires involving acetic acid. Use water spray to keep fire-exposed containers cool. If a leak or spill has not ignited, water may be used to disperse vapors and to protect persons attempting to stop the leak.

Fires involving acetic acid should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of acetic acid may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving acetic acid. Firefighters' protective clothing may not provide protection against permeation by acetic acid.

EXPOSURE LIMITS

- **OSHA PEL**

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for acetic acid is 10 ppm of air (25 mg/m^3) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

- **NIOSH REL**

The National Institute for Occupational Safety Health (NIOSH) has established a recommended exposure limit (REL) of 10 ppm (25 mg/m^3) as an 8-hr TWA and 15 ppm (37 mg/m^3) as a short-term exposure limit (STEL). A STEL is a 15-min TWA exposure that should not be exceeded at any time during a workday [NIOSH 1992].

- **ACGIH TLV®**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned acetic acid a threshold limit value (TLV) of 10 ppm (25 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek and a STEL of 15 ppm (37 mg/m^3) for periods not to exceed 15 min [ACGIH 1991b].

- **Rationale for limits**

The limits are based on the risk of irritation to the eyes, nose, and respiratory tract associated with exposure to acetic acid.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Exposure to acetic acid can occur through inhalation, ingestion, eye or skin contact, and absorption through the skin.

- **Summary of toxicology**

1. *Effects on Animals*: Glacial acetic acid is corrosive to tissues, and concentrated acetic acid solutions (greater than 80% acid) can cause moderate to severe burns. Exposure to the vapors of acetic acid causes eye, skin, mucous membrane, and upper respiratory tract irritation.

When applied to the skin of guinea pigs, acetic acid solutions of 80% or more caused severe burns; concentrations of 50% to 80% caused moderate to severe burns; concentrations of less than 50% caused relatively minor skin damage; and solutions of 10% or less caused no injury [Proctor et al. 1988]. When glacial acetic acid was applied to the eyes of rabbits, it caused immediate and complete destruction; splashes of less concentrated solutions caused less damage [Grant 1986]. The dermal LD_{50} for rabbits was 1,060 mg/kg [NIOSH 1991]. When acetic acid was inhaled, the lowest LC_{50} for mice and guinea pigs exposed for 1 hr was approximately 5,000 ppm [NLM 1991]. Guinea pigs exposed for 1 hr to airborne acetic acid concentrations ranging from 5 to 500 ppm showed an increase in pulmonary flow resistance, a decrease in lung compliance, and an increase in the time constant of the lungs and minute volume [Amdur 1961]. At concentrations above 100 ppm, guinea pigs also showed labored breathing and a decrease in respiratory rate [Amdur 1961]. Mice exposed to acetic acid vapor at approximately

1,000 ppm showed signs of conjunctival and upper respiratory tract irritation [Clayton and Clayton 1981]. The oral LD_{50} in rats was 3,530 mg/kg [NIOSH 1991].

2. *Effects on Humans*: In vapor form, acetic acid is a severe irritant of the eyes, mucous membranes, upper respiratory tract, and skin. In contact with the skin or eyes, acetic acid solutions of 80% or more can be corrosive, causing severe burns of any exposed tissue. Long-term exposure to the vapors of this substance causes chronic bronchitis and other respiratory effects, erosion of tooth enamel, and cracking and darkening of the exposed skin.

When splashed into the eye, glacial acetic acid has caused permanent corneal opacity; skin contact with glacial acetic acid causes burns and tissue destruction [NLM 1991; AIHA 1978]. Ingestion of corrosive concentrations can cause tissue destruction, perforation, and stricture (delayed) of the throat, esophagus, and stomach; intestinal hemorrhage; and heart and renal damage [NLM 1991]. Unacclimatized individuals have experienced eye irritation at concentrations below 10 ppm, tolerable irritation at 25 ppm, and intolerable eye, nose, and throat irritation at 50 ppm [Proctor et al. 1988]. Exposure at 800 to 1,200 ppm becomes intolerable within 3 min of exposure [ACGIH 1991a]. Five workers who had been exposed to acetic acid vapor at 80 to 200 ppm for 7 to 12 years had thickening and blackening of the skin on the hands, eye inflammation, dental erosion (of both canines and incisors), and chronic pharyngitis and bronchitis [Proctor et al. 1988].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to acetic acid vapor can cause redness, inflammation, lacrimation, runny nose, sore throat, coughing, bronchitis, pulmonary edema, labored breathing, and dyspnea. Death can result from circulatory collapse, renal failure, or glottic edema. Skin contact with concentrated solutions of acetic acid produces redness, blistering, and deep burns; these signs may be delayed for as long as 4 hr after contact. Eye contact with concentrated solutions of acetic acid causes immediate pain and tearing, redness, photophobia, and corneal opacities; if the exposure is severe, vision may be permanently impaired. In addition, ingestion can produce throat, esophageal, and gastric irritation, corrosion, stricture, and perforation; nausea; vomiting; diarrhea; hemorrhage; and shock.

2. *Chronic exposure*: Acetic acid vapors can cause sore throat, coughing, difficult breathing, decrements in pulmonary function, and erosion of the enamel on the incisors and canine teeth. Skin sensitization has rarely been reported. Long-term exposure of the skin to acetic acid vapor may cause it to darken, thicken, and crack.

- **Emergency procedures**

WARNING!

Transport victims immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Tissue destruction and blindness may result from exposure to concentrated solutions, vapors, mists, or aerosols of acetic acid! ***Immediately but gently*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Severe burns and skin corrosion may result! ***Immediately*** remove all contaminated clothing! ***Immediately and gently*** wash skin for at least 15 min. Use soap and water if skin is intact; use only water if skin is not intact.

3. *Inhalation exposure*: If vapors, mists, or aerosols of acetic acid are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if acetic acid or a solution containing it is ingested:

—Do ***not*** induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water. Immediately after rinsing, have the victim drink one cup (8 oz) of fluid and ***no more***.

—Do ***not*** permit the victim to drink milk or carbonated beverages!

—Do ***not*** permit the victim to drink any fluid if more than 60 min have passed since initial ingestion.

NOTE: These instructions must be followed exactly. Drinking a carbonated beverage or more than one cup of fluid could create enough pressure to perforate already damaged stomach tissue. The tissue-coating action of milk can sometimes impede medical assessment of tissue damage. Ingestion of any fluid more than 60 min after initial exposure could further weaken damaged tissue and result in perforation.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures

(e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve acetic acid and may result in worker exposures to this substance:

—Production of cellulose acetate, vinyl acetate, inorganic acetates, organic acetates (esters), acetic anhydride, chloroacetic acid, ethyl alcohol, ketene, methyl ethyl ketone, acetone, acetanilide, and acetyl chloride

—Use of acetic acid in the dyeing, pharmaceutical, canning, fermentation, and food-preserving industries; in pigment production; and in the tanning of rubber

—Use of acetic acid as a solvent in the liquid-phase oxidation of p-xylene to terephthalic acid, as a fungicide, and as an insecticide

—Use of acetic acid in the production of plastics and photographic chemicals, as a natural latex coagulant, as an oil-well acidizer, in textile printing, as a laundry sour (neutralizer), and as a solvent for gums, resins, volatile oils, and other substances

—Use of acetic acid in the manufacture of Paris green, white lead, and rinse and stain removers

The following methods are effective in controlling worker exposures to acetic acid, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

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5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety and health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to acetic acid, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, teeth, and respiratory tract. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to acetic acid at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with keratoconjunctivitis or other eye disorders, skin allergies or other skin disorders, erosion of tooth enamel, or respiratory disorders.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employ-

ment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to acetic acid exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of acetic acid on the eyes, skin, teeth, and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissue or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for acetic acid.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne acetic acid is determined by using coconut shell charcoal tubes (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 1.0 liter/min until a maximum air volume of 270 liters is collected. Analysis is conducted by gas chromatography using a flame photometric detector. The limit of detection for this procedure is 0.01 mg/sample. This method is an OSHA modification of Method 1603 from the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

Acetic acid can be absorbed through the skin in toxic amounts, and concentrated solutions of this substance can also cause skin burns. Therefore, if acetic acid contacts the skin, workers should immediately rinse the affected areas with large amounts of water for a minimum of 15 min.

Clothing and shoes contaminated with acetic acid should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the corrosive properties of acetic acid.

A worker who handles acetic acid should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where acetic acid is handled, processed, or stored.

STORAGE

Acetic acid should be stored in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. The storage area should be detached and should be well-ventilated and have acid-resistant floors. The temperature of the storage area should be maintained above 16.7°C (62°F) to prevent rupturing of the containers. Electrical fixtures in the storage area should be vaporproof, and any tools used should be of the nonsparking type. Containers of acetic acid should be protected from physical damage and should be stored separately from oxidizing agents, combustible materials, heat, sparks, and open flame. Because empty containers may contain acetic acid residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving acetic acid, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. If the vapor from the spill has not ignited, use water spray to reduce the vapors and to protect workers attempting to stop the leak.
6. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.
7. For large liquid spills, build dikes far ahead of the spill to contain the acetic acid for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Acetic acid is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is equal to or greater than the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal authorities.

The reportable quantity for acetic acid is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of acetic acid emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although acetic acid is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 CFR 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of acetic acid exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Gloves and protective clothing should be worn to prevent any possibility of skin contact with acetic acid. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been recommended for use against permeation by acetic acid and may provide protection

for periods greater than 8 hr: butyl rubber, Teflon®, and Saranex®. Materials that may withstand permeation for more than 4 but fewer than 8 hr are neoprene, polyethylene, and polyethylene/ethylene vinyl alcohol. Natural rubber, polyvinyl chloride, and Viton® demonstrated questionable protection against permeation by acetic acid. Nitrile rubber and polyvinyl alcohol have demonstrated poor resistance to permeation by acetic acid.

If acetic acid is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which acetic acid might contact the eyes (e.g., through splashes of solution). Splashproof, gas-tight goggles may also be required to prevent irritation of the eyes from acetic acid vapor. Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with acetic acid. Contact lenses should not be worn if the potential exists for acetic acid exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ACETIC ANHYDRIDE

INTRODUCTION

This guideline summarizes pertinent information about acetic anhydride for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_4H_6O_3$

- **Structure**

$(CH_3CO)_2O$

- **Synonyms**

Acetanhydride, acetic acid anhydride, acetyl ether, acetic oxide, acetyl oxide, ethanoic anhydride

- **Identifiers**

1. CAS No.: 108-24-7
2. RTECS No.: AK1925000
3. DOT UN: 1715 39
4. DOT labels: Corrosive, Flammable Liquid

- **Appearance and odor**

Acetic anhydride is a colorless liquid with a strong, pungent, vinegarlike odor. The odor threshold is reported to be between 0.13 and 0.34 part per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 102.1
2. Boiling point (at 760 mm Hg): 139°C (282°F)
3. Specific gravity (water = 1): 1.08 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of acetic anhydride): 3.5
5. Melting point: −73°C (−99.4°F)
6. Vapor pressure at 20°C (68.8°F): 4 mm Hg
7. Solubility: Soluble in cold water; decomposes in hot water to form acetic acid; miscible with alcohol, chloroform, ether, and ethyl acetate
8. Evaporation rate (butyl acetate = 1): 0.46

- **Reactivity**

1. Contact of acetic anhydride vapors with water or air should be avoided.
2. Incompatibilities: Fires and explosions may result from contact of acetic anhydride with water, alcohols, strong oxidizers, chromic acid, amines, or strong caustics.
3. Hazardous decomposition products: Toxic gases and vapors (such as carbon dioxide, carbon monoxide, various hydrocarbons, and acid aerosols) may be released when acetic anhydride is heated or decomposes.
4. Special precautions: Acetic anhydride attacks some coatings and some forms of plastic and rubber. It is corrosive to iron, steel, and other metals.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 2 (moderate fire hazard) to acetic anhydride.

1. Flash point: 49°C (120°F) (closed cup)
2. Autoignition temperature: 316°C (600°F)
3. Flammable limits in air (% by volume): Lower, 2.7; upper, 10.3

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4. Extinguishant: Use carbon dioxide or dry chemical for small fires and alcohol foam for large fires. Water should be used with caution because acetic anhydride reacts with water.

Fires involving acetic anhydride should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of acetic anhydride may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Avoid directing water into containers of acetic anhydride. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving acetic anhydride. Chemical protective clothing that is specifically recommended for acetic anhydride may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by acetic anhydride.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for acetic anhydride is 5 ppm (20 mg/m^3) as a ceiling limit which should not be exceeded during any part of the workday [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 5 ppm (20 mg/m^3) as a ceiling limit [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned acetic anhydride a ceiling limit value of 5 ppm (21 mg/m^3), which should not be exceeded during any part of the working exposure [ACGIH 1991a].

• Rationale for limits

The limits are based on the risk of ocular and respiratory irritation associated with high short-term exposure to acetic anhydride.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to acetic anhydride can occur through inhalation, ingestion, and eye or skin contact. Acetic anhydride also penetrates the skin.

• Summary of toxicology

1. *Effects on Animals*: Acetic anhydride is highly corrosive and causes severe irritation and burns of the eyes, mucous membranes, and skin of exposed animals. When instilled into the eyes, acetic anhydride can be corrosive. It can also penetrate the intact corneal epithelium in concentrations sufficiently high to cause iritis [NLM 1992]. Guinea pigs repeatedly challenged with dermal applications of acetic anhydride developed skin sensitization [Proctor et al. 1988]. The dermal LD_{50} for rabbits is 4,000 mg/kg [NIOSH 1991]. Rats survived exposure to saturated vapors for 5 min [Deichmann and Gerade 1969]. Six rats exposed to 1,000 ppm of acetic anhydride for 4 hr survived, but those inhaling 2,000 ppm for the same interval died [ACGIH 1991b]. The oral LD_{50} for rats is 1,780 mg/kg.

2. *Effects on Humans*: Exposure to acetic anhydride in either the liquid or vapor form causes severe irritation of the eyes, skin, and mucous membranes in humans. Eye contact can lead to corneal burns, erosion, edema, scarring, cataracts with temporary or permanent visual impairment, and inflammation and structural damage of the iris [Grant 1986; Klaassen et al.1986]. In contact with the skin, acetic anhydride causes delayed burns that may be slow to heal [Grayson 1985; Sittig 1985]. The vapor of this substance is reported to be irritating even at a concentration as low as 0.09 ppm [NLM 1992]. Workers exposed to concentrations of acetic anhydride greater than 5 ppm experienced acute eye and upper respiratory tract irritation; their symptoms included severe eye pain and difficult breathing [Proctor et al. 1988]. Inhalation of high concentrations of this substance can cause bronchospasm and ulceration of the nasal mucosa [Proctor et al. 1988]. Humans exposed to the vapor of acetic anhydride occasionally become sensitized to this substance [Proctor et al. 1988]. Ingestion of acetic anhydride can cause corrosion of oral, esophageal, and gastric tissues as well as hemorrhages, strictures, and stenoses but rarely perforations [NLM 1992].

• Signs and symptoms of exposure

1. *Acute exposure*: Acetic anhydride is corrosive to tissues. It can cause a burning sensation in the nose and throat, cough, pain in the chest, difficult breathing, dyspnea, and pulmonary edema. Exposure of the eye to liquid or vaporous acetic anhydride results in excessive tearing, redness, pain, and photophobia. In contact with the skin, acetic anhydride can cause corrosion, burns, and blisters. Ingestion can also induce clammy skin, weak and rapid pulse, nausea, vomiting,

shallow respiration, and decreased urine output. In cases where circulatory collapse has occurred and gone uncorrected for several hours, renal failure and ischemic liver and heart lesions have resulted. Death following ingestion can result from glottic edema or circulatory shock.

2. *Chronic exposure*: Acetic anhydride can cause conjunctivitis, pulmonary edema with coughing and difficult breathing, and skin sensitization with redness, itching, and wheals.

- **Emergency procedures**

> **WARNING!**
>
> **Transport victims immediately to emergency medical facility!**

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Tissue destruction and blindness may result from exposure to concentrated solutions, vapors, mists or aerosols of acetic anhydride! ***Immediately but gently*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Severe burns and skin corrosion may result! ***Immediately*** remove all contaminated clothing! ***Immediately and gently*** wash skin for at least 15 min. Use soap and water if skin is intact; use only water if skin is not intact.

3. *Inhalation exposure*: If vapors, mists, or aerosols of acetic anhydride are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if acetic anhydride or a solution containing it is ingested:

—Do ***not*** induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water. Immediately after rinsing, have the victim drink one cup (8 oz) of fluid and ***no more***.

—Do ***not*** permit the victim to drink milk or carbonated beverages!

—Do ***not*** permit the victim to drink any fluid if more than 60 min have passed since initial ingestion.

NOTE: These instructions must be followed exactly. Drinking a carbonated beverage or more than one cup of fluid could create enough pressure to perforate already damaged stomach tissue. The tissue-coating action of milk may impede medical assessment of tissue damage. Ingestion of any fluid more than 60 min after initial exposure could further weaken damaged tissue and result in perforation.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve acetic anhydride and may result in worker exposures to this substance:

—Manufacture of acetyl compounds, cellulose acetate, cellulose esters, chloroacetic acid, acetyl chloride, triacetate fibers, and vinyl acetate

—Processing of dyes, perfumes, explosives, and flavorings

—Electropolishing of metals and processing of semiconductors

—Use of acetic anhydride as an acetylizer and solvent in examining wool fat, glycerol, fatty and volatile oils, and resins, and in detecting rosins

—Use of acetic anhydride as a dehydrating agent in nitrations, sulfonations, and other reactions where removal of water is necessary

—Use of acetic anhydride in the manufacture of pharmaceuticals, including aspirin, and as an intermediate in the synthesis of pesticides

—Use of acetic anhydride as an esterifying agent for food starch

The following methods are effective in controlling worker exposures to acetic anhydride, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations must be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to acetic anhydride, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to acetic anhydride at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with eye, skin, or respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to acetic anhydride exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of acetic anhydride on the eyes, skin, and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for acetic anhydride.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne acetic anhydride is determined by using a standard midget bubbler containing 10 ml of alkaline hydroxylamine hydrochloride solution. The absorbing solution is made up of equal volumes of hydroxylamine hydrochloride (200 g in 1 liter distilled water) and sodium hydroxide (200 g in 1 liter distilled water). The solution is mixed just before use and is stable for only 2 hr. Samples are collected at a recommended flow rate of 0.2 to 1 liter/min until a recommended air volume of 25 to 100 liters is collected. Analysis is performed colorimetrically using

visible absorption spectrophotometry. A purple-colored complex is formed by adding ferric chloride solution to the sample. The limit of detection for this procedure is 0.05 mg/sample. This method is described in Method 3506 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If acetic anhydride contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min and then wash with soap and water. Get medical help immediately.

Clothing and shoes contaminated with acetic anhydride should be removed immediately and provisions should be made for safely removing this chemical from these articles. If gross exposure occurs, remove contaminated clothing under a safety shower. Speed in removing the contaminated material from the skin is extremely important. Persons laundering contaminated clothing should be informed about the hazardous properties of acetic anhydride, particularly its potential to be corrosive to the skin.

A worker who handles acetic anhydride should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where acetic anhydride or a solution containing acetic anhydride is handled, processed, or stored.

STORAGE

Acetic anhydride should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Outside or detached storage is preferred. Inside storage must be in a standard flammable liquids storage room or cabinet. Steel, galvanized tin, tinned iron, copper, or copper alloys should not be used for piping or valves that will be in contact with acetic anhydride. Containers of acetic anhydride should be protected from physical damage and should be separated from water, alcohols, strong oxidizers, chromic acid, amines, strong caustics, heat, sparks, and open flame. Because containers that formerly contained acetic anhydride may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving acetic anhydride, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. If the leak or spill has not ignited, water spray may be used to reduce vapors.
6. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal. Wash the site with soda ash solution and flush with plenty of water.
7. For large liquid spills, build dikes far ahead of the spill to contain the acetic anhydride for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Acetic anhydride is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is equal to or greater than the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [42 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for acetic anhydride is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of acetic anhydride emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although acetic anhydride is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of acetic anhydride exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with acetic anhydride. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been tested against permeation by acetic anhydride and have demonstrated protection for more than 4 but fewer than 8 hr: butyl rubber and Teflon®. Polyvinyl chloride, nitrile rubber, Viton®, and natural rubber have all demonstrated poor resistance to permeation by acetic anhydride.

If acetic anhydride is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which acetic anhydride might contact the eyes (e.g., through vapors or splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with acetic anhydride. Contact lenses should not be worn if the potential exists for acetic anhydride exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ACETONITRILE

INTRODUCTION

This guideline summarizes pertinent information about acetonitrile for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

C_2H_3N

- **Structure**

CH_3CN

- **Synonyms**

Methyl cyanide, cyanomethane, ethanenitrile, ethyl nitrile, methanecarbonitrile

- **Identifiers**

1. CAS No.: 75-05-8
2. RTECS No.: AL7700000
3. DOT UN: 1648 28
4. DOT labels: Flammable Liquid and Poison

- **Appearance and odor**

Acetonitrile is a flammable, colorless liquid with an aromatic odor. The odor threshold is reported to be 40 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 41
2. Boiling point (at 760 mm Hg): 81.6°C (178.9°F)
3. Specific gravity (water = 1): 0.79 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of acetonitrile): 1.42
5. Melting point: -45°C (-49°F)
6. Vapor pressure at 20°C (68°F): 73 mm Hg
7. Solubility: Miscible with water, methanol, methyl acetate, ethyl acetate, alcohol, ethanol, acetone, acetamide solutions, carbon tetrachloride, chloroform, ethylene chloride, and many unsaturated hydrocarbons
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, or open flame. Vapors form explosive mixtures with air.
2. Incompatibilities: Fire and explosion may result from contact of acetonitrile with perchloric acid, iron (III) salts of perchlorate, nitric acid, oleum, indium, nitrating agents, perfluorourea, chlorosulfonic acid, or other strong oxidizers.
3. Hazardous decomposition products: Toxic gases (such as oxides of nitrogen, carbon monoxide, carbon dioxide, and hydrogen cyanide) may be released in a fire involving acetonitrile.
4. Special precautions: Liquid acetonitrile attacks some coatings and some forms of plastic and rubber.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 3 (severe fire hazard) to acetonitrile.

1. Flash point: 5.6°C (42°F) (closed cup)
2. Autoignition temperature: 523.9°C (975°F)
3. Flammable limits in air (% by volume): Lower, 4.4; upper, 16.0

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4. Extinguishant: Use carbon dioxide, dry chemical, or foams on fires involving acetonitrile. Never direct a stream of water into burning pools of liquid acetonitrile because this may scatter and spread the flames. Water spray may be used to cool containers or to protect persons attempting to stop the leak.

Fires involving acetonitrile should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of acetonitrile may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving acetonitrile. Chemical protective clothing that is specifically recommended for acetonitrile may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by acetonitrile.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for acetonitrile is 40 ppm (70 mg/m^3) as an 8-hr time-weighted average (TWA) concentration and 60 ppm (105 mg/m^3) as a short-term exposure limit (STEL) [29 CFR 1910.1000, Table Z-1-A]. A STEL is a 15-min TWA exposure that should not be exceeded at any time during the workday.

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 20 ppm (34 mg/m^3) as a TWA for up to a 10-hr workshift and a 40-hr workweek [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned acetonitrile a threshold limit value (TLV) of 40 ppm (67 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek and a STEL of 60 ppm (101 mg/m^3) for periods not to exceed 15 min [ACGIH 1991b].

• Rationale for limits

The limits are based on the risks of organic cyanide poisoning and liver and respiratory tract injuries associated with exposure to acetonitrile.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to acetonitrile can occur through inhalation and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Acetonitrile can induce methemoglobinemia and cyanosis because it is metabolized in the body to cyanide. The 8-hr LC_{50} in rats is 7,500 ppm [NIOSH 1991]. The dermal LD_{50} in rabbits is 1,250 mg/kg [NIOSH 1991]. Acutely poisoned animals convulsed and became prostrate before death; autopsy of these animals revealed pulmonary hemorrhage [Proctor et al. 1988]. In mice exposed to 200 or 400 ppm for 6.5 hr/day, 5 days/week for 13 weeks, an increase in liver weight and pathological changes in liver cells were seen at autopsy; signs of anemia were also seen in the high-dose groups before death [ACGIH 1991a]. Dogs and monkeys exposed to a 350-ppm concentration for 7 hr/day, 3 days/week for 13 weeks showed signs of emphysema and other reactive changes in the lungs at autopsy; the monkeys also exhibited brain hemorrhage [Clayton and Clayton 1982]. The oral LD_{50} in rats is 2,730 mg/kg. Teratogenic and embryotoxic effects occurred in hamsters inhaling 5,000 or 8,000 ppm for 1 hr on day 8 of gestation, and a single oral or intraperitoneal dose of 100 to 400 mg/kg also resulted in teratogenic effects in the offspring of exposed rats [ACGIH 1991a].

2. *Effects on Humans*: Acetonitrile is a primary irritant of the eyes, mucous membranes, skin, and upper respiratory tract of exposed workers; it has also caused methemoglobinemia and death in humans acutely overexposed. Two volunteers experienced no ill effects after inhaling 80 ppm for 4 hr; however, one of these individuals experienced bronchial irritation after an exposure to 160 ppm for the same interval [Proctor et al. 1988]. Ten painters developed signs of systemic toxicity when exposed to the vapor of a mixture containing 30% to 40% acetonitrile for 2 workdays. Four of the ten printers required hospitalization. One painter died after experiencing massive hematemesis [Proctor et al. 1988]. Several other industrial fatalities have occurred as a result of acute overexposure to acetonitrile. The lowest oral dose toxic in humans is 570 mg/kg; ingestion of this amount of acetonitrile caused gastrointestinal tract disturbances [NIOSH 1991].

• **Signs and symptoms of exposure**

1. *Acute exposure*: Acetonitrile poisoning can cause flushing or ashen-grey color; chest tightness; headache; nausea; vomiting (with or without blood); sweating; excess saliva production; lassitude; muscle weakness; painful, difficult, or irregular breathing; convulsions; stupor; coma; and cardiac and respiratory arrest.

2. *Chronic exposure*: No signs or symptoms of chronic exposure have been reported.

• **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of acetonitrile. ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of acetonitrile are inhaled, move the victim to fresh air ***immediately.***

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Do ***not*** induce vomiting.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of acetonitrile may result in worker exposures to this substance:

—Use as a solvent for extractive distillation in the manufacture of butadiene and isoprene

—Use as an extractive solvent in separation of fatty acids from fish liver oils; to remove phenol, tar, and color from petroleum hydrocarbons; to recover various alcohols, acids, and dark wood rosins; and in chemical analysis

—Use as a solvent and reactive medium for the preparation of pharmaceuticals, waterproofing compounds, antistatic agents, detergents, polymers, dyestuff intermediates, and for chemical research

—Use as an indifferent medium in physiochemical investigation and in separation of alkaloids in tissue extraction

—Use as a solvent for recrystallization and purification of salts, metals, and steroids; as a spinning solvent for synthetic fibers; as a solvent for epoxy resin coatings

—Use in organic synthesis in preparation of vitamins, perfumes, water softeners, and plasticizers, and as a catalyst to promote ionization reactions

The following methods are effective in controlling worker exposures to acetonitrile, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and

workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety and health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations must be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to acetonitrile, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the liver and kidneys and of the cardiovascular, respiratory, and central nervous systems. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to acetonitrile at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with liver, kidney, cardiovascular, respiratory, or central nervous system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to acetonitrile exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of acetonitrile on the liver, kidneys, and cardiovascular, respiratory, and central nervous system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. Acetonitrile exposure can be monitored by measurement of its metabolites, cyanide and thiocyanate, in the blood or in plasma and urine, respectively. Some sources suggest that blood cyanide levels of 0.1 mg/l or plasma or urine thiocyanate levels above 20 mg/l indicate excessive exposure. Because smokers often have higher levels of both metabolites, pre-exposure baseline measurements are suggested to establish each worker's baseline level.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne acetonitrile is determined by using coconut shell charcoal tubes (400/200-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 25 liters is collected. The sample is then treated with benzene to extract the acetonitrile. Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is 0.01 mg per sample. This method is described in Method 1606 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

Clothing and shoes contaminated with acetonitrile should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Work clothing should not be taken home for laundering. Persons laundering contaminated clothing should be informed about the hazardous properties of acetonitrile, particularly its potential for being absorbed through the skin in toxic amounts.

A worker who handles acetonitrile should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where acetonitrile or a solution containing this substance is handled, processed, or stored.

STORAGE

Acetonitrile should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Outside or detached storage is preferred; inside storage must be in a standard flammable liquids storage area. All electrical service in the storage area should meet code requirements for flammable atmospheres. Containers of acetonitrile should be protected from physical damage and should be stored separately from perchloric acid, iron (III) salts of perchlorate, nitric acid, oleum, indium, nitrating agents, perfluorourea, chlorosulfonic acid, other strong oxidizers, heat, sparks, and open flame. To prevent static sparks, conveying equipment and storage containers should be electrically grounded and bonded during transfer. Because containers that formerly contained acetonitrile may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving acetonitrile, persons not wearing protective equipment and clothing should be restricted from contaminated areas until the cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.

2. Notify safety personnel.

3. Remove all sources of heat and ignition.

4. Isolate and ventilate the area of the spill or leak.

5. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered, vapor-tight container for later disposal.

6. Large quantities of acetonitrile can be collected and atomized in a suitable combustion chamber equipped with an appropriate effluent gas cleaning device.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Acetonitrile is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is above the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal authorities.

The reportable quantity for acetonitrile is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center *immediately* at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of this substance per calendar year are required by EPA [49 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of acetonitrile emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Acetonitrile is listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.] and has been assigned EPA Hazardous Waste No. U003. This substance has been banned from land dis-

posal and may be treated by incineration. Acetonitrile also may be disposed of in an organometallic or organic lab pack that meets the requirements of 40 CFR 264.316 or 265.316.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of acetonitrile exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Gloves, boots, aprons, and gauntlets should be worn as necessary to prevent skin contact either with the vapor or the liquid. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been tested against permeation by acetonitrile and have demonstrated good-to-excellent resistance for periods of at least 8 hr: butyl rubber, polyvinyl alcohol, and Teflon®. Natural rubber, neoprene, nitrile, polyvinyl chloride, and Viton® have demonstrated poor resistance to permeation.

If acetonitrile is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which acetonitrile might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with acetonitrile. Contact lenses should not be worn if the potential exists for acetonitrile exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ACETYLENE TETRABROMIDE

INTRODUCTION

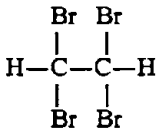
This guideline summarizes pertinent information about acetylene tetrabromide for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$CHBr_2CHBr_2$

- **Structure**



- **Synonyms**

Tetrabromacetylene, tetrabromoethane; symmetrical tetrabromoethane; 1,1,2,2-tetrabromoethane (TBE); Muthmann's liquid

- **Identifiers**

1. CAS No.: 79-27-6
2. RTECS No.: KI8225000
3. DOT UN: 2504 58
4. DOT label: St. Andrew's Cross

- **Appearance and odor**

Acetylene tetrabromide is a noncombustible, heavy, pale yellow liquid with a pungent, camphorlike odor. No quantitative data is available on the odor threshold.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 345.7
2. Boiling point (at 760 mm Hg): 239°C (462.2°F)
3. Specific gravity (water = 1): 2.96 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of acetylene tetrabromide): 11.9
5. Melting point: 0°C (32°F)
6. Vapor pressure at 20°C (68°F): 0.02 mm Hg
7. Solubility: Insoluble in water; miscible with alcohol, chloroform, ether, aniline, glacial acetic acid; soluble in acetone and benzene.
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat
2. Incompatibilities: Toxic vapors may result from contact with chemically active metals or strong caustics, or with hot iron, aluminum, or zinc in the presence of steam.
3. Hazardous decomposition products: Toxic gases and vapors (such as hydrogen bromide, carbonyl bromide, brominated solvents, and carbon monoxide) may be released when acetylene tetrabromide decomposes.
4. Special precautions: Acetylene tetrabromide softens or destroys most plastics and rubbers.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 0 (no fire hazard) to acetylene tetrabromide; this substance is not combustible.

1. Flash point: -18°C (0°F) (closed cup)
2. Autoignition temperature: 335°C (635°F)
3. Flammable limits in air: Not applicable

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

4. Extinguishant: Use water to cool containers of acetylene tetrabromide that are involved in a fire.

Fires involving acetylene tetrabromide should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving acetylene tetrabromide. Chemical protective clothing that is specifically recommended for acetylene tetrabromide may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by acetylene tetrabromide.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for acetylene tetrabromide is 1 ppm (14 mg/m^3) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has not issued a recommended exposure limit (REL) for acetylene tetrabromide [NIOSH 1988, 1991].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned acetylene tetrabromide a threshold limit value (TLV) of 1 ppm (15 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The OSHA and ACGIH limits are based on the risk of hepatotoxic effects associated with exposure to acetylene tetrabromide.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to acetylene tetrabromide can occur through inhalation of the vapors, ingestion of the liquid, and eye or skin contact with the liquid or vapors.

• Summary of toxicology

1. *Effects on Animals*: Acetylene tetrabromide is a central nervous system depressant and a liver, kidney, and lung toxin in animals. When instilled into the eyes of rabbits, the liquid caused slight conjunctival and superficial corneal injury; on the skin of rabbits, a 24-hr application of 500 mg caused a moderate degree of irritation [NIOSH 1991]. The dermal LD_{50} in rats is 5,250 mg/kg [NIOSH 1991]. The inhalation LC_{50} in rats has been reported as 39 ppm (549 mg/m^3) [NIOSH 1991]. Although no noteworthy effects were described for rats, rabbits, and guinea pigs exposed to saturated vapors (unquantified) for up to 2 hr, 3-hr exposures produced respiratory tract irritation, tremors, and CNS depression (ataxia, loss of the righting reflex, and unconsciousness). Only the guinea pigs died, each having postmortem fatty degeneration of the hepatic and renal parenchyma. The tissues for all survivors from the four species appeared histologically normal [Gray 1950]. Female rats exposed to saturated vapors (~14 ppm at 23°C) for 7 hr did not die and had very slight eye and nasal irritation [Hollingsworth et al. 1963]. The oral LD_{50} in rats is 1,100 mg/kg [NIOSH 1991]. In a subchronic study, rats, rabbits, mice, and a monkey were exposed to ambient concentrations of 1, 4, or 14 ppm for 7 hr/day, 5 days/week for approximately 28, 26, or 15 weeks, respectively. The no observable effect level (NOEL) was 1 ppm. The 4-ppm concentration induced slight lung hemorrhage, congestion, edema, slight hepatocellular centrolobular fatty degeneration, and slight swelling of the renal convoluted tubules. Similar pulmonary and liver changes were reported at 14 ppm [Hollingsworth 1963]. Application of 15 mg to the skin of mice, followed 14 days later with a tumor-promoting agent (phorbol myristate acetate) caused a statistically significant increase in forestomach papillomas [Van Duuren et al. 1979; Proctor et al. 1988; NLM 1991].

2. *Effects on Humans*: Acetylene tetrabromide is a central nervous system depressant and a liver toxin in humans. When a chemist was exposed to this substance for 7.5 hr at an estimated concentration of 1 to 2 ppm with a single 10-min peak exposure to 16 ppm, he experienced headache, anorexia, nausea, vomiting, and abdominal pain. During a 9-week hospitalization, clinical studies revealed icterus, urobilinuria, bilirubinuria, and severe and nearly fatal liver damage [Proctor et al. 1988; Clayton and Clayton 1981]. Skin absorption of acetylene tetrabromide may also have been involved in this episode of acute poisoning [Proctor et al. 1988; ACGIH 1991a].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to acetylene tetrabromide can cause irritation of the eyes, nose, and upper respiratory tract; headache; nausea; vomiting; anorexia; abdominal pain; ataxia; CNS depression; and death. Jaundice, urobilinuria, bilirubinuria, and monocytosis have also been reported. Exposure to the eyes or skin with liquid acetylene tetrabromide may cause pain, redness, and a slight but reversible conjunctival irritation and corneal injury.

2. *Chronic exposure*: On the basis of effects seen in animals, exposure to acetylene tetrabromide can cause liver, kidney, and lung damage.

- **Emergency procedures**

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of acetylene tetrabromide. ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of acetylene tetrabromide are inhaled, move the victim to fresh air ***immediately***. Have the victim blow his or her nose to remove residues from nostrils.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if acetylene tetrabromide or any material containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of acetylene tetrabromide may result in worker exposures to this substance:

—Use as a catalyst or catalytic initiator in manufacture of terephthalic acid and synthetic fibers and as a polymer additive in flameproof, flame-retardant polystyrenes, polyurethanes, and polyolefins

—Use in the density separation of mineral salts

—Use as a mercury substitute in gauges, as a level indicator in sight gauges, and as a refractive index liquid in microscopy

—Use as a solvent for fats, oils, and waxes

—Use as an ore flotation agent

The following methods are effective in controlling worker exposures to acetylene tetrabromide, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers

for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to acetylene tetrabromide, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the liver.

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to acetylene tetrabromide at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with impaired liver function.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to acetylene tetrabromide exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of acetylene tetrabromide on the eyes, skin, upper respiratory tract, liver, and kidneys. Liver function studies should be performed on a routine basis, particularly in workers exposed to acetylene tetrabromide levels near the PEL. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissue or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for acetylene tetrabromide.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne acetylene tetrabromide is determined by using a silica gel absorption tube (150/75-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 1.0 liter/min until a maximum air volume of 100 liters is collected. The sample is then treated with tetrahydrofuran to extract the acetylene tetrabromide. Analysis is conducted by gas chromatography using a flame ionization detector. The standard analytical error for this procedure is 0.16. This method is included in the OSHA Computerized Information System [OSHA 1989] and in Method 2003 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If acetylene tetrabromide contacts the skin, workers should immediately wash the affected areas thoroughly with soap and water.

Clothing and shoes contaminated with acetylene tetrabromide should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of acetylene tetrabromide.

A worker who handles acetylene tetrabromide should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where acetylene tetrabromide is handled, processed, or stored.

STORAGE

Acetylene tetrabromide should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of acetylene tetrabromide should be protected from physical damage and should be stored separately from chemically active metals and strong caustics, heat, sparks, and open flame. Because empty containers may contain acetylene tetrabromide residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving acetylene tetrabromide, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. If feasible, remove leaking containers to a safe place.
4. Ventilate atmosphere to reduce vapors.
5. Absorb small spills with sand, vermiculite, or other noncombustible absorbent material and place the material in a covered container for later disposal.
6. For large liquid spills, build dikes far ahead of the spill to contain the acetylene tetrabromide for later disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Acetylene tetrabromide is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center about an accidental release of acetylene tetrabromide; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the annual amount of acetylene tetrabromide emitted or released from their facility.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although acetylene tetrabromide is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limits. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of acetylene tetrabromide exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel,

fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent skin contact with acetylene tetrabromide. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Such clothing may include gloves with long sleeves, aprons, footwear, and face shields. No reports have been published on the resistance of various protective clothing materials to permeation by acetylene tetrabromide; however, Viton®, Teflon®, and polyvinyl alcohol materials have been tested against permeation by a similar compound (ethylene dibromide) and have been found to provide good-to-excellent protection. These materials provided more than 8 hr of resistance to permeation by ethylene dibromide. Since specific test data are not available for acetylene tetrabromide, the information provided here should be considered as a guideline only. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to acetylene tetrabromide.

If acetylene tetrabromide is dissolved in an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Chemical safety glasses, goggles, or face shields should be worn during operations in which acetylene tetrabromide might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with acetylene tetrabromide. Contact lenses should not be worn if the potential exists for acetylene tetrabromide exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ACROLEIN

INTRODUCTION

This guideline summarizes pertinent information about acrolein for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

C_3H_4O

- **Structure**

$CH_2=CHCHO$

- **Synonyms**

Acraldehyde, acrylic aldehyde, acrylaldehyde, trans-acrolein, allyl aldehyde, propenal, 2-propenal, propylene aldehyde, ethylene aldehyde, Aqualine, Biocide, Crolean, Magnacide

- **Identifiers**

1. CAS No.: 107-02-8
2. RTECS No.: AS1050000
3. DOT UN: 1092 30 (inhibited form)
4. DOT labels: Flammable Liquid, Poison (for the inhibited form)

- **Appearance and odor**

Acrolein is a clear, colorless to yellow, flammable liquid with a disagreeable, choking odor. The odor threshold is reported to be between 0.02 and 0.4 part per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 56.1
2. Boiling point (760 mm Hg): 52.5°C (126.5°F)
3. Specific gravity (water = 1): 0.84 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of acrolein): 1.94
5. Melting point: -87.7°C (-125.9°F)
6. Vapor pressure at 20°C (68°F): 210 mm Hg
7. Solubility: Soluble in water, alcohol, ether, and acetone
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, or open flame. The vapors of acrolein form explosive mixtures with air.

2. Incompatibilities: Acrolein is very reactive and polymerizes rapidly and violently in the presence of strong acid or basic catalysts, light, heat, and volatile amines. Upon storage, it forms shock-sensitive and heat-sensitive explosive compounds. Fire and explosions may result from contact of acrolein with oxidizers, acids, alkalies, or ammonia.

3. Hazardous decomposition products: Toxic gases and vapors, including peroxides and oxides of carbon, may be released in a fire involving acrolein.

4. Special precautions: An inhibitor, usually hydroquinone, should be added to this highly unstable material to prevent self-polymerization.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 3 (severe fire hazard) to acrolein.

1. Flash point: -26°C (-15°F) (closed cup)
2. Autoignition temperature: 220°C (428°F)
3. Flammable limits in air (% by volume): Lower, 2.8; upper, 31

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

4. Extinguishant: Use carbon dioxide, dry chemical, or alcohol foam to extinguish fires involving acrolein. Water may be ineffective, but it may be used to keep fire-exposed containers cool or to protect persons attempting to stop a leak involving this substance.

Fires involving acrolein should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of acrolein may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving acrolein. Chemical protective clothing specifically recommended for acrolein may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by acrolein.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for acrolein is 0.1 ppm (0.25 mg/m^3) as an 8-hr time-weighted average (TWA) concentration and 0.3 ppm (0.8 mg/m^3) as a short-term exposure limit (STEL). A STEL is a 15-min TWA exposure that should not be exceeded at any time during a workday [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 0.1 ppm (0.25 mg/m^3) as an 8-hr TWA and 0.3 ppm (0.8 mg/m^3) as a STEL [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned acrolein a threshold limit value (TLV) of 0.1 ppm (0.23 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek and a STEL of 0.3 ppm (0.69 mg/m^3) for periods not to exceed 15 min [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of severe eye, nose, and respiratory irritation associated with exposure to acrolein.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to acrolein can occur through inhalation, ingestion, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Acrolein is a severe irritant and corrosive to the eyes, skin, mucous membranes, and respiratory tract in animals. Eye contact with liquid acrolein has caused severe burns, corrosion, and corneal injury [Grant 1986; Proctor et al. 1988]. The dermal LD_{50} in rabbits is 562 mg/kg [NIOSH 1991]. Skin contact can cause erythema, edema, severe irritation, corrosion, and burns [NIOSH 1991]. The mouse RD_{50} (concentration that decreases respiratory rate by 50% in exposed animals) is 1.7 ppm [NLM 1992]. The 10-min, 30-min, and 8-hr LC_{50}s in rats are 375, 131, and 8 ppm, respectively [AIHA 1989]. Cats exposed for 3.5 hr to 10 ppm showed signs of respiratory irritation, mild narcosis, lacrimation, and salivation [ACGIH 1991a]. The oral LD_{50} is 42 to 46 mg/kg in rats and 28 mg/kg in mice [AIHA 1989]. When swallowed, acrolein induces gastrointestinal distress, pulmonary congestion, and edema [NLM 1992]. Rats, guinea pigs, dogs, and monkeys were repeatedly exposed to 0.7 or 3.7 ppm for 8 hr/day, 5 days/week for 6 weeks. All animals exposed to 0.7 ppm developed inflammatory lung changes. Emphysema was infrequently but more predominantly observed in dogs and monkeys than in rats or guinea pigs. Animals exposed to 3.7 ppm salivated and had ocular and respiratory irritation. Histopathology of survivors revealed nonspecific inflammatory changes in the lungs, liver, and kidneys. Squamous metaplasia of dog and monkey trachea and necrotizing bronchitis with squamous metaplasia of monkey lungs was also observed. In addition, these four species were continuously exposed to 0.21, 0.23, 1.0, or 1.8 ppm acrolein 24 hr/day for 90 days. Findings similar to those cited for the repeated exposure experiment were likewise observed, with the inflammatory changes also being noted in the brains of all acrolein-exposed animals [Lyon et al. 1970]. Male rats died (32 of 57) following exposures to 4 ppm for 6 hr/day, 5 days/week for 62 exposure days. Terminal histopathology revealed bronchiolar necrosis and pulmonary edema in treated animals [Proctor et al. 1988]. Intra-amniotic or intravenous administration of acrolein to pregnant rats induced malformations or embryolethality, respectively [NIOSH 1991]. Acrolein is mutagenic in bacterial test systems [NIOSH 1991]. Mice that were dermally injected with acrolein for 24 weeks did not develop injection-site sarcomas during the ensuing 70-week observation period [NLM 1992]. Syrian golden hamsters inhaled 4 ppm for 7 hr/day, 5 days/week for 52 weeks. Additional groups were also administered benzo(a)pyrene or

N-nitrosodiethylamine. Following 29 weeks without exposure, terminal sacrifice in week 81 demonstrated that no increased tumor incidence had been induced by acrolein [NLM 1992].

2. *Effects on Humans*: Acrolein is a powerful lacrimating agent and severe tissue irritant. Eye contact with liquid acrolein can cause pain, intense lacrimation, blepharoconjunctivitis, swelling of the lids, purulent discharge, photophobia, and corneal injury [Grant 1986; Gosselin et al. 1984; NLM 1992]. Contact of the skin with liquid acrolein causes redness, edema, swelling, vesiculation, and burns. In addition, acrolein can be absorbed through the skin in sufficient amounts to cause systemic effects [Gosselin et al. 1984]. This chemical is a weak skin sensitizer in some exposed individuals [Proctor et al. 1988]. Exposure to 0.25 ppm for 5 min causes moderate irritation of the eyes, mucous membranes, and upper respiratory tract [Clayton and Clayton 1981; Grant 1986]. Exposure to a 1-ppm (2.3-mg/m^3) concentration of acrolein vapor for the same interval is described as intolerable and causes intense lacrimation and severe eye, nose, and throat irritation [Clayton and Clayton 1981; Grant 1986]. Acrolein is a severe lung irritant and tear-inducer at 3 ppm (7 mg/m^3) [IARC 1985]. At higher exposure levels, it can induce significant delayed-onset lung injury, including dyspnea, asthma, congestion, edema, and persistent respiratory insufficiency with decreased pulmonary function [NLM 1992]. Prolonged exposure to 21 ppm causes pulmonary edema, and fatalities have been reported at concentrations as low as 10 ppm; exposure to 150 ppm for 10 min is lethal to humans [Proctor et al. 1988].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acrolein can cause severe irritation or corrosion of the eyes, nose, throat, and lungs, with tearing, pain in the chest, and delayed-onset pulmonary injury with depressed pulmonary function. Contact of liquid acrolein with the eyes may cause corneal burns, corrosion, and blindness; skin contact may result in redness, swelling, chemical burns with blisters, and corrosion.

2. *Chronic exposure*: The signs and symptoms of chronic exposure to acrolein include skin sensitization and contact dermatitis.

- **Emergency procedures**

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Tissue destruction and blindness may result from exposure to concentrated solutions, vapors, mists, or aerosols of acrolein! ***Immediately but gently*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Severe burns, skin corrosion, and absorption of lethal amounts may result! ***Immediately*** remove all contaminated clothing! ***Immediately and gently*** wash skin for at least 15 min. Use soap and water if skin is intact; use only water if skin is not intact.

3. *Inhalation exposure*: If vapors, mists, or aerosols of acrolein are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if acrolein or a solution containing it is ingested:

—Do ***not*** induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water. Immediately after rinsing, have the victim drink one cup (8 oz) of fluid and ***no more***.

—Do ***not*** permit the victim to drink milk or carbonated beverages!

—Do ***not*** permit the victim to drink any fluid if more than 60 min have passed since initial ingestion.

NOTE: These instructions must be followed exactly. Drinking a carbonated beverage or more than one cup of fluid could create enough pressure to perforate already damaged stomach tissue. The tissue-coating action of milk can sometimes impede medical assessment of tissue damage. Ingestion of any fluid more than 60 min after initial exposure could further weaken damaged tissue and result in perforation.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve acrolein and may result in worker exposures to this substance:

—Use of acrolein as an intermediate in the production of glycerine and methionine analogs (poultry feed protein supplements)

—Manufacture of colloidal forms of metals, artificial resins, synthetic fibers, and polyurethane foams

—Chemical synthesis of 1,3,6-hexanetriol, glutaraldehydes, and acrylates

—Use of acrolein as a slimicide in the manufacture of paper

—Use of acrolein in biomedical applications to fix tissue and, with its polymers, to immobilize enzymes

—Subsurface injection of wastewaters to control the growth of microbes in feed lines and to control the growth of algae, aquatic weeds, and mollusks in recirculating process water systems

—Manufacture of pharmaceuticals, perfumes, and food supplements

—Use of acrolein as an alcohol denaturant

—Heating of oils and fats containing glycerol

—Use of acrolein as a liquid fuel

The following methods are effective in controlling worker exposures to acrolein, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

• Preplacement medical evaluation

Before a worker is placed in a job with a potential for exposure to acrolein, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to acrolein at or below the prescribed exposure limit. The health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and

other findings consistent with eye, skin, or respiratory disease.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to acrolein exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of acrolein on the eyes, skin, and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for acrolein.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne acrolein is determined by using a solid sorbent sampling tube containing 2-(hydroxymethyl)piperidine on XAD-2 adsorbent. Samples are collected at a maximum flow rate of 0.1 liter/min until a maximum air volume of 48 liters is collected. The sample is then treated with toluene to extract the acrolein. Analysis is conducted by gas chromatography using a nitrogen-phosphorus detector. This method has a sampling and analytical error of 0.12 and is sufficiently sensitive for full-shift personal monitoring below the PEL of 0.1 ppm. For STEL measurements, the limit of the method is 0.8 ppm for a 15-min sample. This method is included in the OSHA Computerized Information System [OSHA 1989] and in Method 52 of the *OSHA Analytical Methods Manual* [OSHA 1985]. A similar method (Method 2501) can be found in the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If acrolein contacts the skin, workers should immediately wash the affected areas with soap and water.

Clothing contaminated with acrolein should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of acrolein, particularly its potential to cause severe irritation of the eyes and skin.

A worker who handles acrolein should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where acrolein or a solution containing acrolein is handled, processed, or stored.

STORAGE

Acrolein should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Outside or detached storage is preferred. Acrolein must be stored under a nitrogen blanket. Uninhibited acrolein may not be stored, and the level of the inhibitor must be checked regularly during prolonged storage. The storage area should be equipped with an automatic sprinkler or other extinguishing system. All electrical service in the storage area must be of explosionproof design. Containers of acrolein should be protected from physical damage and should be stored separately from alkaline materials (such as caustics, ammonia, or amines), oxidizers, heat, sparks, and open flame. To prevent static sparks, containers and equipment should be grounded and bonded when transferring liquid acrolein. Because empty containers formerly containing acrolein may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving acrolein, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.

2. Notify safety personnel.

3. Remove all sources of heat and ignition.

4. Provide maximum explosionproof ventilation.

5. If feasible, remove leaking containers to a safe place.

6. Absorb small liquid spills with sand, vermiculite, or other noncombustible absorbent material and place the material in a covered container for later disposal.

7. For large liquid spills, build dikes far ahead of the spill to contain the acrolein for later reclamation or disposal, or absorb with vermiculite or sand.

8. After cleanup, the spill area should be washed thoroughly with soap and water.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

If 500 lb or more of acrolein is present at a facility, the owner or operator must comply with EPA's emergency planning requirements [40 CFR 355.30].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is equal to or greater than the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for acrolein is 1 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of acrolein per calendar year are required by EPA [49 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of acrolein emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Acrolein is listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.] and has been assigned EPA Hazardous Waste No. P003. This substance has been banned from land disposal and may be treated by fuel substitution or incineration. Acrolein also may be disposed of in an organometallic or organic lab pack that meets the requirements of 40 CFR 264.316 or 265.316.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of acrolein exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that

involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent skin contact with acrolein. Impervious clothing, gloves, boots, and other protective clothing are recommended when handling this substance. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The only material that has been tested against permeation by acrolein and has demonstrated good-to-excellent resistance for longer than 8 hr is butyl rubber. Natural rubber, neoprene, nitrile, polyvinyl alcohol, polyvinyl chloride, Teflon®, and Viton® have demonstrated poor resistance to permeation by acrolein.

If acrolein is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which acrolein might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with acrolein. Contact lenses should not be worn if the potential exists for acrolein exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ACRYLAMIDE

INTRODUCTION

This guideline summarizes pertinent information about acrylamide for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

C_3H_5NO

- **Structure**

$H_2C=CHCONH_2$

- **Synonyms**

Acrylic amide; propenamide; 2-propenamide; propenoic acid amide; acrylamide monomer

- **Identifiers**

1. CAS No.: 79-06-1
2. RTECS No.: AS3325000
3. DOT UN: 2074 55
4. DOT label: St. Andrew's Cross

- **Appearance and odor**

Acrylamide is a colorless to white, odorless, crystalline solid.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 71.1
2. Boiling point (at 760 mm Hg): 175° to 300°C (347° to 572°F); decomposes on boiling
3. Specific gravity (water = 1): 1.1 at 30°C (86°F)
4. Vapor density (air = 1 at boiling point of acrylamide): 2.4
5. Melting point: 84.5°C (179.3°F)
6. Vapor pressure at 20°C (68°F): 0.007 mm Hg
7. Solubility: Miscible with water; soluble in acetone, ethanol, ethyl ether, and methanol
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Acrylamide decomposes above 175°C (347°F). Violent polymerization may occur when heated or when exposed to ultraviolet light.
2. Incompatibilities: Fires and explosions may result from contact of acrylamide with strong oxidizers.
3. Thermal decomposition products: Toxic gases (such as ammonia, hydrogen, and carbon monoxide) may be released when acrylamide decomposes; toxic oxides of nitrogen may form in fire.
4. Special precautions: None

- **Flammability**

Acrylamide is combustible, but because of its high flash point, it is considered only a slight fire hazard when exposed to heat, sparks, or open flame. It is a combustible, flammable liquid when dissolved in solvent. The National Fire Protection Association has not assigned a flammability rating to

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

acrylamide; other sources rate acrylamide as a moderate fire hazard.

1. Flash point: 138°C (280°F) (closed cup)

2. Autoignition temperature: 424°C (795°F)

3. Flammable limits in air (% by volume): Data not available

4. Extinguishant: Use dry chemical, carbon dioxide, Halon®, water spray, or standard foam for small fires; water spray, fog, or standard foam for large fires.

Fires involving acrylamide should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of acrylamide may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool the containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving acrylamide. Chemical protective clothing specifically recommended for acrylamide may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by acrylamide.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for acrylamide is 0.03 mg/m^3 as an 8-hr time-weighted average (TWA) concentration. The OSHA PEL also bears a "Skin" designation, which indicates that the cutaneous route of exposure (including mucous membranes and eyes) contributes to overall exposure [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 0.03 mg/m^3 as an 8-hr TWA with a "Skin" notation. However, acrylamide has been designated as a potential occupational carcinogen and exposure should be limited to the lowest feasible concentration [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has designated acrylamide an A2 substance (suspected human carcinogen) and assigned acrylamide a threshold limit value (TLV) of 0.03 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek with a "Skin" notation [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of systemic poisoning associated with exposure to acrylamide.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to acrylamide can occur through inhalation of vapor, dust, or aerosol and absorption through the skin or mucous membranes.

• Summary of toxicology

1. *Effects on Animals*: Acrylamide is an irritant, a potent neurotoxin that affects both the central and peripheral nervous systems, a reproductive toxin, and a carcinogen. A 10% aqueous solution of acrylamide applied to abraded rabbit skin caused tissue swelling and redness. Although the 10% aqueous solution immediately caused slight pain and conjunctival irritation, a 40% solution produced severe pain with minimal corneal damage. This damage was repaired within 24 hr following a nonrinsed ocular application [Grant 1986]. Acrylamide is also a moderate skin irritant. The acute dermal LD_{50} in rabbits is 2,250 mg/kg [ACGIH 1991a]. The acute oral LD_{50} for rats, guinea pigs, and rabbits fed aqueous solutions of 2.5% to 12.6% acrylamide ranged from 150 to 180 mg/kg body weight. However, in rats fed a 50% aqueous solution of acrylamide, the LD_{50} was 565 mg/kg and 490 mg/kg for males and females, respectively. The acute lethality of acrylamide is a result of its neurotoxic effects, especially on the central nervous system. The toxic effects of acrylamide on the central nervous system are reversible if the dose and duration of exposure are minimal. Recovery is greatly prolonged if the exposure duration is increased [ACGIH 1991a].

Severe or lethal exposure concentrations can also induce testicular degeneration of the seminephrous tubules, degeneration of the convoluted tubular epithelium of the kidney, fatty degeneration and necrosis of the liver, and congestion of the lungs [NLM 1991]. The primary effects of repeated exposures are neurotoxic and involve the central and peripheral nervous systems. The central nervous system effects predominate during acute and subchronic exposures and can also involve somnolence and hallucinations. The sensory and motor neuronal effects on the peripheral nervous system (such as distal numbness, paresthesias, sensory loss, weakness, ataxia, and paralysis) predominate during chronic exposures [NLM 1991]. Rats, cats, and monkeys have developed neuropathies only when exposed to repeated daily doses of 1 mg/kg or more [ACGIH 1991a].

Male rats and mice that received neurotoxic concentrations of acrylamide orally for 2 to 3 months developed testicular degeneration. The rats consumed 20 mg/kg of body weight per day from drinking water, which contained 400 ppm. The mice received doses of 35.5 mg/kg twice per week [NLM 1991]. Chromosomal alterations in the sperm (but not bone marrow) cells of male DDY mice exposed to acrylamide have also been reported [Sakamoto and Hashimoto 1986]. Although pregnant rats that consumed a diet containing 400 ppm throughout their gestation period developed maternal toxicity (neurotoxicity), only slightly depressed birth weights were noted in their pups [ACGIH 1991a]. Similar consumption of a 200-ppm diet induced an abnormal gait in the pregnant dams but did not affect the growth and development of offspring during their first 6 weeks of postnatal development [ACGIH 1991a]. No developmental defects were induced in fetuses of pregnant dams intubated with 20 mg/kg per day (200 mg/kg total dose) during days 6 to 17 of gestation [NLM 1991].

Studies in mice and rats confirm that acrylamide can act either as an initiator or as a complete carcinogen [NIOSH 1991]. This chemical induces skin-tumor-initiating activity in Sencar mice and lung tumors in A/J mice. Acrylamide administered in drinking water to F344 rats for 2 years caused a statistically increased number of tumors (including cancerous tumors) at multiple sites. The International Agency for Research on Cancer (IARC) found "sufficient evidence of carcinogenicity" for chronically exposed animals [IARC 1986].

2. *Effects on Humans*: Most cases of acrylamide toxicity in humans have resulted from occupational exposures, especially transcutaneous ones. In these cases, episodic contact dermatitis of the hands is usually observed before signs of severe neuropathy become apparent. Workers exposed through the skin to acrylamide dust for 1 to 24 months developed characteristic neurological signs that consisted of postural difficulty, ataxia, lethargy, loss of vibratory sensation, loss of deep tendon reflexes, loss of position sense, and weakness, numbness, and tingling of the extremities. In addition, the extremities were cold and bluish-red in color. The palms of the hands and soles of the feet sweated excessively, and skin peeled from the hands and fingers [Sax 1984; Schaumburg et al. 1983].

Acrylamide toxicity resulting from ingestion of subacute doses (such as in contaminated drinking water) is manifested by central nervous system neuropathy. Drowsiness, disturbed balance, confusion, memory loss, and hallucinations have all been reported following ingestion of acrylamide. Nystagmus and slurred speech have also been noted. Disturbances of vision have not been observed in cases of systemic acrylamide toxicity. In systemic acrylamide poisoning, peripheral neuropathy is late to appear relative to central nervous system effects. The signs and symptoms of acrylamide toxicity remit slowly, and often only partially, following cessation of exposure. Although IARC could find no adequate data that demonstrate an increased cancer incidence in acrylamide-exposed workers, they classify the chemical as 2B, "possibly carcinogenic to humans." This classification is based on the induction of cancers in exposed experimental animals [IARC 1987].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Exposure to acrylamide can cause irritation, muscular stiffness and weakness, ataxia, loss of balance, loss of proprioception, and ability to stand.

2. *Chronic exposure*: Exposure to acrylamide can cause irritation, peeling of the skin and excessive sweating of the hands and feet, somnolence, confusion, hallucinations, memory loss, numbness, sensory loss, loss of tendon reflexes, weakness, nystagmus, slurred speech, incoordination, tremor, muscular atrophy, ataxia, and paralysis.

- **Emergency procedures**

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Irritation may result! ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Acrylamide can cause skin irritation. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If respirable acrylamide is inhaled, move the victim to fresh air ***immediately***. Have the victim blow his or her nose, or use a soft tissue to swab particulates from the nostrils.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if acrylamide is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do *not* force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of acrylamide may result in worker exposures to this substance:

—Use in the manufacture of copolymers and polyacrylamides for use as flocculating and thickening agents in pulp and paper industries, oil production, mining textiles, surface coating, adhesives, dyes, photography, and water and waste treatment

—Use as a grouting material in oil wells, basements, tunnels, mine shafts, caissons, and dams

—Use in miscellaneous processes of monomer acrylamide as a curing agent and in organic synthesis

—Use in soap and cosmetic preparations as thickeners and in preshave lotions, hair grooming preparations, and denture fixtures

—Use in stabilizing soil and in permitting the free flow of foundry sand into molds

—Use in clarifying solutions in chemical and food manufacturing; use in gel form in electrophoresis procedures in laboratories

The following methods are effective in controlling worker exposures to acrylamide, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

• Preplacement medical evaluation

Before a worker is placed in a job with a potential for exposure to acrylamide, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the central nervous system and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to acrylamide at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical

condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history or findings consistent with seizure or other central nervous system disorders or chronic respiratory disease.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to acrylamide exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of acrylamide on the central nervous system and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissue or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for acrylamide.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne acrylamide is determined by using a personal sampling train consisting of a glass fiber filter in a Swinnex cassette (13 mm) followed by a silica gel tube. Plastic cassettes (37 mm) yielded poor recoveries of acrylamide and are therefore unsuitable. Samples are collected at a maximum flow rate of 1.0 liter/min until a maximum air volume of 120 liters is collected. The silica gel tube should then be treated with methanol to extract the acrylamide. An important step in this method is the transfer of the glass-fiber filters to glass vials containing 1 ml of methanol immediately after sampling to avoid losses of acrylamide from the filter by evaporation. The sample is then analyzed by gas chromatography using a nitrogen/phosphorous detector. The limit of detection for this procedure is 1.3 parts per billion (ppb) (0.004 mg/m^3). This method (Method 21) is included in the OSHA Computerized Information System [OSHA 1986]. The NIOSH procedure (Method S158) is described in the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

Because acrylamide can be absorbed through the skin in lethal amounts, workers should immediately remove any contaminated clothing and then should wash thoroughly with soap and water any areas of the skin that have come in contact with this substance.

Clothing and shoes contaminated with acrylamide should be removed immediately and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of acrylamide, particularly its potential for being absorbed through the skin in lethal amounts.

A worker who handles acrylamide should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where acrylamide is handled, processed, or stored.

STORAGE

Acrylamide should be stored in a dark, dry, well-ventilated refrigerated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Storage in an inert atmosphere is recommended. All electrical service in storage areas should be of explosionproof design. Containers of acrylamide should be protected from physical damage and should be stored separately from oxidizing agents, polymerization catalysts, heat, sparks, and open flame. Because empty containers may contain acrylamide residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving acrylamide, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Provide maximum explosionproof ventilation.

5. Use nonsparking tools during cleanup.

6. Carefully collect solid material using sand, vermiculite, or soda ash and place in a covered container for disposal.

7. To the extent feasible, avoid generating dust during cleanup.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Acrylamide is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of acrylamide; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of acrylamide emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although acrylamide is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat any waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of acrylamide exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with acrylamide. Gloves, apron, boots, and a chemical protective suit should be worn when workers are handling this substance. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Polyethylene/ethylene vinyl alcohol has been tested against permeation by acrylamide and has demonstrated good-to-excellent resistance for periods of 4 to 8 hr.

If acrylamide is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which acrylamide might contact the eyes (e.g., through dust particles or splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with acrylamide. Contact lenses should not be worn if the potential exists for acrylamide exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ALLYL ALCOHOL

INTRODUCTION

This guideline summarizes pertinent information about allyl alcohol for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

C_3H_6O

- **Structure**

$CH_2=CHCH_2OH$

- **Synonyms**

3-Hydroxypropene, 1-propene-3-ol, propenol, 2-propenol, 2-propenyl alcohol, allylic alcohol, 2-propene-1-ol, vinyl carbinol, Weed Drench

- **Identifiers**

1. CAS No.: 107-18-6
2. RTECS No.: BA5075000
3. DOT UN: 1098 57
4. DOT labels: Flammable Liquid, Poison

- **Appearance and odor**

Allyl alcohol is a clear, colorless, flammable liquid with a pungent, mustardlike odor. The odor threshold is reported to be below 0.8 part per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 58.1
2. Boiling point (at 760 mm Hg): 96°C (205°F)
3. Specific gravity (water = 1): 0.85 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of allyl alcohol): 2.0
5. Melting point: -129°C (-200.2°F)
6. Vapor pressure at 20°C (68°F): 19 mm Hg
7. Solubility: Miscible with water, alcohol, chloroform, ether, and petroleum ether
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, or open flame
2. Incompatibilities: Fire and explosion may result from contact of allyl alcohol with carbon tetrachloride, chlorosulfonic acid, diallyl phosphite plus phosphorus trichloride, nitric acid, oleum, sodium hydroxide, sulfuric acid, tri-n-bromomelamine, metal halides, caustic soda, or sodium, potassium, magnesium, aluminum, or their alloys.
3. Hazardous decomposition products: Toxic gases (such as carbon monoxide) may be produced when allyl alcohol decomposes.
4. Special precautions: Allyl alcohol attacks some coatings and forms of plastic and rubber.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 3 (severe fire hazard) to allyl alcohol.

1. Flash point: 21.1°C (70°F) (closed cup)
2. Autoignition temperature: 378.3°C (713°F)

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3. Flammable limits in air (% by volume): Lower, 2.5; upper, 18.0

4. Extinguishant: Use dry chemical, alcohol foam, or carbon dioxide to fight fires involving allyl alcohol. Water may be ineffective, but it may be used to keep fire-exposed containers cool. If a leak or a spill has not ignited, water spray should be used to disperse the vapors and protect the individuals attempting to stop the leak.

Fires involving allyl alcohol should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of allyl alcohol may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving allyl alcohol. Chemical protective clothing that is specifically recommended for allyl alcohol may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by allyl alcohol.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for allyl alcohol is 2 ppm (5 mg/m^3) as an 8-hr time-weighted average (TWA) concentration and 4 ppm (10 mg/m^3) as a short-term exposure limit (STEL). A STEL is a 15-min TWA exposure that should not be exceeded at any time during a workday. The OSHA PEL also bears a "Skin" notation, which indicates that the cutaneous route of exposure (including mucous membranes and eyes) contributes to overall exposure [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 2 ppm (5 mg/m^3) as an 8-hr TWA and 4 ppm (10 mg/m^3) as a STEL with a "Skin" notation [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned allyl alcohol a threshold limit value (TLV) of 2 ppm (4.8 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek with a "Skin" notation and a STEL of 4 ppm (9.5 mg/m^3) for periods not to exceed 15 min [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of systemic effects and irritation associated with exposure to allyl alcohol.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to allyl alcohol can occur through inhalation, ingestion, or contact with the skin, eyes, or mucous membranes. Allyl alcohol is rapidly absorbed through the skin.

• Summary of toxicology

1. *Effects on Animals*: Allyl alcohol is a severe irritant of the eyes, nose, upper respiratory tract, and skin in animals; it also causes neurotoxic effects by all routes of exposure [Clayton and Clayton 1981]. Contact of this substance with the eyes of rabbits caused transitory corneal opacity, and skin contact caused mild irritation [NIOSH 1991; Grant 1986]. Although the 4- and 8-hr LC_{50}s in rats are 165 and 76 ppm, respectively, the lowest 4-hr lethal concentration in monkeys is 1,000 ppm [NIOSH 1991]. Rats acutely exposed to 3.9 ppm (a concentration capable of depressing the respiration rate by 50%) exhibited no signs of pulmonary irritation at necropsy [NLM 1991]. Animals sacrificed following acute inhalation showed signs of pulmonary edema and liver congestion and damage at autopsy [Proctor et al. 1988]. When rats were administered allyl alcohol and allowed 96 hr to recover before sacrifice, they developed acidophilia, vacuolation, and necrosis of the pancreatic acinar cells [NLM 1991]. The lowest reported oral LD_{50} in rats is 64 mg/kg [NIOSH 1991]. The dermal LD_{50} in rabbits is 45 mg/kg [NIOSH 1991]. Rats, rabbits, guinea pigs, and dogs exposed to 7 ppm for 7 hr/day during a 6-month period developed cloudy swelling and focal necrosis of the liver plus necrosis of the renal convoluted tubules. These effects were mild and reversible when exposure was discontinued [NLM 1991]. Rats that consumed drinking water containing allyl alcohol (100, 200, or 800 ppm for 15 weeks) had a dose-related decrease in water intake, food consumption, and weight gain but an increase in terminal organ weights for the liver, spleen, and kidneys [NLM 1991]. Allyl alcohol is directly mutagenic in some bacterial test systems [NIOSH 1991; NLM 1991].

2. *Effects on Humans*: Allyl alcohol is a severe irritant of the eyes, nose, upper respiratory tract, and skin in humans;

this substance can be absorbed through the skin in sufficient amounts to cause systemic toxicity. One man was temporarily blinded after being exposed to the vapor of allyl alcohol [Clayton and Clayton 1981]. Irritation of the eyes with tearing is noticeable at 5 ppm in some individuals, and irritation of the nose and throat begins at 10 to 15 ppm [ACGIH 1991a; Grant 1986]. Allyl alcohol is well absorbed through the skin, producing deep muscle pain believed to be caused by muscle spasm [Clayton and Clayton 1981]. In contact with the skin, allyl alcohol causes chemical burns with vesiculation and superficial necrosis [NLM 1991]. Inhalation exposures may lead to pulmonary edema [NLM 1991]. One worker died following a 1-hr exposure to 1,000 ppm [NIOSH 1991]. Systemic toxicity is manifested in humans as visceral congestion, periportal congestion of the liver, nephritis, and blood in the urine [ACGIH 1991a].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to allyl alcohol can cause irritation of the nose, throat, and lungs, and severe overexposure may lead to pulmonary edema with slowly developing distress. Burns and corrosion of the skin plus muscle pain can occur following prolonged contact with the liquid. Exposure of the eyes to liquid or vapor causes irritation, tearing, pain behind the eyeballs, transient corneal injury, and blurred vision and photophobia during exposure to light.

2. *Chronic exposure*: No signs or symptoms of chronic allyl alcohol exposure have been reported, but it may exacerbate chronic respiratory, liver, and kidney disease.

- **Emergency procedures**

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Tissue destruction and blindness may result from exposure to concentrated solutions, vapors, mists, or aerosols of allyl alcohol. ***Immediately but gently*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Severe burns, skin corrosion, and absorption of lethal amounts may result! ***Immediately*** remove contaminated clothing! ***Immediately, continuously, and gently*** wash skin for at least 15 min. Use soap and water if skin is intact; use only water if skin is not intact.

3. *Inhalation exposure*: If vapors, mists, or aerosols of allyl alcohol are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if allyl alcohol or a solution containing it is ingested:

—Seek medical attention ***immediately***.

—Do ***not*** induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water. Immediately after rinsing, have the victim drink one cup (8 oz) of fluid and ***no more***.

—Do ***not*** permit the victim to drink milk or carbonated beverages!

—Do ***not*** permit victim to drink any fluid if more than 60 min have passed since initial ingestion.

NOTE: These instructions must be followed exactly. Drinking a carbonated beverage or more than one cup of fluid could create enough pressure to perforate already damaged stomach tissue. The tissue-coating action of milk may impede medical assessment of tissue damage. Ingestion of any fluid more than 60 min after initial exposure could further weaken damaged tissue and result in perforation.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve allyl alcohol and may result in worker exposures to this substance:

—Preparation of various allyl esters that serve as monomers and prepolymers in the manufacture of resins and plasticizers

—Use of allyl alcohol as a chemical intermediate

—Manufacture of pharmaceuticals and military poison gas

—Use of allyl alcohol as a fungicide, herbicide, and nematicide

—Manufacture of flavorings, perfumes, allyl esters, glycerol, acrolein, and glycerin

The following methods are effective in controlling worker exposures to allyl alcohol, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

• Preplacement medical evaluation

Before a worker is placed in a job with a potential for exposure to allyl alcohol, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, respiratory tract, kidney, and liver. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to allyl alcohol at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with eye, skin, respiratory, kidney, or liver disease.

• Periodic medical examinations and biological monitoring

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to allyl alcohol exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of allyl alcohol on the eyes, skin, respiratory system, kidneys, and liver. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. Although alcohols can be detected in the blood and urine of exposed individuals, no biological monitoring test acceptable for routine use has yet been developed for allyl alcohol.

• Medical examinations recommended at the time of job transfer or termination

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termina-

tion. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne allyl alcohol is determined by using a solid sorbent tube (100/50-mg sections, 20/40 mesh) filled with coconut shell charcoal. Samples are collected at a maximum flow rate of 0.2 liter/min until a minimum air volume of 10 liters is collected. The sample is then treated with a carbon disulfide/dimethylformamide solution to extract the allyl alcohol. Analysis is conducted by gas chromatography using a flame ionization detector. The standard analytical error for this procedure is 0.18. This method is included in the OSHA Computerized Information System [OSHA 1989] and in Method 1402 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

Because allyl alcohol can be absorbed through the skin in lethal amounts, workers should immediately and thoroughly wash with soap and water any areas of the skin that have come in contact with this substance.

Clothing and shoes contaminated with allyl alcohol should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of allyl alcohol, particularly its potential for being absorbed through the skin in toxic amounts.

A worker who handles allyl alcohol should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where allyl alcohol or a solution containing allyl alcohol is handled, processed, or stored.

STORAGE

Allyl alcohol should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Outside or detached storage is preferred; inside storage should be in a standard flammable liquids storage room that is separated from all oxidizing agents. Storage facilities and electrical service should be appropriate for this OSHA Class IB flammable liquid [29 CFR 1910.106]. Containers of allyl alcohol should be protected from physical damage and should be stored separately from oxidizing agents, heat, sparks, and open flame. To prevent static sparks, containers should be grounded and bonded when this substance is transferred from one container to another. Only nonsparking tools may be used to handle allyl alcohol. Because empty containers that formerly contained allyl alcohol may contain product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving allyl alcohol, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. Use water spray to reduce vapors if the spill or leak has not ignited.
6. Absorb small spills with vermiculite, sand, or other noncombustible materials and place the material in a covered container for later disposal.
7. For large liquid spills, build dikes far ahead of the spill to contain the allyl alcohol for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

If 1,000 lb or more of allyl alcohol is present at a facility, the owner or operator must comply with EPA's emergency planning requirements [40 CFR 355.30].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is equal to or greater than the

reportable quantity for that chemical, employers are required by EPA regulation resulting from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for allyl alcohol is 100 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center *immediately* at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of allyl alcohol emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Allyl alcohol is listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.] and has been assigned EPA Hazardous Waste No. P005. This substance has been banned from land disposal and may be treated by fuel substitution or incineration. Allyl alcohol may also be disposed of in an organometallic or organic lab pack that meets the requirements of 40 CFR 264.316 or 265.316.

Providing detailed information about the removal and disposal of chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of allyl alcohol are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous substances to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of allyl alcohol exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information about the selection and use of respirators and the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Because allyl alcohol can be absorbed through the skin in lethal amounts, protective clothing should be worn to prevent skin contact. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been tested against permeation by allyl alcohol and have demonstrated good-to-excellent resistance: butyl rubber, Viton®, and Teflon®. Both butyl rubber and Teflon may provide more than 8 hr of resistance to permeation by allyl alcohol. Neoprene, natural rubber, and polyvinyl alcohol have demonstrated poor resistance to permeation by allyl alcohol.

Safety glasses, goggles, or face shields should be worn during operations in which allyl alcohol might contact the

eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with allyl alcohol. Contact lenses should not be worn if the potential exists for allyl alcohol exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ALLYL CHLORIDE

INTRODUCTION

This guideline summarizes pertinent information about allyl chloride for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

C_3H_5Cl

- **Structure**

$CH_2{=}\ CHCH_2Cl$

- **Synonyms**

3-Chloropropene, 1-chloro-2-propene, α-chloropropylene, chlorallylene, 3-chloropene, 3-chloro-1-propene, 3-chloropropylene, 2-propenyl chloride

- **Identifiers**

1. CAS No.: 107-05-1
2. RTECS No.: UC7350000
3. DOT UN: 1100 57
4. DOT labels: Flammable Liquid, Poison

- **Appearance and odor**

Allyl chloride is a colorless, yellow, or purple liquid with an unpleasant, garliclike odor. The odor threshold is reported to be 0.47 part per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 76.5
2. Boiling point (at 760 mm Hg): 44° to 45°C (111.2° to 113°F)
3. Specific gravity (water = 1): 0.94
4. Vapor density (air = 1 at boiling point of allyl chloride): 2.6
5. Melting point: -134.5°C (-209°F)
6. Vapor pressure at 20°C (68°F): 295 mm Hg
7. Solubility: Slightly soluble in water; miscible with alcohol, chloroform, ether, and petroleum ether
8. Evaporation rate (butyl acetate = 1): Approximately 7

- **Reactivity**

1. Conditions contributing to instability: Violent polymerization and explosions may occur when allyl chloride is heated or comes into contact with acid catalysts, ferric chloride, aluminum chloride, Lewis acids, or Ziegler-type initiators.
2. Incompatibilities: Fires and explosions may result from contact of allyl chloride with ethylene diamine, ethyleneimine, oleum, chlorosulfonic acid, or with benzene or toluene in the presence of ethyl aluminum dichloride or ethyl aluminum sesquichloride.
3. Hazardous decomposition products: Toxic gases and vapors (such as hydrogen chloride, phosgene, and carbon monoxide) may be released in a fire involving allyl chloride.
4. Special precautions: Allyl chloride attacks some coatings and some forms of plastic and rubber. This substance is also highly corrosive to steel.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 3 (severe fire hazard) to allyl chloride.

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Occupational Safety and Health Administration

1. Flash point: -31.7°C (-25°F) (closed cup)

2. Autoignition temperature: 391°C (737°F)

3. Flammable limits in air (% by volume): Lower, 3.3; upper, 11.1

4. Extinguishant: Use carbon dioxide, dry chemical, or alcohol foam to extinguish fires involving allyl chloride; do *not* use a solid stream of water because the stream will scatter and spread the fire.

Fires involving allyl chloride should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of allyl chloride may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a cylinder becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving allyl chloride. Chemical protective clothing that is specifically recommended for allyl chloride may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by allyl chloride.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for allyl chloride is 1 ppm (3 mg/m^3) as an 8-hr time-weighted average (TWA) concentration and 2 ppm (6 mg/m^3) as a short-term exposure limit (STEL). A STEL is a 15-min TWA exposure that should not be exceeded at any time during a workday [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 1 ppm (3 mg/m^3) as a TWA for an 8-hr workshift and a 40-hr workweek and 2 ppm (6 mg/m^3) as a STEL [NIOSH 1988].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned allyl chloride a threshold limit value (TLV) of 1 ppm (3 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek and a STEL of 2 ppm (6 mg/m^3) for periods not to exceed 15 min. The TLV also bears a "Skin" notation, which indicates that the cutaneous route of exposure (including mucous membranes and eyes) contributes to overexposure [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of liver and kidney damage, and neuropathic effects associated with exposure to allyl chloride. The TLV also recommends a "Skin" notation; however, the TLV Committee has solicited quantitative data to serve as a basis for further evaluating the need for a "Skin" notation [ACGIH 1991a].

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to allyl chloride can occur through inhalation, ingestion, skin absorption, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Allyl chloride is an irritant of the eyes, mucous membranes, and skin in animals; chronic exposure causes liver, kidney, lung, and nervous system damage. When instilled into the eyes of rabbits, allyl chloride caused damage rated as 2 on an ascending severity scale of 1 to 10 [Grant 1986]. Prolonged contact of allyl chloride with the skin causes moderate irritation [Clayton and Clayton 1981; NIOSH 1991]. The maximum acute allyl chloride exposures survived by rats were 29,300 ppm for 15 min, 2,900 ppm for 1 hr, and 290 ppm for 3 hr [NLM 1992]. Mice and rats have also survived 6-hr acute exposures of 800 ppm but not 1,000 to 2,000 ppm. The no-effect level in rats was 200 ppm, and dose-related kidney damage was induced in mice and rats exposed to ≥500 and 300, respectively [ACGIH 1991a]. One of six rats died following an acute 4-hr exposure of 2,000 ppm [Smyth and Carpenter 1948]. The 2-hr LC_{50} was 3,514 ppm in rats and 3,674 ppm in mice. The target organs of toxicity were the liver, kidneys, nervous system, and lungs [ACGIH 1991a]. Rats exposed to 16,000 ppm for 2 hr developed eye and nose irritation, weakness, incoordination, drowsiness, and dyspnea before death. Histopathology at autopsy revealed pulmonary hemorrhage, severe kidney damage, and mild liver injury [Proctor et al. 1988]. Tissue burns and pulmonary edema may develop on a delayed basis [NLM 1992]. The dermal LD_{50} in rabbits is 2,063 mg/kg [Smyth and Carpenter 1948]. In prolonged contact with the skin, allyl chloride caused moderate irritation [Grant 1986]. The oral LD_{50} in rats is

700 mg/kg [Smyth and Carpenter 1948]. Rats, guinea pigs, rabbits, and dogs exposed to allyl chloride at 8 ppm for 7 hr/day for 1 month were asymptomatic but had liver and kidney necrosis at autopsy [Clayton and Clayton 1981]. When these animals were exposed at 3 ppm on the same regimen for 6 months, no exposure-related effects were seen at autopsy (except for reversible liver effects in female rats) [Clayton and Clayton 1981]. Allyl chloride was neurotoxic in multiple species by inhalation, gavage, and parenteral routes of administration. The neurotoxicity has been classified as a degenerative central-peripheral distal axonopathy [ACGIH 1991a]. Allyl chloride was embryotoxic and had developmental effects in rats and mice exposed by inhalation, or by oral or intraperitoneal routes of administration [NIOSH 1991]. Allyl chloride was fetotoxic in rats exposed to 300 ppm, but not in rats exposed to 30 ppm. The chemical was not fetotoxic in rabbits or embryotoxic or teratogenic in rats or rabbits following inhalation of 30 or 300 ppm for 7 hr/day on gestation days 6 to 15 (rats) or 6 to 18 (rabbits) [NLM 1992]. Allyl chloride is mutagenic in *Salmonella typhimurium* and induces gene conversions in *Saccharomyces cerevisiae* [NLM 1992]. It has also been tested for carcinogenicity in mice by several routes of exposure: gavage, skin application, and intraperitoneal injection. A nonsignificant increase in metastasizing squamous cell carcinomas was noted in the forestomachs of mice treated by gavage with doses ranging from 129 to 258 mg/kg. No skin tumors resulted from repeated skin applications; however, allyl chloride acted as an initiator in mice receiving single dermal applications in two-stage carcinogenesis assays. Mice given intraperitoneal injections of allyl chloride showed a significant increase in the incidence of lung adenomas [IARC 1985]. Rats treated by gavage with doses ranging from 55 to 71 mg/kg showed no increase in the incidence of tumors [IARC 1985]. On the basis of these studies, the International Agency for Research on Cancer (IARC) has concluded that there is insufficient evidence that allyl chloride is a carcinogen in treated animals [IARC 1985].

2. *Effects on Humans*: Allyl chloride is an irritant of the eyes, mucous membranes, upper respiratory tract, and skin in humans. Exposure to 25 ppm causes nasal irritation; 50 to 100 ppm causes eye irritation; and concentrations greater than these result in eye pain, conjunctivitis, sensitivity to light, and corneal burns [Grant 1986; Clayton and Clayton 1981; NLM 1992]. Exposure to saturated vapors for a few minutes can be life-threatening [NLM 1992]. Prolonged skin contact may cause a painful sensation described as a deep "bone ache" [Clayton and Clayton 1981]. Other signs and symptoms of chronic exposure have included headache, dizziness, vertigo, nausea, vomiting, proteinuria, hematuria, electrolyte elevations, increased glomerular filtration rates, severe kidney injury, and polyneuropathies [NLM 1992]. Workers exposed to concentrations of allyl chloride above 3 mg/m^3 (1 ppm) demonstrated evidence of kidney dysfunction; exposures to unspecified concentrations were reported to impart a garlic odor to the breath and skin of exposed workers and to alter the results of their liver function tests [Clayton and Clayton 1981]. Exposed female workers had decreased maximum ventilatory capacities [NLM 1992]. Workers exposed to allyl chloride concentrations ranging from 1 to 113 ppm for 16 months showed clinical signs of reversible liver damage as these signs subsided following cessation of exposure [IARC 1985]. Weakness, paresthesia, numbness, and distal neuropathy have been seen in chronically exposed workers; removal from exposure caused a reversal of their neurotoxic signs and symptoms [ACGIH 1991a].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Exposure to allyl chloride can cause irritation of the eyes, with redness, pain, conjunctivitis, corneal burns, and a sensitivity to light that may not be manifested for several hours after exposure; irritation of the upper respiratory tract, with coughing, difficult breathing, and delayed-onset pulmonary edema; and redness and irritation of the skin.

2. *Chronic exposure*: Exposure to allyl chloride can cause irritation of tissues including the respiratory tract mucosa, photophobia, headache, dizziness, vertigo, nausea, vomiting, dyspnea, deep bone or muscle pain caused by prolonged skin contact, and numbness, weakness, and tingling or prickly sensations in the hands and feet.

- **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of allyl chloride. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of allyl chloride are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if allyl chloride or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve allyl chloride and may result in worker exposures to this substance:

—Manufacture of glycerin, epichlorohydrin, allyl alcohol, allyl amines, allyl silanes, allyl ethers of starch, and 1,2,3-trichloropropane; pharmaceuticals; polymers, plastics, and resins; perfumes; and insecticides

—Use of allyl chloride as a catalyst and modifier in the production of resins

—Use of allyl chloride in the production of barbiturates and hypnotic agents

The following methods are effective in controlling worker exposures to allyl chloride, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

• Preplacement medical evaluation

Before a worker is placed in a job with a potential for exposure to allyl chloride, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, liver, kidneys, and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific

job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to allyl chloride at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with chronic eye, respiratory, liver, or kidney abnormalities.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to allyl chloride exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of allyl chloride on the eyes, liver, kidneys, and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

No biological monitoring test acceptable for routine use has yet been developed for allyl chloride.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population. Because occupational exposure to allyl chloride may cause diseases with prolonged latent periods, the need for medical monitoring may extend well beyond the termination of employment.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne allyl chloride is determined by using coconut shell charcoal tubes (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 1.0 liter/min until a maximum air volume of 100 liters is collected. The sample is then treated either with benzene or a mixture of carbon disulfide/dimethylformamide (99:1) to extract the allyl chloride. Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is 0.01 mg per sample. This method is described in Method No. 1000 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If allyl chloride contacts their skin, workers should immediately wash the affected areas with soap and water.

Clothing and shoes contaminated with allyl chloride should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of allyl chloride, particularly its potential to be irritating to and absorbed by the skin.

A worker who handles allyl chloride should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where allyl chloride or a solution containing allyl chloride is handled, processed, or stored.

STORAGE

Allyl chloride should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. The storage area must meet OSHA requirements for Class IB flammable liquids [29 CFR 1910.106]. Containers of allyl chloride should be protected from physical damage and should be separated from incompatible chemicals, heat, sparks, and open flame. To prevent static sparks, metal containers and equipment used to transfer allyl chloride must be grounded and bonded. Because empty containers may still hold allyl chloride residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving allyl chloride, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. Use water spray to reduce vapors, but do not use water spray to prevent ignition in closed spaces.

6. Prohibit contact with the material unless personnel are wearing fully effective personal protective equipment.

7. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

8. Dike far ahead of large liquid spills for later disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether these requirements have been changed.

- **Emergency planning requirements**

Allyl chloride is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a chemical release that is equal to or greater than the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal authorities.

The reportable quantity for allyl chloride is 1,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of allyl chloride per calendar year are required by EPA [40 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of allyl chloride emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although allyl chloride is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of allyl chloride exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular

respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing (gloves, face shields, aprons, boots, and body-covering clothing) should be worn to prevent skin contact with allyl chloride. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Polyvinyl alcohol and Teflon® have been tested against permeation by allyl chloride and have demonstrated breakthrough times of 1 to 4 hr. Butyl rubber, natural rubber, polyvinyl chloride, and Viton® have demonstrated poor resistance to permeation by allyl chloride.

If allyl chloride is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, gas-tight goggles, or face shields should be worn during operations in which allyl chloride might contact the eyes (e.g., through splashes of solution); face shields alone, however, are not adequate for eye protection. Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with allyl chloride. Contact lenses should not be worn if the potential exists for allyl chloride exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR 2-AMINOPYRIDINE

INTRODUCTION

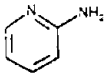
This guideline summarizes pertinent information about 2-aminopyridine for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$(NH_2)C_5H_4N$

- **Structure**



- **Synonyms**

α-Aminopyridine; 1,2-dihydro-2-iminopyridine; 2-pyridylamine; o-aminopyridine; amino-2-pyridine; α-pyridinamine, 2 AP

- **Identifiers**

1. CAS No.: 504-29-0
2. RTECS No.: US1575000
3. DOT UN: 2671 55
4. DOT label: Poison

- **Appearance and odor**

2-Aminopyridine is a combustible, colorless or white, crystalline solid that has an odor described as "characteristic."

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 94.1
2. Boiling point (at 760 mm Hg): 210.6°C (411.1°F)
3. Specific gravity (water = 1): Greater than 1
4. Vapor density (air = 1 at boiling point of 2-aminopyridine): 3.2
5. Melting point: 58.1°C (136.6°F)
6. Vapor pressure at 25°C (77°F): 0.8 mm Hg
7. Solubility: Soluble in water, alcohol, benzene, ether, and acetone
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, or open flame
2. Incompatibilities: Fires and explosions may result from contact of 2-aminopyridine with strong oxidizers, strong acids, or sodium nitrate.
3. Thermal decomposition products: Toxic gases (such as oxides of nitrogen, carbon dioxide, and carbon monoxide) may be released when 2-aminopyridine burns or is heated to decomposition.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to 2-aminopyridine; other sources rate 2-aminopyridine as a moderate fire hazard.

1. Flash point: 68°C (154°F) (closed cup)
2. Autoignition temperature: Data not available
3. Flammable limits in air: Data not available

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

4. Extinguishant: Use dry chemical, carbon dioxide, or alcohol foam to extinguish fires involving 2-aminopyridine. Do not use a solid stream of water because the stream will scatter and spread the fire. However, water spray may be used to cool fire-exposed containers.

Fires involving 2-aminopyridine should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of 2-aminopyridine may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving 2-aminopyridine. Chemical protective clothing that is specifically recommended for 2-aminopyridine may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by 2-aminopyridine.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for 2-aminopyridine is 0.5 part per million (ppm) parts of air (2 mg/m^3) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 0.5 ppm (2 mg/m^3) as an 8-hr TWA [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned 2-aminopyridine a threshold limit value (TLV) of 0.5 ppm (2 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of systemic poisoning associated with exposure to 2-aminopyridine.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to 2-aminopyridine can occur through inhalation, ingestion, eye or skin contact, and absorption through the skin.

• Summary of toxicology

1. *Effects on Animals*: 2-Aminopyridine is a dermally absorbed, central nervous system stimulant and convulsant in animals. When instilled into the eyes of rabbits, 2-aminopyridine causes only mild, reversible injury [Grant 1986]. 2-Aminopyridine is rapidly absorbed through the skin and has caused convulsions and death in guinea pigs exposed by this route [Clayton and Clayton 1981]. The acute dermal LD_{50} in guinea pigs is 0.5 ml/kg (approximately 500 mg/kg) [Clayton and Clayton 1981]. The acute oral LD_{50} is 50 mg/kg in mice and 200 mg/kg in rats. Acutely poisoned animals exhibit tremors, excitement, seizures, and tetany before death from respiratory failure [Clayton and Clayton 1981]. 2-Aminopyridine is nonmutagenic in *Salmonella typhimurium* [NLM 1992].

2. *Effects on Humans*: Intoxication from 2-aminopyridine can occur from inhalation of the dust or vapor or from skin absorption following direct contact. 2-Aminopyridine is a convulsant in humans and is moderately irritating to the skin and eyes [Clayton and Clayton 1981]. The lowest concentration and duration of exposure reported to be toxic in humans is 5 ppm for 5 hr; the toxic effects caused by this exposure include confusion and convulsions [NIOSH 1991]. A worker who was milling 2-aminopyridine developed high blood pressure, headache, nausea, and flushing of the extremities; subsequent air sampling demonstrated a level of 5.2 ppm; this worker had recovered completely by the following day [Clayton and Clayton 1981]. A chemical operator who continued to work for 1½ hr in clothing contaminated with 2-aminopyridine developed headache, difficult breathing, dizziness, and convulsions and died from respiratory failure [Clayton and Clayton 1981]. He may also have absorbed this substance through his skin [ACGIH 1991a]. Ingestion of as little as 60 mg in adult humans has resulted in severe poisoning, which included such signs and symptoms as: profuse sweating, burning of throat, weakness, nausea, disorientation, dizziness, thirst, ocular paresthesias, psychoticlike behavior, tremors, dyspnea, and convulsions [NLM 1992].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to 2-aminopyridine can cause irritation, headache, dizziness, nausea, flushing of the extremities, elevated blood pressure, weakness, difficult breathing, confusion, ocular paresthesias, seizures, and stupor. In severe poisoning, exposure to this substance may cause respiratory failure and death.

2. *Chronic exposure*: No signs or symptoms of chronic exposure to 2-aminopyridine have been reported.

- **Emergency procedures**

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Irritation may result! ***Immediately*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: 2-Aminopyridine can cause skin irritation and can be absorbed through the skin in lethal amounts. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water for at least 15 min.

3. *Inhalation exposure*: If respirable 2-aminopyridine is inhaled, move the victim to fresh air ***immediately***. Have the victim blow his or her nose or use a soft tissue to swab particulates from the nostrils.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if 2-aminopyridine or a solution containing it is ingested:

—Do ***not*** induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve 2-aminopyridine and may result in worker exposures to this substance:

—Manufacture of pharmaceuticals, especially antihistamines

—Manufacture of hair dyes and other dyes

—Use of 2-aminopyridine in chemical synthesis

The following methods are effective in controlling worker exposures to 2-aminopyridine, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to 2-aminopyridine, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the central nervous and respiratory systems. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to 2-aminopyridine at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history or findings consistent with seizure or other central nervous system disorders or chronic respiratory disease.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to 2-aminopyridine exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of 2-aminopyridine on the central nervous and respiratory systems. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissue or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for 2-aminopyridine.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne 2-aminopyridine is determined by using two Tenax-GC tubes in series (the first tube contains a single 35-mg section and the second tube contains a single 17-mg section; both sections are 35/60 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 12 liters is collected. The sample is then analyzed by gas chromatography using a flame ionization detector. This method is included in the OSHA Computerized Information System [OSHA 1986]. NIOSH has a similar method for analyzing 2-aminopyridine (Method S158) in the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

Because 2-aminopyridine can be absorbed through the skin in lethal amounts, workers should immediately remove any contaminated clothing and wash thoroughly with soap and water any areas of the skin that have come in contact with this substance.

Clothing and shoes contaminated with 2-aminopyridine should be removed immediately and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of 2-aminopyridine, particularly its potential for being absorbed through the skin in lethal amounts.

A worker who handles 2-aminopyridine should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where 2-aminopyridine is handled, processed, or stored.

STORAGE

2-Aminopyridine should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. All electrical service in storage areas should be of explosionproof design. Containers of

2-aminopyridine should be protected from physical damage and should be stored separately from oxidizing agents, strong acids, sodium nitrate, heat, sparks, and open flame. Because empty containers may contain 2-aminopyridine residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving 2-aminopyridine, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Provide maximum explosionproof ventilation.
5. Use nonsparking tools during cleanup.
6. Carefully collect solid material and place it in a covered container for disposal.
7. To the extent feasible, avoid generating dust during cleanup.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

2-Aminopyridine is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of 2-aminopyridine; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of 2-aminopyridine emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although 2-aminopyridine is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of 2-aminopyridine exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional informa-

tion on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with 2-aminopyridine. Gloves, aprons, boots, and chemical-protective suits should be worn when workers are handling this substance. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to 2-aminopyridine permeation; however, butyl rubber has been tested against chemically similar materials (pyridines) and has demonstrated good-to-excellent resistance. Since specific test data are not available for 2-aminopyridine, the information provided here should be considered as a guideline only. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to 2-aminopyridine.

If 2-aminopyridine is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which 2-aminopyridine might contact the eyes (e.g., through dust particles or splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with 2-aminopyridine. Contact lenses should not be worn if the potential exists for 2-aminopyridine exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR AMMONIA

INTRODUCTION

This guideline summarizes pertinent information about ammonia for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

NH_3

- **Structure**

NH_3

- **Synonyms**

Anhydrous ammonia, ammonia gas, Am-fol, Nitro-sil, aqua ammonia, spirit of hartshorn

- **Identifiers**

1. CAS No.: 7664-41-7

2. RTECS No.: BO0875000

3. DOT UN: 1005 15 (anhydrous); 2073 15 (solutions containing more than 44% ammonia); 2672 60 (solutions containing 12% to 44% ammonia)

4. DOT labels: Poison Gas, Nonflammable Gas

- **Appearance and odor**

At room temperature, ammonia is a colorless, flammable gas; it is shipped as a liquid under its own vapor pressure. This substance has a penetrating and pungent odor. The odor threshold is reported to be 5 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 17.0

2. Boiling point (at 760 mm Hg): -33.4°C (-28°F)

3. Specific gravity: 0.77 at 0°C (32°F)

4. Vapor density (air = 1 at boiling point of ammonia): 0.6

5. Melting point: -77.7°C (-107.8°F)

6. Vapor pressure at 20°C (68°F): 8,500 mm Hg

7. Solubility: Very soluble in water, alcohol, ether, and chloroform

8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Under certain conditions, mixtures of ammonia and air will explode when ignited.

2. Incompatibilities: Fires and explosions may result from contact of ammonia with trimethylammonium amide, 1-chloro-2,4-dinitrobenzene, o-chloronitrobenzene, platinum, trioxygen difluoride, selenium difluoride dioxide, boron halides, acids, mercury, chlorine, iodine, bromine, hypochlorites, or chlorine bleach.

3. Hazardous decomposition products: Toxic gases (such as hydrogen gas, nitrogen gas, and nitrous oxides) may be released when ammonia decomposes.

4. Special precautions: Liquid ammonia attacks some coatings and some forms of plastic and rubber; this substance should not be allowed to contact copper, brass, bronze, or galvanized steel.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 1 (slight fire hazard) to ammonia.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

1. Flash point: Not applicable (ammonia is a gas at room temperature).

2. Autoignition temperature: 651°C (1,204°F)

3. Flammable limits in air (% by volume): Lower, 16; upper, 25.

4. Extinguishant: Use water spray or fog.

Fires involving ammonia should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and should ventilate closed spaces before entering. Containers of ammonia may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Do not get water inside the container. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Because ammonia is highly soluble in water, dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving ammonia. Firefighters' protective clothing may not provide protection against permeation by ammonia.

EXPOSURE LIMITS

- **OSHA PEL**

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for ammonia is 35 ppm (27 mg/m^3) as a 15-min short-term exposure limit (STEL) [29 CFR 1910.1000, Table Z-1-A]. A STEL is a 15-min time-weighted average (TWA) exposure which should not be exceeded at any time during the workday.

- **NIOSH REL**

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for ammonia of 25 ppm (17 mg/m^3) as an 8-hr TWA and 35 ppm as a STEL [NIOSH 1992a].

- **ACGIH TLV®**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned ammonia a threshold limit value (TLV) of 25 ppm (17 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek; a STEL of 35 ppm (24 mg/m^3) has been established for periods not to exceed 15 min [ACGIH 1991b].

- **Rationale for limits**

The limits are based on the risk of eye irritation and respiratory effects associated with exposure to ammonia. OSHA did not find it necessary to establish a TWA to protect against chronic effects. OSHA concluded that a STEL would protect against the substance's irritant effects.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Exposure to ammonia can occur through inhalation and eye or skin contact.

- **Summary of toxicology**

1. *Effects on Animals*: Ammonia is a severe irritant of the eyes, respiratory tract, and skin. Liquified ammonia can induce freezing, burns, and corrosion of tissues. Exposure of guinea pigs to 5,000 to 6,000 ppm for 30 to 120 min induced blindness [AIHA 1988]. The approximate 1-hr LC_{50} for cats and rabbits was 9,900 ppm. This concentration induced severe bronchiolar damage, alveolar congestion, edema atelectasis, hemorrhage, and emphysema in the animals that died [NLM 1991]. The 4-hr LC_{50} in rats is 2,000 ppm, and the oral LD_{50} is 350 mg/kg [NIOSH 1992b]. In mice, the RD_{50} (the concentration capable of reducing respiratory rate by 50%) was approximately 300 ppm. Continued exposure for 6 hr/day for 5 days produced nasal lesions including hypertrophy, hyperplasia, epithelial erosion, ulceration, and necrosis [NLM 1991]. Continuous exposure to ammonia for several weeks at 658 ppm produced marked eye irritation in dogs and rabbits and corneal opacity in rabbits [Grant 1986]. Rats similarly exposed developed interstitial pneumonitis with calcification of the bronchi and renal tubules, epithelial proliferation of the renal tubules, myocardial fibrosis, and fatty liver [NLM 1991]. Rats, guinea pigs, dogs, rabbits, and monkeys exposed to 1,100 ppm for 8 hr/day, 5 days/week for 6 weeks showed signs of moderate eye and nasal irritation but no signs of systemic poisoning [AIHA 1988]. Although all monkeys, dogs, and rabbits survived a continuous 90-day exposure to 680 ppm, this exposure was fatal to 13 of 15 rats and 4 of 15 guinea pigs [AIHA 1988]. No clinically significant findings were detected at autopsy in rats continuously exposed to 180 ppm for 90 days [AIHA 1988; Clayton and Clayton 1981].

2. *Effects on Humans*: Ammonia gas is severely irritating to the eyes and to the moist skin and mucous membranes of humans. In contact with the eyes, liquid anhydrous ammonia causes severe damage that may lead to blindness [Proctor et al. 1988]. When in contact with the skin, liquified ammonia can cause freezing and third-degree burns [NLM 1991; Proctor et al. 1988]. Two volunteers exposed to ammonia at approximately 24 ppm showed signs of mild nasal irritation

on clinical examination [Clayton and Clayton 1981]. Five of six volunteers exposed to 30 or 50 ppm for 10 min reported mild to moderate eye and upper respiratory tract irritation [Clayton and Clayton 1981]. At 130 ppm, however, volunteers experienced lacrimation and nose and throat irritation; one volunteer experienced pulmonary irritation [Clayton and Clayton 1981]. Exposure of humans to 500 ppm for 30 min caused changes in respiratory rate, and exposure to 1,720 ppm produced coughing in exposed individuals [AIHA 1988]. Accidental exposure to ammonia gas or the vapors of ammonia at high concentrations (approximately 2,500 to 6,500 ppm) for up to 2 hr induced chemical pneumonitis, burns (eyes, face, and mouth), severe local edema, dyspnea, progressive cyanosis, and death [Proctor et al. 1988; Clayton and Clayton 1981]. Death is normally caused by either suffocation or pulmonary edema [Clayton and Clayton 1981]. In near-lethal cases, residual effects may include visual impairment, decreased pulmonary function, and hoarseness [Clayton and Clayton 1981].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Increasing ambient concentrations can cause contact irritation of the eyes and respiratory tract, tearing, hoarseness, violent coughing, painful breathing, impaired vision, severe eye damage, blindness, dyspnea, cyanosis, suffocation, and death. Direct contact with liquid anhydrous ammonia can cause frostbite and corrosion of the eyes and skin.

2. *Chronic exposure*: Exposure to ammonia can induce irritation of the eyes, nose, and upper respiratory tract, with coughing and difficult breathing.

- **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of frostbite, toxicity, or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: If tissue is frozen, seek medical attention ***immediately***; if tissue is not frozen, ***immediately and thoroughly*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids. If irritation, pain, swelling, lacrimation, or photophobia persists, get medical attention as soon as possible.

2. *Skin exposure*: If frostbite has occurred, seek medical attention ***immediately***; do ***not*** rub the affected areas or flush them with water. If frostbite has ***not*** occurred, ***immediately and thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: Move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if an ammonia solution is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of ammonia may result in worker exposures to this substance:

—Use as a soil fertilizer

—Use in the manufacture of fertilizers; as a solvent in the manufacture of textiles, leather, and pulp and paper processing; and as a stabilizer in the manufacture of rubber

—Use in organic and inorganic synthesis of nitric acid, urea, plastics, fibers, synthetic resins, pharmaceuticals, pesticides, explosives, rocket fuels, cyanides, amides, dyestuffs, amines, flame retardants, household cleaners, sulfuric acid, and alkalies

—Use in mining and metallurgy, ore extraction and purification, treatment of scrap metal, annealing, atomic hydrogen welding, electronics, and nitriding of steel

—Use in petroleum refining as a neutralizing agent, in the manufacture and recovery of cracking catalysts, and in the dewaxing of lubrication oils

—Use as a commercial refrigerant in food processing, the production of ice, cold storage, and de-icing operations

—Use as a substitute for calcium in the bisulfite pulping of wood

—Use with chlorine to purify municipal and industrial water supplies

The following methods are effective in controlling worker exposures to ammonia, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

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MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations must be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to ammonia, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to ammonia at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with eye, skin, or respiratory tract diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to ammonia exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of ammonia on the eyes, skin, and respiratory tract. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for ammonia.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termina-

tion. Any changes in the worker's health status should be compared with those expected for a suitable reference population. Because occupational exposure to ammonia may cause diseases with prolonged latent periods, the need for medical monitoring may extend well beyond the termination of employment.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne ammonia is determined by using sulfuric-acid-impregnated carbon bead tubes (Supelco ORBO-77 tubes). Samples are collected at a maximum flow rate of 0.1 liter/min until a minimum air volume of 1.5 liters or a maximum air volume of 24 liters is collected. The samples are desorbed with deionized water and analyzed by ion chromatography. The limit of detection for this procedure is 1.5 ppm. This method is described in *OSHA Analytical Laboratory Method* ID-188 [OSHA 1988]. NIOSH has a similar method for analyzing ammonia using liquid sorbent badges and the same analytical procedure (Method 6701) in the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If ammonia contacts the skin, workers should immediately wash the affected areas with large quantities of water. Clothing contaminated with liquid ammonia should be removed immediately and should then be thoroughly flushed with cold water. Persons laundering contaminated clothing should be informed of the hazardous properties of ammonia, particularly its potential for skin irritation.

A worker who handles ammonia should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where ammonia or a solution containing ammonia is handled, processed, or stored.

STORAGE

Ammonia should be stored in a cool, well-ventilated, fire-resistant area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Outside or detached storage is preferred. Containers of ammonia should be protected from physical damage and should be separated from oxidizers, combustible materials, heat, sparks, and open flame. Explosion proof electrical service must be installed in storage areas. Because containers that formerly contained ammonia may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving ammonia, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. Use water spray to reduce vapors; do not put water directly on the leak or spill area.
6. For small leaks, flood the area with cool water.
7. For large liquid spills, build dikes far ahead of the spill to contain the ammonia for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Employers owning or operating a facility with 500 lb or more of ammonia onsite must comply with EPA's emergency planning requirements [40 CFR 355.30].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of a hazardous substance into the environment (including the abandonment or discarding of contaminated containers) of hazardous substances. In the event of a release that is equal or greater than the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for ammonia is 100 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center *immediately* at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of ammonia per calendar year are required by EPA [49 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of ammonia emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although ammonia is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limits. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of ammonia exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. If the use of respirators is necessary, the only respirators permitted are those that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Gloves, boots, aprons, full-body suits, etc. should be worn as necessary. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been tested against ammonia and have demonstrated good to excellent resistance: butyl rubber and Teflon®. Butyl rubber may provide more than 8 hr of resistance to permeation. Saranex® has demonstrated poor resistance to permeation by ammonia.

If ammonia is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which ammonia might contact the eyes. Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with ammonia.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR AMMONIUM SULFAMATE

INTRODUCTION

This guideline summarizes pertinent information about ammonium sulfamate for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$NH_4SO_3NH_2$

- **Synonyms**

Ammonium amidosulfonate, ammonium amidosulphate, monoammonium sulfamate, sulfamic acid, monoammonium salt, sulfamate, Ammate, Amcide, Ammat, Amicide

- **Identifiers**

1. CAS No.: 7773-06-0
2. RTECS No.: WO6125000
3. DOT UN: None
4. DOT label: None

- **Appearance and odor**

Ammonium sulfamate is a white, brown-gray, or colorless crystalline noncombustible solid that is odorless.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 114.1
2. Boiling point (at 760 mm Hg): Decomposes at 160°C (320°F)
3. Specific gravity (water = 1): 1.77
4. Vapor density: Not applicable
5. Melting point: 131°C (268°F)
6. Vapor pressure at 20°C (68°F): Zero
7. Solubility: Highly soluble in water and liquid ammonia; moderately soluble in glycerol, glycol, and formamide; slightly soluble in ethanol
8. Evaporation rate: Not applicable

- **Reactivity**

1. Conditions contributing to instability: Heat
2. Incompatibilities: Fires and explosions may result from contact of ammonium sulfamate with strong oxidizers, hot water, potassium, sodium, sodium nitrite, metal chlorates, or hot acid solutions.
3. Hazardous decomposition products: Toxic gases (such as nitrogen or sulfur oxides and carbon monoxide) may be released when ammonium sulfamate decomposes.
4. Special precautions: Ammonium sulfamate is corrosive to mild steel.

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to ammonium sulfamate; this substance is not combustible.

1. Flash point: Not applicable
2. Autoignition temperature: Not applicable
3. Flammable limits in air: Not applicable
4. Extinguishant: Use an extinguishant that is suitable for the materials involved in the surrounding fire.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving ammonium sulfamate.

EXPOSURE LIMITS

• **OSHA PEL**

The current Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) for ammonium sulfamate are 10 mg/m^3 (total dust) and 5 mg/m^3 (respirable fraction) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• **NIOSH REL**

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 10 mg/m^3 (total dust) and 5 mg/m^3 (respirable fraction) as 8-hr TWAs [NIOSH 1992].

• **ACGIH TLV®**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned ammonium sulfamate a threshold limit value (TLV) of 10 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• **Rationale for limits**

The limits are based on the risk of physical irritation associated with exposure to ammonium sulfamate.

HEALTH HAZARD INFORMATION

• **Routes of exposure**

Exposure to ammonium sulfamate can occur through inhalation and eye or skin contact.

• **Summary of toxicology**

1. *Effects on Animals*: Ammonium sulfamate has a low order of toxicity in animals. When instilled into the eyes of rabbits, a 4% solution caused no irritation [Grant 1986]. The application of 20% to 50% solutions of ammonium sulfamate to the shaved skin of rats failed to produce irritation or systemic toxicity [ACGIH 1991a]. However, rabbits dermally exposed to 15% to 30% solutions for 20 days developed slight skin reactions [NLM 1991]. The oral LD_{50} is 2,000 mg/kg for rats and 3,100 mg/kg for mice [NIOSH 1991]. Continuous feeding studies in rats have shown that chronic ingestion of high doses of ammonium sulfamate impairs growth but produces no other adverse effects [ACGIH 1991a]. Intraperitoneal injection of 0.8 g/kg ammonium sulfamate in rats produced respiratory stimulation and prostration before death occurred [Proctor et al. 1988].

2. *Effects on Humans*: Ammonium sulfamate dust can cause irritation of the eyes, skin, and mucous membranes. Few data are available on the effects of ammonium sulfamate exposure in humans. Repeated application of a 4% solution to the forearms of five volunteers did not produce irritation [Proctor et al. 1988]. Ingestion has caused gastrointestinal disturbances.

• **Signs and symptoms of exposure**

1. *Acute exposure*: The signs and symptoms of acute overexposure to ammonium sulfamate include possible irritation of the eyes and nose, cough, gastrointestinal disturbances, respiratory stimulation, prostration, and death.

2. *Chronic exposure*: No signs or symptoms of chronic ammonium sulfamate exposure have been reported.

• **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Irritation may result! ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Irritation may result. ***Immediately and thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: Move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if ammonium sulfamate is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures

(e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve ammonium sulfamate and result in worker exposures to this substance:

—Application of ammonium sulfamate as a herbicide for control of woody plants

—Manufacture of fire-retardant compositions for flameproofing textiles and paper products

—Generation of nitrous oxide gas

—Manufacture of electroplating solutions

The following methods are effective in controlling worker exposures to ammonium sulfamate, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to ammonium sulfamate, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and upper respiratory tract. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to ammonium sulfamate at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with drug allergies, aspirin intolerance, or eye, skin, or upper respiratory tract diseases; individuals using anticoagulant medications also may be at increased risk.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to ammonium sulfamate exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of ammonium sul-

famate on the eyes, skin, or upper respiratory tract or on blood clotting time. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for ammonium sulfamate.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne ammonium sulfamate is determined by using tared, low-ash polyvinyl chloride filters (5 microns). Samples are collected at a maximum flow rate of 2 liters/min until a maximum air volume of 960 liters is collected. This is a gravimetric field test method based on the total weight collected; therefore, the sample does not need to be submitted to the laboratory for analysis. This method is described under "Filter Weighting Procedure" in the *OSHA Industrial Hygiene Technical Manual* [OSHA 1985]. Additional information can be found in Method 348 of the *Occupational Exposure Sampling Strategy Manual* [NIOSH 1977].

PERSONAL HYGIENE

If ammonium sulfamate contacts the skin, workers should wash the affected areas with soap and water.

Clothing and shoes that are grossly contaminated with ammonium sulfamate should be removed and provisions should be made for safely removing this chemical from these articles.

A worker who handles ammonium sulfamate should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where ammonium sulfamate is handled, processed, or stored.

STORAGE

Ammonium sulfamate should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of ammonium sulfamate should be protected from physical damage and should be separated from strong oxidizers, water, potassium, sodium, sodium nitrite, metal chlorates, hot acid solutions, heat, sparks, and open flame. Because containers that formerly contained ammonium sulfamate may still hold product residues, they should be handled appropriately.

SPILLS

In the event of a spill involving ammonium sulfamate, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate atmosphere to reduce the dust concentration.
5. Cover spills with a plastic sheet or tarp to minimize spreading; use a clean shovel to place the material into a clean, dry container; cover and remove the container from the spill area.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Ammonium sulfamate is not subject to EPA's emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is above the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act

(CERCLA) [40 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for ammonium sulfamate is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by SARA [42 USC 11022] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of ammonium sulfamate emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although ammonium sulfamate is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of ammonium sulfamate exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective gloves and clothing should be worn to prevent skin contact with ammonium sulfamate. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to ammonium sulfamate permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to ammonium sulfamate.

If ammonium sulfamate is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which ammonium sulfamate might contact the eyes (e.g., through dust particles). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with ammonium sulfamate. Contact lenses

should not be worn if the potential exists for ammonium sulfamate exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR n-AMYL ACETATE

INTRODUCTION

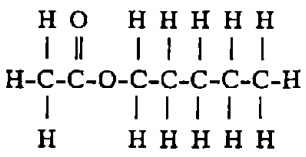
This guideline summarizes pertinent information about n-amyl acetate for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$CH_3COO(CH_2)_4CH_3$

- **Structure**



- **Synonyms**

Pentyl acetate, amyl acetic ester, pear oil, acetic acid, amyl ester, acetic acid, pentyl ester, amyl acetate, amyl acetic ether, pent-acetate, 1-pentanol acetate, primary amyl acetate

- **Identifiers**

1. CAS No.: 628-63-7
2. RTECS No.: AJ1925000
3. DOT UN: 1104 26
4. DOT label: Flammable Liquid

- **Appearance and odor**

n-Amyl acetate is a flammable, colorless liquid with a bananalike odor. The odor threshold is reported to be 0.15 part per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 130.2
2. Boiling point (at 760 mm Hg): 149°C (300°F)
3. Specific gravity (water = 1): 0.88 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of n-amyl acetate): 4.5
5. Melting point: -70.5°C (-94.9°F)
6. Vapor pressure at 20°C (68°F): 4 mm Hg
7. Solubility: Slightly soluble in water, miscible with alcohol and ether
8. Evaporation rate (butyl acetate = 1): 0.42

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, or flames
2. Incompatibilities: Fire and explosion may result from contact with nitrates, strong oxidizers, strong alkalies, or strong acids.
3. Hazardous decomposition products: Toxic gases (such as carbon monoxide), acrid smoke, and irritating fumes may be released when n-amyl acetate decomposes.
4. Special precautions: n-Amyl acetate can damage some plastics, rubbers, and coatings.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 3 (severe fire hazard) to n-amyl acetate.

1. Flash point: 25°C (77°F) (closed cup)
2. Autoignition temperature: 360°C (680°F)
3. Flammable limits in air (% by volume): Lower, 1.1; upper, 7.5

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4. Extinguishant: Use dry chemical, carbon dioxide, or alcohol foam to fight fires involving n-amyl acetate. Water should not be used as an extinguishant because it will spread the flames.

Fires involving n-amyl acetate should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of n-amyl acetate may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving n-amyl acetate. Firefighters' protective clothing may not provide protection against permeation by n-amyl acetate.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for n-amyl acetate is 100 ppm (525 mg/m^3) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 100 ppm (525 mg/m^3) as an 8-hr TWA [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned n-amyl acetate a threshold limit value (TLV) of 100 ppm (525 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of irritation of the eyes and respiratory passages associated with exposure to n-amyl acetate.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to n-amyl acetate can occur through inhalation, ingestion, or contact with the skin, eyes, and mucous membranes. n-Amyl acetate can also be absorbed slowly through the skin.

• Summary of toxicology

1. *Effects on Animals*: n-Amyl acetate is an irritant of the eyes, skin, and respiratory tract in animals. When instilled into the eyes of rabbits, n-amyl acetate liquid causes mild and reversible corneal epithelial injury [Grant 1986]. When it contacts the skin, n-amyl acetate causes defatting [AIHA 1978]. The oral LD_{50} in rats is 6,500 mg/kg [NIOSH 1991]. In rabbits, the LD_{50} in a 24-hr covered skin penetration test is greater than 20 ml/kg [AIHA 1978]. All rats exposed to approximately 5,200 ppm died within 8 hr [ACGIH 1991a]. Autopsies of animals chronically exposed at 2,000 to 5,000 ppm for extended (not further specified) periods showed injury to the lungs, brain, liver, and kidneys [AIHA 1978].

2. *Effects on Humans*: n-Amyl acetate is an irritant of the eyes, skin, and mucous membranes in humans; at high concentrations, it causes narcosis. At concentrations above 300 ppm, exposure causes burning of the eyes and conjunctival hyperemia [Grant 1986]. The lowest toxic concentration reported in humans is 200 ppm for 30 min; exposure to this concentration causes eye irritation and headaches [NIOSH 1991; Proctor et al. 1988]. Prolonged or repeated skin contact with n-amyl acetate liquid causes defatting and irritation and may lead to dermatitis [AIHA 1978].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to n-amyl acetate can cause headache, dizziness, cardiac arrhythmia, narcosis, nausea, pulmonary edema, and irritation of the eyes, nose, and throat. Skin contact with liquid n-amyl acetate results in irritation, and eye contact causes irritation, redness, and a burning sensation.

2. *Chronic exposure*: Chronic exposure to n-amyl acetate can cause defatting of the skin and contact dermatitis.

• Emergency procedures

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid

choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of n-amyl acetate. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of n-amyl acetate are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if n-amyl acetate or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve n-amyl acetate and may result in worker exposures to this substance:

—Use of n-amyl acetate as a vehicle solvent in the manufacture of cellulose nitrate lacquers, lacquer thinners, adhesives, paints, enamels, enamel removers, nitrate cements, and film cements

—Spray, hand, brush, or coating applications of paints, lacquers, lacquer thinners, film cements, enamels, adhesives, nitrate cements, and enamel removers

—Extraction of penicillin from fermentation broth during production of antibiotics

—Manufacture of photographic film, quick-drying inks, metallic inks, transfer inks, and artificial fruit-flavoring agents

—Use of n-amyl acetate as a vehicle solvent during molding operations in the manufacture of cellulose nitrate plastics, toys, eyeglass frames, combs, and novelties

—Manufacture of furniture polish, leather polish, and shoe polish

—Pre-spotting and spotting operations in the dry cleaning industry

The following methods are effective in controlling worker exposures to n-amyl acetate, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures.

To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with potential for exposure to n-amyl acetate, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to n-amyl acetate at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with chronic eye, skin, or respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to n-amyl acetate exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of n-amyl acetate on the eyes, skin, and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for n-amyl acetate.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne n-amyl acetate is determined by using a charcoal tube (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 10 liters is collected. The sample is then treated with carbon disulfide to extract the n-amyl acetate. Analysis is conducted by gas chromatography using a flame ionization detector. The standard analytical error for this procedure is 0.08. This method is included in the OSHA Computerized Information System [OSHA 1989] and in Method 1450 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If n-amyl acetate contacts the skin, workers should immediately wash the affected areas with soap and water.

Clothing and shoes contaminated with n-amyl acetate should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of n-amyl acetate, particularly its potential for causing irritation.

A worker who handles n-amyl acetate should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where n-amyl acetate or a solution containing it is handled, processed, or stored.

STORAGE

n-Amyl acetate should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of n-amyl acetate should be protected from physical damage and should be stored separately from strong oxidizers, strong alkalies, nitrates, strong acids, heat, sparks, and open flame. To prevent static sparks, metal storage containers should be bonded and electrically grounded. All tools and equipment used to open or close containers of n-amyl acetate should be of the non-

sparking type. Drums used to store n-amyl acetate must be equipped with self-closing valves, pressure-vacuum bungs, and flame arresters. Because empty containers that formerly contained n-amyl acetate may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving n-amyl acetate, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.

2. Notify safety personnel.

3. Remove any hot metal surface and all sources of heat and ignition.

4. Provide maximum explosionproof ventilation.

5. Use nonsparking tools for cleanup.

6. Absorb liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

7. For large liquid spills, build dikes far ahead of the spill to contain the n-amyl acetate for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

n-Amyl acetate is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of a hazardous substance into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is equal to or greater than the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for n-amyl acetate is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of n-amyl acetate emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although n-amyl acetate is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act of 1976 as amended (RCRA) [42 U.S.C. 690 et seq], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of n-amyl acetate are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous substances to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of n-amyl acetate exceeds

prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information about selection and use of respirators and the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any skin contact with n-amyl acetate. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Polyvinyl alcohol has demonstrated good-to-excellent resistance to permeation by n-amyl acetate, withstanding permeation for more than 4 but fewer than 8 hr. Butyl rubber has demonstrated limited resistance to permeation. Natural rubber, neoprene, nitrile rubber, Viton®, and polyvinyl chloride have demonstrated poor resistance to permeation by n-amyl acetate.

If n-amyl acetate is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which n-amyl acetate might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with n-amyl acetate. Contact lenses should not be worn if the potential exists for n-amyl acetate exposure.

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NIOSH [1987b]. Respirator decision logic. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-108.

NIOSH [1991]. Registry for toxic effects of chemical substances database: n-amyl acetate. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Standards Development and Technology Transfer, Technical Information Branch.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE

FOR sec-AMYL ACETATE

INTRODUCTION

This guideline summarizes pertinent information about sec-amyl acetate for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_7H_{14}O_2$

- **Structure**

$CH_3COOCH(CH_3)C_3H_7$

- **Synonyms**

2-Pentyl acetate, 2-pentanol acetate, 1-methylbutyl acetate, 2-acetoxypentane

- **Identifiers**

1. CAS No.: 626-38-0
2. RTECS No.: AJ2100000
3. DOT UN: 1104 26
4. DOT label: Flammable Liquid

- **Appearance and odor**

sec-Amyl acetate is a flammable, colorless liquid with a mild, transient, pear- or banana-like odor. The odor threshold is reported to be between 0.002 and 0.08 part per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 130.2
2. Boiling point (at 760 mm Hg): 121°C (249°F)
3. Specific gravity (water = 1): 0.87 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of sec-amyl acetate): 4.5
5. Melting point: −78°C (−109°F)
6. Vapor pressure at 20°C (68°F): 7 mm Hg
7. Solubility: Slightly soluble in water; soluble in alcohol and ether
8. Evaporation rate (butyl acetate = 1): 0.9

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, or open flame
2. Incompatibilities: Fires and explosions may result in contact of sec-amyl acetate with nitrates, strong oxidizers, strong alkalies, or strong acids.
3. Hazardous decomposition products: Toxic gases (such as carbon monoxide) may be released when sec-amyl acetate is heated to decomposition.
4. Special precautions: sec-Amyl acetate may soften or dissolve plastics.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 3 (severe fire hazard) to sec-amyl acetate.

1. Flash point: 32°C (89°F) (closed cup)
2. Autoignition temperature: Data not available

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3. Flammable limits in air (% by volume): Lower, 1.0; upper, 7.5

4. Extinguishant: Use dry chemical, Halon®, alcohol foam, water spray, or carbon dioxide for small fires involving sec-amyl acetate; use water spray, fog, or alcohol foam for large fires involving this substance. Water may be ineffective, but it may be used to cool fire-exposed containers.

Fires involving sec-amyl acetate should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of sec-amyl acetate may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving sec-amyl acetate. Firefighters' protective clothing may not provide protection against permeation by sec-amyl acetate.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for sec-amyl acetate is 125 ppm (650 mg/m^3) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 125 ppm (650 mg/m^3) as an 8-hr TWA [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned sec-amyl acetate a threshold limit value (TLV) of 125 ppm (665 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of eye and respiratory tract irritation associated with exposure to sec-amyl acetate.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to sec-amyl acetate can occur through inhalation, ingestion, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: sec-Amyl acetate is an irritant of the eyes, skin, and respiratory tract in animals; at high concentrations, this substance is a narcotic. Guinea pigs exposed to a 2,000 ppm experienced eye and nose irritation; at 5,000 ppm, these animals showed signs of narcosis and congestion of the lungs, with symptoms of incoordination occurring in 90 min and unconsciousness in 5 hr [ACGIH 1991a]. The lowest lethal concentration (LC_{LO}) in guinea pigs is 10,000 ppm for 5 hr [NIOSH 1991]. At autopsy, acutely poisoned animals showed slight congestion of the brain, lungs, liver, and kidneys [ACGIH 1991a; Clayton and Clayton 1981]. No chronic systemic effects have been reported.

2. *Effects on Humans*: sec-Amyl acetate is an irritant of the eyes, nose, throat, and upper respiratory tract in humans. Humans exposed to 200 ppm for 3 to 5 min experienced mild eye and nose irritation and severe throat irritation [Proctor and Hughes 1978; NIOSH 1991], and exposure to 300 ppm caused bloodshot eyes [Proctor and Hughes 1978; Clayton and Clayton 1981]. An exposure to 1,000 ppm for 1 hr caused serious (not further specified) toxic effects [Proctor et al. 1988]. On the basis of effects seen in animals, exposure to high concentrations of this substance is likely to cause narcosis [Proctor et al. 1988]. Repeated exposure of the skin to liquid sec-amyl acetate causes dermatitis [Proctor and Hughes 1978]. No chronic systemic effects have been reported in humans.

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to sec-amyl acetate can cause eye irritation with pain and redness, and skin irritation and dermatitis.

2. *Chronic exposure*: Prolonged or repeated contact of the skin with sec-amyl acetate can cause defatting of the skin and dermatitis.

• **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of sec-amyl acetate. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of sec-amyl acetate are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if sec-amyl acetate or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve sec-amyl acetate and may result in worker exposures to this substance:

—Application of lacquers, varnishes, enamels, and metallic paints

—Use of sec-amyl acetate as a solvent for chlorinated rubber, nitrocellulose, ethyl cellulose, celluloid products, cements, coated papers, lacquers, and plastic wood

—Manufacture of artificial leather, leather-finish linoleum, photographic film, artificial silk, and furniture polish

—Manufacture of nail enamels, textile printing and sizing compounds, metallic paints, perfumes, pearlescent coatings, printing compounds, and washable wallpaper

The following methods are effective in controlling worker exposures to sec-amyl acetate, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To

place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to sec-amyl acetate, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory tract. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may increase risk when a worker is exposed to sec-amyl acetate at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with chronic eye, skin, or respiratory disease.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to sec-amyl acetate exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of sec-amyl acetate on the eyes, skin, and respiratory tract. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissue or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for sec-amyl acetate.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne sec-amyl acetate is determined by using a solid sorbent tube containing coconut shell charcoal (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 10 liters is collected. The sample is then treated with carbon disulfide to extract the sec-amyl acetate. Analysis is conducted by gas chromatography using a flame ionization detector. The standard analytical error for this procedure is 0.12. This method is included in the OSHA Computerized Information System [OSHA 1989] and in Method 1450 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If sec-amyl acetate contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min and then wash with soap and water.

Clothing and shoes contaminated with sec-amyl acetate should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of sec-amyl acetate, particularly its potential to be irritating to the skin.

A worker who handles sec-amyl acetate should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where sec-amyl acetate or a solution containing sec-amyl acetate is handled, processed, or stored.

STORAGE

sec-Amyl acetate should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of sec-amyl acetate should

be protected from physical damage and should be stored separately from oxidizers, nitrates, strong alkalies, strong acids, heat, sparks, and open flame. To prevent static sparks, metal containers used to transfer this substance should be bonded and grounded. Only nonsparking tools should be used when handling containers of sec-amyl acetate. Because empty containers that formerly contained sec-amyl acetate may contain product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving sec-amyl acetate, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate the area of the spill or leak.
5. Use nonsparking tools for cleanup.
6. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.
7. For large liquid spills, build dikes far ahead of the spill to contain the sec-amyl acetate for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

sec-Amyl acetate is not subject to EPA's emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is equal to or greater than the reportable quantity for that chemical, employers are required by EPA regulations resulting from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal authorities.

The reportable quantity for sec-amyl acetate is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of sec-amyl acetate emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although sec-amyl acetate is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of sec-amyl acetate are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of sec-amyl acetate exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent skin contact with sec-amyl acetate. Solvent-resistant gloves and clothing are recommended. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Polyvinyl alcohol has been tested against permeation by this substance and has demonstrated good-to-excellent resistance.

If sec-amyl acetate is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which sec-amyl acetate might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with sec-amyl acetate. Contact lenses should not be worn if the potential exists for exposure to sec-amyl acetate.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE

FOR ANILINE

INTRODUCTION

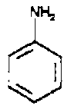
This guideline summarizes pertinent information about aniline for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_6H_5NH_2$

- **Structure**



- **Synonyms**

Aminobenzene, aminophen, aniline oil, benzenamine, blue oil, kyanol, krystallin, cyanol, phenylamine

- **Identifiers**

1. CAS No.: 62-53-3
2. RTECS No.: BW6650000
3. DOT UN: 1547 57
4. DOT label: Poison

- **Appearance and odor**

Aniline is an oily, colorless to brown, combustible liquid that darkens on exposure to air and light. It has the characteristic aromatic amine-like odor. The odor threshold is reported to be 1.1 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 93.12
2. Boiling point (at 760 mm Hg): 184°C (363°F)
3. Specific gravity (water = 1): 1.02 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of aniline): 3.22
5. Melting point: -6.3°C (20.7°F)
6. Vapor pressure at 20°C (68°F): 0.68 mm Hg
7. Solubility: Moderately soluble in water; miscible with alcohol, benzene, chloroform, and most organic solvents
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame. The vapors of aniline form explosive mixtures with air.
2. Incompatibilities: Fires and explosions may result from contact with halogens, acids (including nitric and sulfuric acids), oxidizing agents (perchlorates, peroxides, perchromates, etc.), ozone, and trichloromelamine or hexachloromelamine.
3. Hazardous decomposition products: Toxic gases (such as ammonia, carbon oxides, and nitrogen oxides) may be released when aniline is heated and/or decomposes.
4. Special precautions: Liquid aniline attacks some coatings and some forms of plastic and rubber.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 2 (moderate fire hazard) to aniline.

1. Flash point: 70°C (158°F) (closed cup)
2. Autoignition temperature: 615°C (1,139°F)

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

3. Flammable limits in air (% by volume): Lower, 1.3; upper, 11

4. Extinguishant: Use carbon dioxide, dry chemical, Halon®, water spray, or standard foam to fight fires involving aniline; never direct a solid stream of water into burning pools of liquid aniline because this will scatter and spread the fire. Water may be used to disperse vapors or to protect persons attempting to stop the leak.

Fires involving aniline should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny entry to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Cylinders of aniline may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of cylinders. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving aniline. Chemical protective clothing that is specifically recommended for aniline may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by aniline.

EXPOSURE LIMITS

- **OSHA PEL**

The current Occupational Safety and Health Administration (OSHA) PEL for aniline is 2 ppm (8 mg/m^3) as an 8-hr time-weighted average (TWA) concentration. The OSHA PEL also bears a "Skin" notation, which indicates that percutaneous absorption is a route of exposure (including mucous membranes and eyes) [29 CFR 1910.1000, Table Z-1-A].

- **NIOSH REL**

The National Institute for Occupational Safety and Health (NIOSH) has recommended that aniline be designated a potential occupational carcinogen and that exposure be limited to the lowest feasible concentration. Contact with the worker's skin should be minimized [NIOSH 1990, 1992b].

- **ACGIH TLV®**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned aniline a threshold limit value (TLV) of 2 ppm (7.6 mg/m^3) as a TWA and has also assigned aniline a "Skin" notation [ACGIH 1991b].

- **Rationale for limits**

OSHA and ACGIH limits are based on the risk of methemoglobinemia associated with exposure to aniline. The NIOSH cancer designation is based on significant evidence of increased bladder cancer in humans [NIOSH 1990].

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Exposure to aniline can occur through inhalation and by absorption through the eyes or skin.

- **Summary of toxicology**

1. *Effects on Animals*: Aniline causes methemoglobinemia in animals. Head-only versus whole-body exposure of rats for 4 hr resulted in LC_{50}s of 839 ppm and 478 ppm, respectively. These data demonstrate the significant extent to which dermal absorption occurs during ambient exposures. The dermal LD_{50} in rabbits is 820 mg/kg [NIOSH 1992a]. The oral LD_{50} in rats is 250 mg/kg, and the lowest lethal concentration in the same species is 250 ppm for 4 hr [NIOSH 1992a]. Dogs, rats, guinea pigs, and mice were exposed to 5 ppm daily for 6 months; no adverse effects were seen in these animals, except that rats developed a moderate degree of methemoglobinemia [Oberst et al. 1956]. At autopsy, rats given aniline for 5, 10, or 20 days showed splenic congestion, increased hematopoiesis, and bone marrow hyperplasia [NLM 1990]. The threshold for methemoglobinemia in rats required an exposure of 90 ppm for 4 hr. In vivo experiments with aniline induced DNA damage in the livers and kidneys of rats, and sister chromatid exchanges in the bone marrow cells of mice [NLM 1990]. In a single oral bioassay in mice and rats, aniline hydrochloride caused a significant increase in the incidence of hemangiosarcomas, sarcomas, and fibrosarcomas of the spleen and of fibrosarcomas and sarcomas of multiple body organs [NCI 1978; IARC 1987]. Based on this evidence, the International Agency for Research on Cancer (IARC) has concluded that the evidence for the carcinogenicity of aniline in animals is limited [IARC 1987].

2. *Effects on Humans*: Exposure to aniline causes the formation of methemoglobin, which results in a functional anemia that interferes with the ability of the blood to carry oxygen. Aniline is particularly dangerous because of the ease with which this substance is absorbed by the body after inhalation of the vapors or after contact of the skin with either the vapors or liquid. The oral aniline dose estimated to be lethal to 50% of exposed individuals is between 15 and 30 g, although as little as 1 g has caused mortality [Proctor et al.

1988]. Several deaths have been reported in workers acutely poisoned by aniline; cyanosis preceded death from asphyxiation [ACGIH 1991a]. Human volunteers exposed to aniline concentrations in the range of 7 to 53 ppm showed mild signs of cyanosis; increasing the concentration to 100 or 160 ppm for 1 hr caused serious signs and symptoms [Proctor et al. 1988]. Oral administration of 25 to 65 mg to adult volunteers caused a significant dose-dependent elevation in methemoglobin in the blood [Proctor et al. 1988]. Some studies suggest that chronic exposure to low concentrations of aniline is associated with the development of anemia, digestive disturbances, lack of energy, and headache [Proctor et al. 1988]. Early studies of workers exposed to aniline and to other chemicals, including some known bladder carcinogens, showed an excess of bladder cancer deaths. Studies in workers exposed to aniline alone have shown no excess risk of bladder cancer, although these studies are generally methodologically inadequate in various respects. Based on this evidence, IARC has concluded that the epidemiologic evidence of carcinogenicity is inadequate for aniline [IARC 1987]. An epidemiologic study of workers exposed to aniline and o-toluidine showed an increased risk of bladder cancer among exposed workers [NIOSH 1989, 1990]. The effects of o-toluidine and aniline could not be separated epidemiologically.

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to aniline can induce bluish discoloration of the lips, nose, earlobes, and nailbeds; headache; weakness; irritability; drowsiness; dizziness; ringing in the ears; difficult breathing; lethargy; incoordination; rapid heart beat; and unconsciousness. The onset of these signs and symptoms may be delayed as long as 4 hr after exposure. Hemolytic anemia, jaundice, and wine-colored urine may occur after severe overexposure, and these signs may be delayed for as long as 1 week after exposure.

2. *Chronic exposure*: Chronic exposure to aniline may cause headache, anemia, gastrointestinal disturbances, and lethargy. Workers who have been exposed to aniline should be notified that they may be at increased risk of bladder cancer, and they should be alerted to its signs and symptoms. These include (1) blood in the urine, (2) other changes in the appearance of the urine, (3) changes in urinary habits, (4) lumps in the groin or lower abdomen, and (5) pain in the lower abdomen or back [NIOSH 1990].

- **Emergency procedures**

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Immediately rinse concentrated solutions, vapors, mists, or aerosols of aniline from the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Aniline can be absorbed through the skin in lethal amounts. ***Immediately*** remove all contaminated clothing and wash contaminated skin with soap and water for at least 15 min.

3. *Inhalation exposure*: If vapors, mists, or aerosols of aniline are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if aniline or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve aniline and may result in worker exposures to this substance:

—Manufacture of rigid polyurethanes; chemical synthesis of intermediates for dyestuffs and rubber processing; production of methylenediphenyl isocyanate and polymethylene polyphenylisocyanate

—Synthesis of pharmaceuticals, intermediates for pharmaceuticals, hydroquinone for photographic processing, and intermediates for agricultural chemicals

—Manufacture of cloth-marking inks, indelible inks, and lithographic and other printing inks

—Production of monomers for use in nylon fiber manufacture and synthesis of resins

—Manufacture of perfumes, varnishes, black shoe polishes, solvents, paint removers, optical whitening agents, laboratory reagents, and wood stains

The following methods are effective in controlling worker exposures to aniline, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to aniline, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the cardiovascular system, blood, liver, and kidneys. A complete blood count also should be performed.

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to aniline at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with cardiovascular system, blood, liver, or kidney diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to aniline exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of aniline on the cardiovascular system, blood, liver, and kidneys. A complete blood count should be performed. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Since aniline is a potential bladder carcinogen, exposed workers should have an annual urine analysis, including microscopic examination for microhematuria and cytologic examination for neoplastic cells [NIOSH 1990].

Biological monitoring involves sampling and analysis of body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. p-Amino-phenol, a metabolite of aniline, can be measured in the urine of exposed workers. A concentration of 50 mg of total p-aminophenol per liter of urine correlates with an airborne exposure to

2 ppm. The sample should be collected at the end of the exposure period or in the first few hours after the cessation of exposure [ACGIH 1986]. A second method of monitoring for aniline exposure is to measure the methemoglobin concentration of the blood; methemoglobinemia is the first sign of excessive aniline exposure. A methemoglobin level of 1.5% in a specimen taken at the end of the exposure period or shift is a nonspecific indicator of exposure to aniline or other methemoglobinemia-inducing agents [ACGIH 1986].

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne aniline is determined by using silica gel tubes (150/75-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 30 liters is collected. The sample is then treated with 95% ethanol to extract the aniline. Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is 0.01 mg per sample. This method is described in Method 2002 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

Incidents involving dermal exposure to aniline should be treated as an emergency. Workers should flush the affected areas immediately with plenty of water for 15 min and then thoroughly wash with soap and water. All areas of the body, including the scalp, hair, fingernails, and toenails, should be scrubbed carefully.

Clothing contaminated with aniline should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering the contaminated clothing should be informed of the hazardous properties of aniline, particularly its potential for being absorbed through the skin in toxic amounts.

A worker who handles aniline should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where aniline is handled, processed, or stored.

STORAGE

Aniline should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Outside or detached storage is preferred. Containers should be inspected regularly for leakage. Containers of aniline should be protected from physical damage and should be separated from oxidizers, acids, and other incompatible chemicals, sunlight, heat, sparks, and open flame. Because containers that formerly contained aniline may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving aniline, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate atmosphere to reduce concentration.
5. Protective clothing and respiratory equipment must be worn by cleanup personnel to prevent any skin and eye contact or vapor inhalation; cleanup personnel also should work upwind or use optimum exhaust ventilation.
6. Absorb spilled material with clay, vermiculite, or other noncombustible absorbent material and place the material in a covered container for later disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities for hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Employers owning or operating a facility with 1,000 lb or more of aniline onsite must comply with EPA's emergency planning requirements [40 CFR 355.30].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the

event of a release that is above the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for aniline is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center *immediately* at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of aniline per calendar year are required [49 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of aniline emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Aniline is listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], and has been assigned EPA Hazardous Waste No. U012. Aniline is approved for land disposal as long as its concentration in the waste or treatment residual does not exceed 14 mg/kg. Aniline may also be disposed of in an organometallic or organic lab pack that meets the requirements of 40 CFR 264.316 or 265.316.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limits. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of aniline exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Because aniline can be readily absorbed through the skin, protective clothing should be worn to prevent any possibility of skin contact with liquid aniline or aniline vapors. In work areas where there is a potential for dermal exposure to aniline, gloves, boots, aprons, and gauntlets should be worn. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been recommended for use against permeation by aniline and may provide protection for periods greater than 8 hr: butyl rubber and polyvinyl alcohol. Materials that may withstand permeation for more than 4 hr but fewer than 8 hr are Teflon®, Saranex®/Tynek®, and polyethylene/ethylene vinyl alcohol (e.g., 4H® or Silver Shield®). Natural rubber, neoprene, nitrile rubber, polyvinyl chloride, and Viton® have demonstrated poor resistance to

permeation by aniline. Polyethylene has questionable value as a protective material.

If aniline is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which aniline might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with aniline. Contact lenses should not be worn if the potential exists for aniline exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE

FOR ANISIDINE (o-, p-ISOMERS)

INTRODUCTION

This guideline summarizes pertinent information about anisidine (both the ortho- and the para-isomers) for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

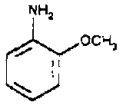
SUBSTANCE IDENTIFICATION

o-ANISIDINE

- **Formula**

$NH_2C_6H_4OCH_3$

- **Structure**



- **Synonyms**

o-Methoxyaniline, 2-methoxyaniline, 2-aminoanisole, o-anisylamine, 2-methoxybenzenamine, o-methoxyphenylamine

- **Identifiers**

1. CAS No.: 90-04-0
2. RTECS No.: BZ5410000
3. DOT UN: 2431 55
4. DOT label: St. Andrew's Cross

- **Appearance and odor**

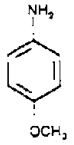
The ortho- form of anisidine is a reddish or yellowish liquid that has a characteristic amine (fishy) odor.

p-ANISIDINE

- **Formula**

$NH_2C_6H_4OCH_3$

- **Structure**



- **Synonyms**

p-Methoxyaniline, 4-methoxyaniline, 4-methoxybenzenamine, p-anisylamine, p-aminoanisole, 4-aminoanisole

- **Identifiers**

1. CAS No.: 104-94-9
2. RTECS No.: BZ5450000
3. DOT UN: None
4. DOT label: None

- **Appearance and odor**

The para- form of anisidine is a light reddish-brown, fused crystalline mass that has a characteristic amine (fishy) odor.

CHEMICAL AND PHYSICAL PROPERTIES

o-ANISIDINE

- **Physical data**

1. Molecular weight: 123.2
2. Boiling point (at 760 mm Hg): 225°C (437°F)
3. Specific gravity (water = 1): 1.1 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of o-anisidine): 4.3
5. Melting point: 5°C (41°F)
6. Vapor pressure at 20°C (68°F): Less than 0.1 mm Hg

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

7. Solubility: Practically insoluble in water; miscible with alcohol and ether

8. Evaporation rate: Data not available

• **Reactivity**

1. Conditions contributing to instability: o-Anisidine is volatile with steam and unstable with heat.

2. Incompatibilities: Fires and explosions may result from contact with strong oxidizers.

3. Hazardous decomposition products: Toxic gases (such as oxides of nitrogen and carbon monoxide) may be released during the thermal decomposition of anisidine.

4. Special precautions: Liquid anisidine attacks some coatings and some forms of plastic and rubber.

• **Flammability**

The National Fire Protection Association has assigned a flammability rating of 1 (slight fire hazard) to o-anisidine.

1. Flash point: 118°C (244°F) (open cup)

2. Autoignition temperature: Data not available

3. Flammable limits in air: Data not available

4. Extinguishant: Use dry chemical, carbon dioxide, Halon®, water spray, or standard foam to fight small fires involving anisidine; use water spray, fog, or standard foam to fight large fires involving anisidine.

Fires involving anisidine should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of anisidine may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving anisidine. Chemical protective clothing that is specifically recommended for anisidine may not provide thermal protection unless stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by anisidine.

p-ANISIDINE

• **Physical data**

1. Molecular weight: 123.2

2. Boiling point (at 760 mm Hg): 246°C (475.4°F)

3. Specific gravity (water = 1): 1.07 at 57°C (134.6°F)

4. Vapor density (air = 1 at boiling point of p-anisidine): 4.3

5. Melting point: 57°C (134.6°F)

6. Vapor pressure at 20°C (68°F): Less than 0.1 mm Hg

7. Solubility: Sparingly soluble in water; freely soluble in methanol, ethanol, and ether

8. Evaporation rate: Data not available

• **Reactivity**

1. Conditions contributing to instability: p-Anisidine is unstable with heat.

2. Incompatibilities: Fires and explosions may result from contact with strong oxidizers.

3. Hazardous decomposition products (both isomers): Toxic gases (such as oxides of nitrogen and carbon monoxide) may be released during the thermal decomposition of anisidine.

4. Special precautions: Liquid anisidine attacks some coatings and some forms of plastic and rubber.

• **Flammability**

p-Anisidine is considered a severe fire hazard, but the National Fire Protection Association has not assigned a flammability hazard rating to this chemical.

1. Flash point: 30°C (86°F) (closed cup)

2. Autoignition temperature: Data not available

3. Flammable limits in air: Data not available

4. Extinguishant: Use dry chemical, carbon dioxide, Halon, water spray, or standard foam to fight small fires involving anisidine; use water spray, fog, or standard foam to fight large fires involving anisidine.

Fires involving anisidine should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of anisidine may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain

fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving anisidine. Chemical protective clothing that is specifically recommended for anisidine may not provide thermal protection unless stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by anisidine.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for anisidine (both isomers) is 0.5 mg/m^3 (0.1 ppm) as an 8-hr time-weighted average (TWA). The OSHA PEL also bears a "Skin" notation, which indicates that the cutaneous route of exposure (including mucous membranes and eyes) contributes to overall exposure [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 0.5 mg/m^3 as an 8-hr TWA for both the para- and ortho-isomers. The NIOSH REL also bears a "Skin" notation. NIOSH considers the ortho-isomer to be a potential occupational carcinogen; exposure should therefore be limited to the lowest feasible concentration [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned both isomers of anisidine a threshold limit value (TLV) of 0.5 mg/m^3 (0.1 ppm) as a TWA for a normal 8-hr workday and a 40-hr workweek. The ACGIH has also assigned a "Skin" notation to anisidine [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of systemic effects associated with exposure to anisidine. NIOSH considers o-anisidine to be a potential occupational carcinogen because of positive carcinogenic results in studies of rats and mice.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to o- and p-anisidine can occur through inhalation of the dust or vapor, ingestion, or eye or skin contact. Anisidine is readily absorbed through the skin.

• Summary of toxicology

1. *Effects on Animals*: Anisidine causes methemoglobinemia and is a carcinogen in experimental animals. The toxicologic literature is often unclear about the particular isomer or mixture of isomers involved in a given study; when information about the specific form of anisidine is available, it is included in the following discussion. The oral LD_{50} in rats is 2,000 mg/kg for o-anisidine and 810 mg/kg for p-anisidine [NIOSH 1991]. Mice exposed to anisidine (isomer not specified) at 2 to 6 ppm for 2 hr/day for 1 year developed anemia and reticulocytosis [Proctor et al. 1988]. Animals that received subacute doses of either of the anisidine isomers developed anemia and other blood changes and showed signs of kidney damage at autopsy [IARC 1982]. Mice and rats fed diets containing up to 30,000 mg/kg o-anisidine hydrochloride for 7 weeks showed reductions in weight gain, and animals fed lower doses for the same period showed blackened, granular, and/or enlarged spleens [IARC 1982]. Eight-week feeding studies involving p-anisidine hydrochloride caused similar effects in rats and mice [IARC 1982]. o-Anisidine hydrochloride in the diet caused transitional-cell carcinomas of the urinary bladder in both rats and mice [IARC 1982]. The rats in this study also had statistically increased numbers of renal transitional-cell carcinomas and thyroid follicular-cell carcinomas [IARC 1982]. p-Anisidine hydrochloride did not cause cancer in mice, and the results of a carcinogenicity bioassay in rats were inconclusive [IARC 1982]. On the basis of this evidence, the International Agency for Research on Cancer (IARC) has concluded that sufficient evidence exists for the carcinogenicity of o-anisidine hydrochloride in animals but not for p-anisidine [IARC 1982].

2. *Effects on Humans*: Anisidine causes methemoglobinemia in humans. Some members of a group of workers exposed to 0.4 ppm of anisidine (isomer not specified) for 6 months (3.5 hr/day) did not exhibit clinical signs of anemia but showed the following blood changes: increased methemoglobin, sulfhemoglobin, and Heinz body formation [Proctor et al. 1988]. Anisidine (form not specified) causes dermatitis on repeated or prolonged contact and is also known to be a mild skin sensitizer [Proctor et al. 1988].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to anisidine can cause methemoglobinemia, including bluish coloring of the skin, ear lobes, and lips; headache; dizziness; drowsiness; nausea and vomiting; and, in severe cases, unconsciousness and death.

2. *Chronic exposure*: Chronic exposure to anisidine can cause anemia, pallor, methemoglobinemia, fatigue, shortness of breath, and palpitations. Dermatitis and skin sensitization (which include redness and itching of the skin, blisters, swelling, and pain) may also occur. Because three cancer sites (bladder, kidney, and thyroid) have been found in animals, exposure to o-anisidine may cause cancers in humans.

• Emergency procedures

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to particulates or concentrated solutions, vapors, mists, or aerosols of anisidine. ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If the particulates, vapors, mists, or aerosols of anisidine are inhaled, move the victim to fresh air ***immediately***. Have the victim blow his or her nose, or use a soft tissue to swab particulates from the nostrils

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if anisidine or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do *not* force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve anisidine and may result in worker exposures to this substance:

—Manufacture of azo- or triphenyl-methane dyes and intermediates

—Production of a derivative that is used as an expectorant in drugs for humans and animals and as a muscle relaxant in drugs for humans

—Preparation of organic compounds, synthesis of guaiacol and hair dyes

—Use of anisidine as a corrosion inhibitor for steel storage, as an antioxidant for some polymercaptan resins, and as a dye assist

—Use of anisidine as an analytic agent and as an intermediate in the synthesis of compounds in the form of liquid crystals

—Use of anisidine in the production of pharmaceutical and textile-processing chemicals

The following methods are effective in controlling worker exposures to anisidine, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt

immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to anisidine, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the blood, liver, kidneys, and cardiovascular system. A complete blood count, reticulocyte count, and urinalysis should be done.

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to anisidine at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with chronic blood disorders, chronic liver or kidney disease, or chronic cardiovascular disease.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to anisidine exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of anisidine on the blood, liver, kidneys, and cardiovascular system. A complete blood count, reticulocyte count, and urinalysis should be performed. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. The measurement of methemoglobin in the blood is a nonspecific, qualitative indicator of exposure to a variety of chemical agents such as anisidine that induce the formation of methemoglobin. Methemoglobin levels cannot be linked quantitatively to airborne concentrations of anisidine; methemoglobin monitoring thus serves only as a screening test to identify workers who may be overexposed. A methemoglobin level of 1.5% of total hemoglobin is recommended by some sources as a biological exposure index. Blood specimens should be collected while exposure to anisidine is occurring, and, if possible, the specimens should be analyzed at the place of collection.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne anisidine (o-, p-isomers) is determined by using XAD-2 solid sorbent tubes (150/75-mg sections, 20/50 mesh). Samples are collected at a maximum flow rate of 1 liter/min until a maximum air volume of 320 liters is collected. The sample is then treated with methanol to extract the anisidine. Analysis is conducted by high-pressure liquid chromatography using an ultraviolet absorption detector. The limit of detection for this procedure is 0.35 µg per sample. This method is described in Method 2514 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

Workers should immediately and thoroughly wash with soap and water any areas of the skin that have come in contact with the substance because anisidine can be absorbed through the skin in toxic amounts.

Clothing and shoes contaminated with anisidine should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of anisidine, particularly its potential for being absorbed through the skin in toxic amounts.

A worker who handles anisidine should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where anisidine or a solution containing anisidine is handled, processed, or stored.

STORAGE

Anisidine should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Storage areas for p-anisidine should be suitable for combustible solids. Containers of anisidine should be protected from physical damage and should be separated from oxidizing agents, heat, sparks, and open flame. Metal conveying and storage equipment should be grounded and bonded to prevent sparks. Bulk storage systems should be of explosionproof design. Because containers that formerly contained anisidine may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving anisidine, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.

2. Notify safety personnel.

3. Remove all sources of heat and ignition.

4. Ventilate potentially explosive atmospheres.

5. Make sure that cleanup personnel wear appropriate protective clothing and equipment to prevent skin and eye contact and inhalation.

6. For small dry spills, use a clean shovel and place the material in a clean, dry container; cover and remove the container from the spill area.

7. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

8. For large liquid spills, build dikes far ahead of the spill to contain the anisidine for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous release, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Anisidine is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of anisidine; there is no reportable quantity for anisidine.

- **Community right-to-know requirements**

Employers are not required by SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of anisidine emitted or released from their facility.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although anisidine is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [42 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of anisidine are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if

the ambient concentration of anisidine exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [1987a].

PERSONAL PROTECTIVE EQUIPMENT

Gloves and protective clothing should be worn to prevent any skin contact with anisidine. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to anisidine permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to anisidine.

If anisidine is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which anisidine dust or liquid might contact the eyes. Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with anisidine. Contact lenses should not be worn if the potential exists for anisidine exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ANTU

INTRODUCTION

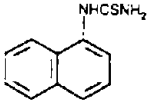
This guideline summarizes pertinent information about ANTU for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_{11}H_{10}N_2S$

- **Structure**



- **Synonyms**

α-Naphthylthiourea, 1-naphthalenylthiourea, 1-(1-naphthyl)-2-thiourea, 1-naphthylthiourea, α-naphthylthiocarbamide, Alrato, Anturat, Bantu, Dirax, Kill Kantz, Krysid, Naphtox, Rattrack, Rat-tu, Smeesana

- **Identifiers**

1. CAS No.: 86-88-4
2. RTECS No.: YT9275000
3. DOT UN: 1651 53
4. DOT label: Poison

- **Appearance and odor**

ANTU is a colorless, white, or gray crystalline compound that is odorless. Commercial ANTU preparations are often contaminated with as much as 2% 2-naphthylamine, a recognized human carcinogen. ANTU is no longer manufactured in the United States.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 202.3
2. Boiling point (at 760 mm Hg): Decomposes
3. Specific gravity (water = 1): Greater than 1
4. Vapor density (air = 1 at boiling point of ANTU): 6.99
5. Melting point: 198°C (388.4°F)
6. Vapor pressure at 20°C (68°F): Nearly zero
7. Solubility: Practically insoluble in water, fairly soluble in hot alcohol, and soluble in acetone and triethylene glycol
8. Evaporation rate: Not applicable

- **Reactivity**

1. Conditions contributing to instability: None
2. Incompatibilities: Fires and explosions may result from contact of ANTU with strong oxidizers; ANTU also reacts with silver nitrate.
3. Hazardous decomposition products: Toxic gases (such as sulfur dioxide, oxides of nitrogen, and carbon monoxide) may be released in a fire involving ANTU.
4. Special precautions: None

- **Flammability**

ANTU may burn, but it will not ignite readily.

1. Flash point: Not applicable
2. Autoignition temperature: Not applicable
3. Flammable limits in air: Not applicable
4. Extinguishant: Use dry chemical, carbon dioxide, Halon®, water spray, or standard foam to fight small fires involving ANTU; use water spray, fog, or standard foam to fight large fires involving ANTU.

Fires involving ANTU should be fought upwind and from the maximum distance possible. Isolate the hazard area and

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving ANTU. Firefighters' protective clothing may not provide protection against permeation by ANTU.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for ANTU is 0.3 mg/m^3 of air as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for ANTU of 0.3 mg/m^3 as an 8-hr TWA [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned ANTU a threshold limit value (TLV) of 0.3 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of pulmonary effects associated with exposure to ANTU.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to ANTU can occur through inhalation, ingestion, and eye or skin contact; by analogy with other thiourea products, percutaneous absorption of ANTU is likely.

• Summary of toxicology

1. *Effects on Animals*: ANTU causes pulmonary edema and pleural effusion in exposed animals. The toxicity of ANTU varies widely among different species of animals but is especially high in adult Norway rats [Hayes 1982]. The oral LD_{50} is 6 mg/kg in rats and 4,250 mg/kg in monkeys [NIOSH 1991]. Sixty percent of rats fed a 35-mg/kg dose of ANTU died; their autopsies revealed interstitial pulmonary edema and pericardial effusions as well as mild liver damage [Proctor et al. 1988]. Rats given lethal doses of ANTU also showed increases in blood sugar, decreases in liver glycogen stores, decreased or absent urine output, and lesions of the kidney at autopsy [Gosselin et al. 1984]. After repeated doses, animals developed a tolerance to the acute toxicity of ANTU [Proctor et al. 1988]. ANTU may have antithyroid properties when administered to animals in sublethal, chronic doses [Gosselin et al. 1984]. ANTU is mutagenic in several in vitro assay systems [Hayes 1982; NIOSH 1991]. Carcinogenicity bioassays in two strains of mice were negative [Hayes 1982].

2. *Effects on Humans*: ANTU is believed to have caused bladder cancer in workers exposed during the application of ANTU-containing rodenticides; however, the causative agent in these cancers may have been β-naphthylamine, which was present in ANTU as an impurity [Orjelick 1975]. A total of 14 cases of urothelial tumors were reported [Davies et al. 1982]. When ingested, ANTU is probably not toxic to humans except in relatively large amounts; on the basis of the results of acute toxicity testing in monkeys, the mean lethal oral dose in humans is estimated to be 4 g/kg [Gosselin et al. 1984]. No reported cases have involved the ingestion of pure ANTU, but accidental or suicidal ingestions of ANTU in combination with other rat poisons have been reported. One man ingested 80 g of a rat poison that contained 30% ANTU and then drank a large amount of alcohol; he subsequently showed the following ANTU-related effects: vomiting, difficult breathing, cyanosis, and fluid in the lungs [Gosselin et al. 1984]. ANTU is reported to have caused contact eczema in one occupationally exposed worker [Hayes 1982]. Workers handling products containing thiourea (such as ANTU) have shown dermal absorption and destructive changes of the thyroid gland [ACGIH 1991a].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute inhalation exposure may produce coughing, lung edema, dyspnea, trenchitis, or pneumonitis [NLM 1991]. Ingestion of ANTU can induce vomiting, difficult breathing, blueness of the skin and mucous membranes, and lung edema. Tissue contact can cause eye or skin irritation.

2. *Chronic exposure*: ANTU can cause blood or pus in the urine, pain on urination, and other signs and symptoms of bladder cancer. Hypothyroidism with weight gain, dryness of the skin, eczema, and bradycardia have also been associated with occupational exposure to ANTU.

• Emergency procedures

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: ***Immediately and thoroughly*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: ANTU can be absorbed through the skin in lethal amounts. ***Immediately*** remove all contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water for at least 15 min.

3. *Inhalation exposure*: If particulates or vapors, mists, or aerosols of ANTU are inhaled, move the victim to fresh air ***immediately***. Have the victim blow his or her nose.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if ANTU or any material containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations involve ANTU and may result in worker exposures to this substance:

—Manufacture of ANTU

—Formulation and use of ANTU as a rodenticide to control the Norway rat

The following methods are effective in controlling worker exposures to ANTU, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

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MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

• Preplacement medical evaluation

Before a worker is placed in a job with a potential for exposure to ANTU, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the thyroid and adrenal glands, respiratory tract, liver, and bladder. Medical monitoring for respiratory disease should

be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to ANTU at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with chronic respiratory disease, hypothyroidism, other endocrine disease, chronic liver disease, or bladder disorders.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to ANTU exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of ANTU on the lungs, thyroid, adrenal gland, liver, and bladder. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for ANTU.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population. Because exposure to ANTU may cause diseases with long latencies, medical surveillance may need to be continued long after job termination.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne ANTU is determined by using a 37-mm, 1-micron polytetrafluoroethylene filter. Samples are collected at a maximum flow rate of 2.0 liters/min until a maximum air volume of 480 liters is collected. The samples are desorbed with methanol. Analysis is conducted by high-performance liquid chromatography using an ultraviolet light detector. The limit of detection for this procedure is 5 µg per sample. This method is described in Method No. S276 of the *NIOSH Manual of Analytical Methods* [NIOSH 1978].

PERSONAL HYGIENE

Because ANTU can be absorbed through the skin in toxic amounts, workers should dust off any solid ANTU from their skin, flush the affected areas immediately with plenty of water for 15 min, and then wash the area twice with soap and water.

Clothing and shoes contaminated with ANTU should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of ANTU, particularly its potential to be hazardous to the respiratory system, bladder, and endocrine system.

A worker who handles ANTU should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where ANTU or a solution containing ANTU is handled, processed, or stored.

STORAGE

ANTU should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of ANTU should be protected from physical damage and should be separated from strong oxidizers, heat, sparks, and open flame. Because empty containers may contain ANTU residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving ANTU, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete.

The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.

2. Notify safety personnel.

3. Ventilate the atmosphere to reduce the concentration of ANTU.

4. For small dry spills, use a clean shovel and place the material into a clean, dry container; cover and remove the container from the spill area.

5. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

6. For large liquid spills, build dikes far ahead of the spill to contain the ANTU for later disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether these requirements have been changed.

- **Emergency planning requirements**

If 10,000 lb or more of ANTU is present, the owner or operator must comply with EPA's emergency planning requirements [40 CFR 355.30]. If ANTU is in the form of a finely divided powder or is handled in solution or in molten form, the employer must comply with these requirements if 5,000 lb or more is present at the facility.

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is greater than the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for ANTU is 100 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of ANTU emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. ANTU is listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], and has been assigned EPA Hazardous Waste No. P072. This substance has been banned from land disposal and may be treated by incineration. ANTU may also be disposed of in an organometallic or organic lab pack that meets the requirements of 40 CFR 264.316 or 265.316.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of ANTU exceeds prescribed exposure limits. Respirators may be used

(1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with ANTU. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to ANTU permeation; however, one source recommends polyethylene to protect against permeation by ANTU. Since specific test data are not available for ANTU, the information provided here should be considered as a guideline only. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to ANTU.

If ANTU is dissolved in an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which ANTU might contact the eyes (e.g., through dust particles or splashes of ANTU-containing solutions). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with ANTU. Contact lenses should not be worn if the potential exists for ANTU exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR AZINPHOS-METHYL

INTRODUCTION

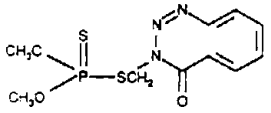
This guideline summarizes pertinent information about azinphos-methyl for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_{10}H_{12}N_3O_3PS_2$

- **Structure**



- **Synonyms**

Guthion; methyl guthion; benzotriazine derivative of methyl dithiophosphate; benzotriazine-dithiophosphoric acid, dimethoxy ester; O-O-dimethyl S-[4-oxo-1,2,3-benzotriazin-3(4H)-yl-methyl] phosphoro-dithioate; Bay 9027; Bayer 9027; Carfene; Cotnion methyl; Gusathion

- **Identifiers**

1. CAS No.: 86-50-0
2. RTECS No.: TE1925000
3. DOT UN: 2783 55
4. DOT label: Poison

- **Appearance and odor**

Azinphos-methyl is an organophosphorus pesticide. The technical product is a brown waxy solid; no data are available regarding the odor of this substance.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 317.34
2. Boiling point (at 760 mm Hg): Decomposes at temperatures above 200°C (392°F)
3. Specific gravity (water = 1): 1.44 at 20°C (68°F)
4. Vapor density: Not applicable
5. Melting point: 73° to 74°C (163.4° to 165.2°F)
6. Vapor pressure at 20°C (68°F): 0.00038 mm Hg
7. Solubility: Slightly soluble in water; soluble in methanol, ethanol, propylene glycol, xylene, and other organic solvents
8. Evaporation rate: Negligible

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, or flame.
2. Incompatibilities: Fires and explosions may result from contact of azinphos-methyl with strong oxidizers.
3. Hazardous decomposition products: Toxic gases and dusts (such as oxides of nitrogen, phosphorus, and sulfur) may be released when azinphos-methyl is heated to decomposition.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to azinphos-methyl; this substance may burn, but it does not ignite readily.

1. Flash point: Data not available
2. Autoignition temperature: Data not available
3. Flammable limits in air: Data not available
4. Extinguishant: Use dry chemical, carbon dioxide, Halon®, water spray, or standard foam to fight small fires involving

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

azinphos-methyl; use water spray, fog, or standard foam to fight large fires involving this substance.

Fires involving azinphos-methyl should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of azinphos-methyl may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving azinphos-methyl. Chemical protective clothing that is specifically recommended for azinphos-methyl may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by azinphos-methyl.

EXPOSURE LIMITS

• OSHA PEL

The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for azinphos-methyl is 0.2 mg/m^3 of air as an 8-hr time-weighted average (TWA). The OSHA PEL also bears a "Skin" notation, which indicates that the cutaneous route of exposure (including mucous membranes and eyes) contributes to overall exposure [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 0.2 mg/m^3 as an 8-hr TWA with a "Skin" notation [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned azinphos-methyl a threshold limit value (TLV) of 0.2 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek; the TLV also bears a "Skin" notation [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of anticholinesterase effects associated with exposure to azinphos-methyl.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to azinphos-methyl can occur through inhalation, ingestion, skin absorption, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Azinphos-methyl is a cholinesterase inhibitor in animals that is capable of inducing death from respiratory arrest. Significant dermal absorption can occur in animals. The dermal LD_{50} is about 65 mg/kg in mice and 220 mg/kg in rats [NIOSH 1991]. Among rats that inhaled an aerosol of technical grade product containing 72% to 73% azinphos-methyl, the 1-hr LC_{50} was approximately 75 mg/m^3 (69 mg/m^3 for males and 79 mg/m^3 for females). The signs and symptoms of toxic cholinesterase inhibition included salivation, lacrimation, exophthalmos, defecation, urination, and muscle fasciculations before respiratory failure and death [NIOSH 1991; SRI 1978]. The oral LD_{50} was 15 mg/kg in mice and 7 mg/kg in rats [NIOSH 1991]. Rats that inhaled azinphos-methyl at 4.72 mg/m^3 for 12 weeks (6 hr/day, 5 days/week) showed a significant reduction in erythrocyte and plasma cholinesterase activity [Proctor et al. 1988]. Rats tolerated a dietary concentration of 5 ppm for 60 days without cholinesterase inhibition; at 20 ppm for 60 days, however, brain and red blood cell cholinesterase levels were inhibited by as much as 30% [ACGIH 1991a]. When azinphos-methyl was administered to pregnant mice and rats, it caused no adverse developmental effects in the offspring [NIOSH 1991; NLM 1991]. A National Cancer Institute study provided equivocal evidence that oral dosing of male rats with azinphos-methyl causes cancer of the thyroid and pancreas; this substance was not shown to be carcinogenic in female rats or in male or female mice [NCI 1978].

2. *Effects on Humans*: Azinphos-methyl is a cholinesterase inhibitor in humans. Eight workers engaged in the formulation of a wettable azinphos-methyl powder were exposed to concentrations as high as 9.6 mg/m^3; blood serum levels in some workers were depressed to 78% of their pre-exposure baseline cholinesterase levels [Proctor et al. 1988]. In a group of male agricultural workers working in a field that had been treated with azinphos-methyl, the mean red blood cell cholinesterase activity was significantly below that of workers engaged in an untreated field [NLM 1991]. Volunteers ingesting 4 to 20 mg azinphos-methyl/day for 30 days did not show a drop in cholinesterase levels [ACGIH 1991a].

• Signs and symptoms of exposure

1. *Acute exposure*: The following signs and symptoms of acute exposure to azinphos-methyl vary with the route of entry and the degree of exposure [NLM 1991]. Effects associated with inhalation exposure include a feeling of

tightness in the chest, wheezing, bronchoconstriction, excessive bronchial secretion, laryngeal spasms, excessive salivation, cyanosis, miosis, pain in and between the eyes, blurring of distant vision, tearing, rhinorrhea, and frontal headache. Within 15 to 120 min of ingestion, gastrointestinal effects appear—anorexia, nausea, vomiting, abdominal cramps, and diarrhea. After skin absorption, sweating and muscle twitching occur in the area of skin contact. If overexposure by any route is severe, signs and symptoms include muscular weakness, involuntary twitching, and eventually paralysis. The most serious consequence is paralysis of the respiratory muscles. Effects on the central nervous system include giddiness, confusion, ataxia, slurred speech, Cheyne-Stokes respiration, convulsions, coma, and loss of reflexes. Blood pressure may fall, and cardiac irregularities (including complete heart block) may occur; these effects are sometimes reversible if adequate pulmonary ventilation is established. Unless the exposure is lethal, complete symptomatic recovery usually occurs within 1 week; however, increased susceptibility to the effects of anticholinesterase agents usually persists for several weeks after exposure.

2. *Chronic exposure*: Repeated exposure to azinphos-methyl at concentrations below those that will cause symptoms after a single exposure can cause the same signs and symptoms as acute exposure.

- **Emergency procedures**

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: ***Immediately and thoroughly*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Azinphos-methyl can be absorbed through the skin in lethal amounts. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water for at least 15 min.

3. *Inhalation exposure*: If particulates or vapors, mists, or aerosols of azinphos-methyl are inhaled, move the victim to fresh air ***immediately***. Have the victim blow his or her nose to remove particulates or residues from the nostrils.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if azinphos-methyl or any material containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Induce vomiting by having the victim touch the back of the throat with a finger until productive vomiting ceases. Do ***not*** give syrup of ipecac because of possible onset of respiratory depression and seizures.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations involve azinphos-methyl and may result in worker exposures to this substance:

—Manufacture, formulation, and application of azinphos-methyl as an insecticide and acaricide on field crops, fruits, vegetables, cotton, tobacco, nuts, sugar cane, soybeans, ornamentals, grasses, and trees

—Use of azinphos-methyl as an additive in the food and drinking water of animals

The following methods are effective in controlling worker exposures to azinphos-methyl, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to azinphos-methyl, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the blood. A baseline red blood cell acetylcholinesterase level should be established for each potentially exposed worker.

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to azinphos-methyl at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with decreases in blood cholinesterase activity.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to azinphos-methyl exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of azinphos-methyl on blood cholinesterase activity. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. Red blood cell cholinesterase activity can be measured to monitor both acute and chronic exposure to azinphos-methyl. A worker should be removed from exposure if his or her erythrocyte cholinesterase level drops to or below 40% of the pre-exposure baseline value for that individual; he or she should not be allowed to return to work until this level has again reached 80% of the pre-exposure baseline level.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

Neither NIOSH nor OSHA has a validated method for sampling azinphos-methyl in the workplace. However, the following secondary analytical method, which has not been validated, is available.

A worker's exposure to airborne azinphos-methyl is determined by using a specially designed tube called an OSHA versatile sampler (OVS-2) containing XAD-2 resin (270/140-mg sections, 20/60 mesh) and a glass fiber filter. Samples are collected at a recommended flow rate of 1 liter/min until a recommended air volume of 480 liters is collected. The sample is desorbed with toluene. Analysis is conducted by gas chromatography using a flame photometric detector and an OV-1 column at 175°C (347°F). The limit

of detection for this procedure is 5 μg/sample. This method is described in the OSHA Laboratory In-House Methods File [OSHA 1991].

PERSONAL HYGIENE

Because azinphos-methyl can be deadly if absorbed through the skin, an exposed worker should remove any contaminated clothing immediately and flush the affected areas with copious amounts of water for 15 min; the worker should then wash thoroughly with soap and water. At the end of the day, workers who handle azinphos-methyl or liquid containing azinphos-methyl should use soap and water to wash any areas of the body that may have contacted this pesticide, even if none is detected on the skin.

Clothing and shoes contaminated with azinphos-methyl should be removed immediately; speed in removing these articles is essential. Persons laundering contaminated clothing should be informed of the hazardous properties of azinphos-methyl, particularly its potential for being absorbed through the skin.

A worker who handles azinphos-methyl should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where azinphos-methyl or a solution containing it is handled, processed, or stored.

STORAGE

Azinphos-methyl should be stored in a cool, dry, well-ventilated area in tightly sealed original containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of azinphos-methyl should be protected from physical damage and should be separated from oxidizers, heat, sparks, and open flame. Azinphos-methyl should never be stored near any type of food. Because containers that formerly contained azinphos-methyl may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving azinphos-methyl, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Ventilate the atmosphere to reduce the concentration.
4. Use water spray to reduce vapors.
5. For dry spills (azinphos-methyl in solid form), use a clean shovel and place the material in a clean, dry container; cover and remove the container from the spill area.
6. Absorb small liquid spills (azinphos-methyl formulations) with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.
7. For large liquid spills, build dikes far ahead of the spill to contain the azinphos-methyl for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Employers owning or operating a facility with 10,000 lb or more of azinphos-methyl onsite must comply with EPA's emergency planning requirements [40 CFR 355.30]. (The employer must comply with these requirements if azinphos-methyl is in the form of a finely divided powder or is handled in solution or in molten form, and if 10 lb or more is present at the facility.)

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is above the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for azinphos-methyl is 1 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of azinphos-methyl emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although azinphos-methyl is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [42 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of azinphos-methyl exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with azinphos-methyl. Gloves, overalls, and boots should be worn when handling azinphos-methyl or any organophosphorus pesticide. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been recommended for use against permeation by azinphos-methyl and may provide protection for periods greater than 8 hr: neoprene and nitrile rubber. Natural rubber and polyvinyl chloride have demonstrated questionable resistance to permeation by azinphos-methyl.

If azinphos-methyl is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which azinphos-methyl might contact the eyes (e.g., through dust particles, mists, or splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with azinphos-methyl. Contact lenses should not be worn if the potential exists for azinphos-methyl exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BENZOYL PEROXIDE

INTRODUCTION

This guideline summarizes pertinent information about benzoyl peroxide for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_{14}H_{10}O_4$

- **Structure**

$(C_6H_5CO)_2O_2$

- **Synonyms**

Benzoic acid, benzoperoxide; benzoyl superoxide; diphenylglyoxal peroxide; dibenzoyl peroxide; Acetoxyl; Acnegel; Benzac; Clearasil BP Acne Treatment; Cuticura Acne Cream; Debroxide; Dry and Clear Acne Cream; Epiclear; Fostex; Incidol; Lucidol; Luperco AA; Nayper B; Novadelox; Oxy-5; Oxy Wash; Panoxyl; Persadox; Quinolor Compound; Sulfoxyl; Topex; Vanoxide; Xerac

- **Identifiers**

1. CAS No.: 94-36-0
2. RTECS No.: DM8575000 (for the technical product)
3. DOT UN: 2085 49 (for the technical product)
4. DOT label: Organic Peroxide

- **Appearance and odor**

Benzoyl peroxide is a white crystalline solid that has a faint benzaldehyde odor.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 242.2
2. Boiling point (at 760 mm Hg): Decomposes explosively at temperatures above 105°C (221°F)
3. Specific gravity (water = 1): 1.33 at 25°C (77°F)
4. Vapor density: Not applicable
5. Melting point: 103° to 105°C (217.4° to 221°F)
6. Vapor pressure at 20°C (68°F): Less than 0.1 mm Hg
7. Solubility: Sparingly soluble in water, alcohol, or vegetable oils; soluble in chloroform, ether, and benzene
8. Evaporation rate: Not applicable

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, friction, or impact. Confined storage of dry benzoyl peroxide may lead to decomposition and explosion.
2. Incompatibilities: Benzoyl peroxide is extremely reactive, and fires and explosions may result from contact with strong acids, oxidizing and reducing agents, metals, metal oxides, amines, accelerators, methyl methacrylate, organic matter, carbon tetrachloride and ethylene, dimethylaniline, or lithium aluminum hydride.
3. Hazardous decomposition products: Toxic gases, vapors, and particulates (such as benzoic acid, phenyl benzoate, terphenyls, biphenyls, benzene, carbon monoxide, and carbon dioxide) may be released when benzoyl peroxide decomposes.
4. Special precautions: Benzoyl peroxide is highly reactive and may explode spontaneously; it must be kept wet in a mixture containing at least 1% water.

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• **Flammability**

The National Fire Protection Association has assigned a flammability rating of 4 (extreme fire hazard) to benzoyl peroxide.

1. Flash point: 80°C (176°F)

2. Autoignition temperature: 80°C (176°F)

3. Flammable limits in air: Data not available

4. Extinguishant: Use water only; do ***not*** use chemical or carbon dioxide extinguishants.

Fires involving benzoyl peroxide should be fought from an explosionproof location. In advanced or massive fires, the area should be evacuated. Isolate the hazard area and deny access to unnecessary personnel. If fire occurs in the vicinity of containers of benzoyl peroxide, water should be used to keep containers cool. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving benzoyl peroxide.

EXPOSURE LIMITS

• **OSHA PEL**

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for benzoyl peroxide is 5 mg/m^3 of air as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• **NIOSH REL**

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 5 mg/m^3 as a TWA for up to a 10-hr workshift and a 40-hr workweek [NIOSH 1992].

• **ACGIH TLV®**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned benzoyl peroxide a threshold limit value (TLV) of 5 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• **Rationale for limits**

The limits are based on the risk of respiratory irritation associated with exposure to benzoyl peroxide.

HEALTH HAZARD INFORMATION

• **Routes of exposure**

Exposure to benzoyl peroxide can occur through inhalation, ingestion, or contact with the skin or eyes.

• **Summary of toxicology**

1. *Effects on Animals*: Benzoyl peroxide is an irritant of the eyes, mucous membranes, and skin in animals. When instilled into the eyes of rabbits, benzoyl peroxide dust caused irritation [IARC 1985]. A 10% solution of benzoyl peroxide applied to the skin of guinea pigs caused a moderate degree of skin irritation [IARC 1985]. In rats, the 4-hr LC_{50} is estimated to be 700 ppm, and the oral LD_{50} is 7,710 mg/kg [ACGIH 1991a; NIOSH 1991]. During an acute 4-hr exposure to 2,458 ppm (24,300 mg/m^3), rats showed eye tearing and squinting, difficult breathing, excessive salivation, erythema, and motor excitation followed by depression; all animals recovered within the 24- or 48-hr period following termination of exposure [NIOSH 1977]. In a chick embryo assay, embryo toxicity and malformations were induced by benzoyl peroxide [NLM 1991]. Chronic feeding studies in rats showed decreased weight gain in the medium- and high-dose groups and testicular atrophy among males in the high-dose group [IARC 1985].

2. *Effects on Humans*: Benzoyl peroxide is an irritant of the eyes, skin, and mucous membranes in humans. This substance is also a skin sensitizer. Workers exposed to 12.2 mg/m^3 experienced strong irritation of the nose and upper respiratory tract [Proctor et al. 1988]. In prolonged and repeated contact with the skin, benzoyl peroxide has caused dermal irritation and sensitization [IARC 1985].

• **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to benzoyl peroxide can cause moderate to severe irritation of the eyes, nose, and throat, with redness and tearing of the eyes, runny nose, cough, and difficult breathing. In contact with the skin, benzoyl peroxide causes redness and swelling.

2. *Chronic exposure*: Chronic exposure to benzoyl peroxide can cause dermatitis. Some sensitized individuals may also experience whorls, swelling, itching, and redness of the skin.

• **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Irritation may result! ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Irritation may result. ***Immediately and thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: Move the victim to fresh air *immediately*.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if benzoyl peroxide is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do *not* force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of benzoyl peroxide may result in worker exposures to this substance:

—Use as an initiator in free radical polymerization

—Use in production of polystyrene and related resins

—Use in auto-repair kits, optical and dental castings, and other molding applications

—Use in vulcanization of natural and synthetic rubbers

—Use in textile manufacture as a burn-out agent for cellulose acetate to produce lace-like appearance in mixed fabrics

—Use in printing pastes

—Use in topical non-prescription medications as a treatment of acne, burns, dermatitis, poisoning, and external wounds, and as an antiseptic and local anesthetic

—Use as a bleaching agent for flour, cheese, fats, oils, and waxes

—Use in the manufacture of special fast-drying inks for printing on plastic surfaces and in the embossing of vinyl flooring

—Use as a fixing agent in light microscopy

The following methods are effective in controlling worker exposures to benzoyl peroxide, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

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MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to benzoyl peroxide, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and

physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the respiratory tract and skin and on a history of skin allergies. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to benzoyl peroxide at or below the prescribed exposure limit. The examining licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with skin or respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health licensed medical practitioner. Additional examinations may be necessary if a worker develops symptoms attributable to benzoyl peroxide exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of benzoyl peroxide on the skin and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for benzoyl peroxide.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne benzoyl peroxide is determined by using a cellulose ester membrane filter (0.8 micron). Samples are collected at a maximum flow rate of 3 liters/min until a maximum air volume of 400 liters is collected. Immediately after sampling, the sample filters are transferred into a 20-ml scintillation vial and are then sealed and shipped under refrigeration. Upon receipt by the laboratory, the samples are frozen until they are to be analyzed. The sample is then treated with ethyl ether to extract the benzoyl peroxide. Analysis is conducted by high-performance liquid chromatography using ultraviolet light detection. The limit of detection for this procedure is 0.01 mg per sample. This method is described in Method 5009 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If benzoyl peroxide contacts the skin, workers should remove any contaminated clothing immediately while drenching the affected area with water and then wash with soap and water.

Clothing and shoes contaminated with benzoyl peroxide should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of benzoyl peroxide.

A worker who handles benzoyl peroxide should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where benzoyl peroxide is handled, processed, or stored.

STORAGE

Benzoyl peroxide should be stored in a cool, dry, well-ventilated, fireproof area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Isolated, remote, or detached storage is preferred. The storage area should be equipped with an automatic fire suppression system. To prevent static sparks, all containers and equipment used in shipping, receiving, or transferring operations should be bonded and grounded. Only nonsparking tools may be used with benzoyl peroxide. Any storage system should have an explosion-relief design, and electrical installations and heating facilities should be prohibited in these storage areas. Only the small amount of benzoyl peroxide that is needed for a single work shift should be removed from storage at one time. Containers of benzoyl peroxide should be protected from incompatible chemicals, physical damage, shock, rough handling, friction,

sunlight, heat, sparks, and open flame. Because containers that formerly contained benzoyl peroxide may still hold product residues, they should be handled appropriately.

SPILLS

Before benzoyl peroxide is used in the workplace, an emergency plan to handle any contingencies, including spills, should be developed and practiced. In the event of a spill involving benzoyl peroxide, the plan should be implemented. The following steps should be undertaken following a spill:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres using maximum explosionproof ventilation.
5. Cleanup personnel must wear fire-resistant and antistatic protective clothing.
6. Use nonsparking tools for cleanup. Do *not* use cellulosic materials (rags, paper, straw, etc.) to clean up spilled benzoyl peroxide.
7. All benzoyl peroxide spills should be inactivated by adding cold, 10% sodium hydroxide solution to the spilled material in an amount equal to 10 times the weight of the spill. This process takes up to 3 hr to complete.

SPECIAL REQUIREMENTS

The U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Benzoyl peroxide is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of benzoyl peroxide; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of benzoyl peroxide per calendar year are required by EPA [49 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of benzoyl peroxide emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although benzoyl peroxide is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of benzoyl peroxide exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular

respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Fire- and static-resistant protective clothing should be worn to prevent skin contact with benzoyl peroxide. Gloves, boots, aprons, and gauntlets are recommended to prevent prolonged or repeated skin contact. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to benzoyl peroxide permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to benzoyl peroxide.

If benzoyl peroxide is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which benzoyl peroxide might contact the eyes (e.g., through dust particles). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with benzoyl peroxide. Contact lenses should not be worn if the potential exists for benzoyl peroxide exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BORON OXIDE

INTRODUCTION

This guideline summarizes pertinent information about boron oxide for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

B_2O_3

- **Synonyms**

Anhydrous boric acid, boric anhydride, boric oxide, boron sesquioxide, boron trioxide, diboron trioxide, fused boric acid

- **Identifiers**

1. CAS No.: 1303-86-2
2. RTECS No.: ED7900000
3. DOT UN: None
4. DOT label: None

- **Appearance and odor**

Boron oxide is a noncombustible, odorless, colorless or white, brittle substance that occurs as hygroscopic granules or in flake or powder form.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 69.6
2. Boiling point (at 760 mm Hg): 1,842°C (3,380°F)
3. Specific gravity: 2.5 at 20°C (68°F)
4. Vapor density: Not applicable
5. Melting point: 450°C (842°F)
6. Vapor pressure at 20°C (68°F): Approximately 0 mm Hg
7. Solubility: Soluble in ethanol, glycerol, and hot water; slightly soluble in cold water
8. Evaporation rate: Not applicable

- **Reactivity**

1. Conditions contributing to instability: Boron oxide reacts slowly with water to form boric acid.
2. Incompatibilities: Fires and explosions may result from contact of boron oxide with bromine pentafluoride or calcium oxide.
3. Hazardous decomposition products: None
4. Special precautions: None

- **Flammability**

This substance is not combustible.

1. Flash point: Not applicable
2. Autoignition temperature: Not applicable
3. Flammable limits in air: Not applicable
4. Extinguishant: Use an extinguishant that is suitable for the materials involved in the surrounding fire.

Fires involving boron oxide should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving boron oxide.

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EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for boron oxide is 10 mg/m^3 (total dust) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for boron oxide of 10 mg/m^3 as an 8-hr TWA [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned boron oxide a threshold limit value (TLV) of 10 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of eye and upper respiratory tract irritation associated with exposure to boron oxide.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to boron oxide can occur through inhalation, ingestion, or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Boron oxide is an irritant of the skin and mucous membranes in animals. The oral LD_{50} in mice is 3,163 mg/kg [NIOSH 1991]. Application of boron oxide dust to the shaved skin of rabbits caused redness that persisted for several days [Wilding et al. 1959]. When instilled into the eyes of rabbits, the dust caused conjunctivitis [Wilding et al. 1959]. Rats exhibited mild nasal irritation when exposed to a boron oxide aerosol at 470 mg/m^3 for 6 hr/day, 5 days/week for 10 weeks [NLM 1991; ACGIH 1991a]. Young rats intubated with a 10% boron oxide slurry for 3 weeks showed no adverse effects [ACGIH 1991a].

2. *Effects on Humans*: Exposure to boron oxide causes irritation of the eyes and respiratory tract; dryness of the mouth, nose, and throat; sore throat; and a productive cough [Garabrant et al. 1984]. A group of 113 workers exposed to the dust of boron oxide and boric acid at mean concentrations of 4.1 mg/m^3 (range 1.2 to 8.5 mg/m^3; exposures occasionally in excess of 10 mg/m^3) exhibited statistically significant increases in eye, nose, and upper respiratory tract symptoms [Garabrant et al. 1984].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to boron oxide can cause pain and redness of the eyes, tearing, irritation of the nasal membranes, sore throat, and cough.

2. *Chronic exposure*: No signs or symptoms of chronic exposure to boron oxide have been reported.

• Emergency procedures

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Irritation may result! ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Irritation may result. ***Immediately and thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: Move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if boron oxide is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve boron oxide and may result in worker exposures to this substance:

—Preparation of fluxes for enamels and glazes

—Laboratory analysis of silicates

—Manufacture of glass for heat-resistance

—Use of boron oxide in blowpipe analysis

—Application as a herbicide

—Production of surface coatings and use of boron oxide in the electronics industry

—Production of boron, boron master alloys, borides, metal borates, and boron carbide, nitrides, and halides

—Use of boron oxide as an additive to provide fire-resistance to enamels, paints, and insulation

—Use of boron oxide as an additive for glass fibers

The following methods are effective in controlling worker exposures to boron oxide, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to boron oxide, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes and skin.

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to boron oxide at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with eye or skin diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to boron oxide exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of boron oxide on the eyes or skin. Current health status should be compared with the

baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. Serum borate concentrations are qualitative indicators of exposure to borate compounds (including boron oxide), but these levels cannot be correlated with airborne concentrations of borates. Therefore, no biological monitoring test acceptable for routine use has yet been developed for boron oxide.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne boron oxide is determined by using tared, low-ash polyvinyl chloride filters (5-micron). Samples are collected at a maximum flow rate of 2 liters/min until a maximum air volume of 960 liters is collected. This is a gravimetric field test method based on the total weight collected and does not need to be submitted to the laboratory for analysis. This method is described in the section on filter weighing procedures in the *OSHA Chemical Information Manual* [OSHA 1987]. Additional information can be found in Method 0500 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If boron oxide contacts the skin, workers should flush the affected areas immediately with plenty of water for at least 15 min and then wash with soap and water.

Clothing contaminated with boron oxide should be removed promptly.

A worker who handles boron oxide should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where boron oxide or a solution containing boron oxide is handled, processed, or stored.

STORAGE

Boron oxide should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of boron oxide should be protected from physical damage, kept dry, and stored separately from bromine pentafluoride or calcium oxide, heat, sparks, and open flame. Because containers that formerly contained boron oxide may still hold product residues, they should be handled appropriately.

SPILLS

In the event of a spill involving boron oxide, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill.

1. Scoop up spilled material and place the material in a covered container for later reclamation or disposal.

2. Avoid generating dust during cleanup by using a vacuum or a wet method.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Boron oxide is not subject to EPA emergency planning requirements [40 CFR 355.30].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of boron oxide; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022] to submit a Toxic Chemical Release Inventory Form

(Form R) to EPA reporting the amount of boron oxide emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although boron oxide is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limits. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of boron oxide exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective gloves and clothing should be worn to prevent repeated skin contact with boron oxide. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to boron oxide permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to boron oxide.

If boron oxide is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which boron oxide might contact the eyes (e.g., through dust particles or splashes of boric acid). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with boron oxide. Contact lenses should not be worn if the potential exists for boron oxide exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BORON TRIFLUORIDE

INTRODUCTION

This guideline summarizes pertinent information about boron trifluoride for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

BF_3

- **Synonyms**

Trifluoroboron, boron fluoride, trifluoroborane

- **Identifiers**

1. CAS No.: 7637-07-2
2. RTECS No.: ED2275000
3. DOT UN: 1008 15
4. DOT label: Nonflammable Gas and Poison

- **Appearance and odor**

Boron trifluoride is a nonflammable, colorless gas that fumes in moist air and has a pungent, irritating odor. The odor threshold is reported to range from 1 to 1.5 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 67.8
2. Boiling point (at 760 mm Hg): -100°C (-148°F)
3. Specific gravity (water = 1): 2.99 at 20°C (68°F)
4. Relative density (air = 1 at boiling point of boron trifluoride): 2.3
5. Melting point: -127.1°C (-196.8°F)
6. Vapor pressure at 20°C (68°F): Greater than 1 mm Hg
7. Solubility: Soluble in water and in most saturated and halogenated hydrocarbons and aromatic compounds; very soluble in concentrated acids and organic solvents
8. Evaporation rate: Not applicable

- **Reactivity**

1. Conditions contributing to instability: Boron trifluoride hydrolyzes in moist air to boric acid, hydrogen fluoride, and fluoboric acid. It also decomposes in hot water to form boric acid and fluoboric acid. This substance also decomposes when heated.
2. Incompatibilities: Fires and explosions may result from contact of boron trifluoride with alkali metals, alkaline earth metals (except magnesium), alkyl nitrate, or calcium oxide. Boron trifluoride incandesces when heated with alkali metals or alkaline earth metals (except magnesium).
3. Hazardous decomposition products: Toxic gases and vapors (such as fluorine and fluorine compounds) may be released when boron trifluoride is heated to decomposition.
4. Special precautions: Boron trifluoride corrodes most metals in the presence of moisture.

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to boron trifluoride; this substance is not flammable and will not support combustion.

1. Flash point: Not applicable
2. Autoignition temperature: Not applicable
3. Flammable limits in air: Not applicable
4. Extinguishant: Use an extinguishant that is suitable for the materials involved in the surrounding fire.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Fires involving boron trifluoride should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of boron trifluoride may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Do not get water inside containers. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Firefighters should wear a full set of protective clothing, including a self-contained breathing apparatus, when fighting fires involving boron trifluoride.

EXPOSURE LIMITS

• OSHA PEL

The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for boron trifluoride is 1 ppm (3 mg/m^3) of air as a ceiling limit. A worker's exposure to boron trifluoride shall at no time exceed this ceiling limit [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 1 ppm (3 mg/m^3) as a ceiling limit [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned boron trifluoride a ceiling limit of 1 ppm (2.8 mg/m^3), which should not be exceeded during any part of the working day [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of severe pulmonary irritation associated with exposure to boron trifluoride.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to boron trifluoride can occur through inhalation and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Boron trifluoride is potentially a corrosive poisonous gas that can cause burns to the nasal and respiratory passages, eyes, and skin. It can also be dermally absorbed. Acute exposure of guinea pigs to 100 ppm resulted in the death of all animals. The 1-hr and 4-hr LC_{50}s for rats are 387 (320-467) and 393 ppm, respectively. Before the deaths of these animals, they exhibited respiratory irritation, pneumonia, kidney damage, retarded growth, and severe progressive dental fluorosis [NLM 1991]. In six studies, subchronic exposure of multiple species spanned 0.67 to 100 ppm for 0.5 to 6 months [NLM 1991]. Irritation was noted at all reported levels. Serum chemistry changes (dysproteinemia, decreased globulinemia and cholinesterase), nervous lability, decreased body weight, and pneumonitis occurred at 1 to 4 ppm over a 3 to 6 month exposure period. Rales, renal tubular necrosis, and death occurred at 6 ppm following 3 to 6 months of exposure. Progressive pulmonary involvement (difficult breathing, pneumonitis, emphysema, and alveolar collapse) and death from respiratory failure were noted during months 3 to 6 at 12.8 ppm. Increased lung and liver weights were noted in animals exposed to 22 or 60 ppm for 2 weeks. A 1-month exposure of six species to 100 ppm caused lung and kidney damage and the death of all animals [NLM 1991].

2. *Effects on Humans*: Boron trifluoride is a severe irritant of the nasal passages, lungs, skin, and eyes in humans, producing burns similar to those caused by hydrofluoric acid. Because this substance forms acids when it comes into contact with moisture, the eyes and skin can be severely burned if exposed to boron trifluoride. Exposure at 50 ppm for 30 to 60 min is believed to be lethal to humans [Braker and Mossman 1980]. Eight of 13 workers exposed for 1 to 27 years to boron trifluoride concentrations ranging from an estimated 0.1 to 1.8 ppm showed decreased pulmonary function (forced ventilatory capacity and expiratory volume) on clinical examination, although their chest X-rays were normal [Clayton and Clayton 1981]. A group of 78 workers exposed for 10 to 15 years to boron trifluoride at unspecified concentrations (estimated occasionally to be as high as 32 ppm) developed nosebleeds and dryness of the nasal mucosa, bleeding gums, dry and scaly skin, and joint pain. Concurrent exposures to ethylene and isobutylene were also reported [Parmeggiani 1983; Proctor et al. 1988].

• Signs and symptoms of exposure

1. *Acute exposure*: Severe ambient exposure to boron trifloride can cause severe irritation or burns of the eyes, eyelids, and skin, inflammation and congestion of the lungs, cardiovascular collapse, respiratory failure, and death. Direct tissue contact with the gas can cause frostbite. Inhalation can induce severe salivation, nausea, gastritis, gastroenteritis, abdominal pain, retching, and prolonged vomiting with hematemesis, watery or tarry diarrhea, dehydration, shock, palor, cyanosis, coldness, rapid weak

pulse, rapid shallow breathing, drowsiness, hyporeflexia or convulsions, dilated pupils, coma, and death. Survivors may develop pyloric stenosis, hepatic cirrhosis, and renal damage.

2. *Chronic exposure*: Chronic exposure to boron trifluoride can cause nosebleeds and dryness of the nasal mucosa, bleeding gums, dry and scaly skin, joint pain, osteosclerosis, increased bone density and brittleness, mottled tooth enamel, weight loss, anemia, weakness, and decreased pulmonary function.

- **Emergency procedures**

WARNING

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: If tissue is frozen, seek medical attention ***immediately***. In addition, tissue destruction and blindness may result! ***Immediately but gently*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: If frostbite occurs, seek medical attention ***immediately***. In addition, severe burns, skin corrosion, and absorption of toxic amounts may result! ***Immediately and gently*** wash skin for at least 15 min. Use soap and water if skin is intact; use only water if skin is not intact.

3. *Inhalation exposure*: If boron trifluoride is inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of boron trifluoride may result in worker exposures to this substance:

—Use as a Lewis acid catalyst for alkylation of aromatic compounds and in the polymerization of phenolic and epoxy resins

—Use in nuclear technology for separation of boron isotopes, as a filling gas for neutron counters, in the production of neutron-absorbing salts for molten-salt breeder reactors, and in ionization chambers to detect weak neutrons

—Use as a fumigant

—Use in gas brazing and in the production of diborane and other boron-containing compounds

—Use in the electronics industry to treat separators for high-temperature cells, to prepare high-breakdown voltage varistors, and to enhance the surface conductivity of perylene

—Use in the magnesium industry during casting and heat-treating operations as a fire retardant and antioxidant

The following methods are effective in controlling worker exposures to boron trifluoride, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to boron trifluoride, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the respiratory system, kidneys, and skin. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to boron trifluoride at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with respiratory system, kidney, or skin diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to boron trifluoride exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of boron trifluoride on the respiratory system, kidneys, and skin. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. Urinary fluoride is a nonspecific indicator of exposure to a fluoride compound. Maintaining preshift and postshift urinary fluoride concentrations below 4 and 7 mg/g creatinine, respectively, appears to protect against the development of bony fluorosis.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population. Because occupational exposure to boron trifluoride may cause diseases with prolonged latent periods, the need for medical monitoring may extend well beyond the termination of employment.

WORKPLACE MONITORING AND MEASUREMENT

Neither NIOSH nor OSHA has a recommended method for sampling boron trifluoride in the workplace. However, the following secondary analytical method, which has not been validated, is available. A worker's exposure to airborne boron trifluoride is determined by using a midget fritted-glass bubbler containing 10 ml of 0.1M ammonium fluoride. Samples are collected at a maximum flow rate of 1 liter/min until a maximum air volume of 480 liters is collected. A stock standard is made by dissolving 0.125 g of potassium tetrafluoroborate in 100 ml of 0.1M ammonium fluoride. Working standards are then made by making serial dilutions of the stock standard in 0.1M ammonium fluoride to the appropriate ranges. Analysis is done using the fluoborate specific-ion electrode and a double junction reference electrode. This method is described in the OSHA Laboratory In-House Methods File [OSHA 1989].

PERSONAL HYGIENE

If boron trifluoride contacts the skin, the victim should immediately and thoroughly wash the affected areas with soap and water. Medical attention should be obtained immediately.

Clothing contaminated with boron trifluoride should be removed immediately. In case of massive exposure, the contaminated clothing should be removed under a drenching safety shower and medical attention should be obtained immediately.

A worker who is exposed to boron trifluoride should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where boron trifluoride is present.

STORAGE

Boron trifluoride should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Outside or detached storage in a noncombustible structure is preferred. Cylinders should be stored and handled in accordance with OSHA's compressed gases standard [29 CFR 1910.101]. Containers of boron trifluoride should be protected from physical damage and should be stored separately from alkali metals, alkaline earth metals (except magnesium), alkyl nitrates, calcium oxide, heat, sparks, and open flame. Because containers that formerly contained boron trifluoride may still hold product residues, they should be handled appropriately.

LEAKS

Before boron trifluoride is used in the workplace, emergency procedures should be established and made known to all affected personnel. In the event of a leak involving boron trifluoride, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a leak:

1. Evacuate the leak area for at least 50 ft in all directions.
2. Notify safety personnel.
3. Stop the leak or remove the leaking cylinder if this can be done safely.
4. Do not get water inside cylinders containing boron trifluoride.
5. Flush the leak area with enough water to flood it.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Employers owning or operating a facility with 500 lb or more of boron trifluoride onsite must comply with EPA's emergency planning requirements [40 CFR 355.30].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is above the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for boron trifluoride is 1 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center *immediately* at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of boron trifluoride emitted or released from their facility annually.

• **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although boron trifluoride is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat any waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

• **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of boron trifluoride exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

• **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with boron trifluoride. Gloves, aprons, coveralls, long sleeves, and other protective equipment are recommended as necessary for workers exposed to boron trifluoride. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to boron trifluoride permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to boron trifluoride.

If boron trifluoride is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which boron trifluoride gas might contact the eyes. Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with boron trifluoride. Contact lenses should not be worn if the potential exists for boron trifluoride exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BROMINE

INTRODUCTION

This guideline summarizes pertinent information about bromine for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

• **Formula**

Br_2

• **Synonyms**

Caswell No. 112

• **Identifiers**

1. CAS No.: 7726-95-6
2. RTECS No.: EF9100000
3. DOT UN: 1744 59
4. DOT label: Corrosive

• **Appearance and odor**

Bromine is a heavy, noncombustible, red-brown fuming liquid with an irritating and suffocating odor. The odor threshold is reported to be 0.05 to 3.5 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data**

1. Atomic number: 35
2. Molecular weight: 159.8
3. Boiling point (at 760 mm Hg): 58.8°C (137.8°F)
4. Specific gravity (water = 1): 3.1 at 20°C (68°F)
5. Vapor density (air = 1 at boiling point of bromine): 3.5
6. Melting point: -7.2°C (18.9°F)
7. Vapor pressure: 172 mm Hg at 20°C (68°F); 100 mm Hg at 9.3°C (48.7°F)
8. Solubility: Very slightly soluble in water; freely soluble in alcohol, ether, carbon tetrachloride, carbon disulfide, aqueous solutions of bromides, chloroform, and concentrated hydrochloric acid.
9. Evaporation rate: Data not available

• **Reactivity**

1. Conditions contributing to instability: Bromine emits toxic fumes when it is heated or in contact with steam or water.
2. Incompatibilities: Bromine is a powerful oxidizer; in contact with organic or other readily oxidizable materials, it may cause fires and explosions. Contact of liquid bromine with aqueous ammonia or with metals may cause violent reactions. Anhydrous bromine reacts violently with aluminum, titanium, mercury, or potassium. Bromine is also incompatible with alkali hydroxides, arsenites, carbonyls, alcohols, ferrous and mercurous salts, hypophosphites, and many other substances.
3. Hazardous decomposition products: Toxic fumes may be released in a fire involving bromine.
4. Special precautions: Bromine attacks some coatings and some forms of plastic and rubber. This substance corrodes iron, steel, stainless steel, and copper.

• **Flammability**

The National Fire Protection Association has assigned a flammability rating of 0 (no fire hazard) to bromine; however, it is a strong oxidizer and accelerates the burning of combustibles. The heat of such reactions may cause nearby combustible materials to ignite.

1. Flash point: Not applicable
2. Autoignition temperature: Not applicable
3. Flammable limits in air: Not applicable

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

4. Extinguishant: Use dry chemical, carbon dioxide, Halon®, water spray, or alcohol foam to fight fires involving bromine. Because bromine can react with steam or with small amounts of water, containers should be cooled and surrounding fires should be extinguished by flooding with large amounts of water. Anhydrous ammonia vapor released from a safe distance can be used to neutralize large quantities of bromine vapor; do ***not*** use aqueous ammonia because it may react violently with liquid bromine.

Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving bromine. Chemical protective clothing that is specifically recommended for bromine may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by bromine.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for bromine is 0.1 ppm (0.7 mg/m^3) as an 8-hr time-weighted average (TWA) concentration and 0.3 ppm (2 mg/m^3) as a short-term exposure limit (STEL). A STEL is a 15-min TWA exposure that should not be exceeded at any time during a workday [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 0.1 ppm (0.7 mg/m^3) as an 8-hr TWA and 0.3 ppm (2 mg/m^3) as a STEL [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned bromine a threshold limit value (TLV) of 0.1 ppm (0.7 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek and a STEL of 0.3 ppm (2 mg/m^3) for periods not to exceed 15 min [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of severe irritation of the eyes, mucous membranes, lungs, and skin associated with exposure to bromine.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to bromine can occur through eye or skin contact, inhalation, and ingestion.

• Summary of toxicology

1. *Effects on Animals*: Bromine is a corrosive and severe irritant to the eyes, skin, mucous membranes, and respiratory tract in animals and can be rapidly fatal when inhaled. The lowest observed lethal concentration (LC_{Lo}) is 140 ppm for 7 hr in cats and guinea pigs and 180 ppm for 6.5 hr in rabbits [NIOSH 1991]. Cats, rabbits, and guinea pigs exposed to 180 ppm for 7 hr developed severe eye irritation with clouding of the cornea, severe irritation of the respiratory tract, and difficult breathing; at 23 ppm, however, the irritation and dyspnea was mild [NLM 1992]. Guinea pigs and rabbits exposed to 300 ppm for 3 hr developed lung edema, pseudomembranous deposits on the trachea and bronchi, and hemorrhages of stomach mucosa. Animals that died several days after this exposure showed evidence of bronchopneumonia and central nervous system disturbances at autopsy [Clayton and Clayton 1981]. The 2-hr and 9-min LC_{50}s for mice are 240 and 750 ppm, respectively [ACGIH 1991a; NLM 1992]. Rats, mice, and rabbits inhaling 0.2 ppm of bromine for 4 months showed disturbances in respiratory, endocrine, and nervous system functioning; exposure to 0.02 ppm for the same interval caused no adverse effects [NLM 1992]. Rats fed 0.01 mg/kg bromine for 6 months showed changes in conditional reflexes and in several blood indices.

2. *Effects on Humans*: Bromine is corrosive to the eyes, skin, mucous membranes, and respiratory tract in humans. Eye contact can result in severe, painful, and destructive burns of the eyes [Sittig 1985; AIHA 1978]. Brief contact of the skin with liquid bromine causes vesicles and pustules, and prolonged contact leads to deep, painful burns that ulcerate and are slow to heal [Sittig 1985; Clayton and Clayton 1981]. Repeated contact of the skin with bromine in liquid or vapor form may cause dermatitis and halogen-acne [Rom 1983; Deichmann and Gerarde 1969]. Inhalation of airborne concentrations below 1 ppm causes tearing of the eyes; exposure to 4 ppm can be tolerated for only 30 to 60 min; 10 ppm induces respiratory damage and is considered immediately dangerous to life or health; and 30 ppm would cause death in a short time [Clayton and Clayton 1981; NIOSH 1987b; NLM 1992]. Acute nonlethal exposures can also induce coughing, nosebleed, feelings of oppression, dizziness, headache, and delayed onset of abdominal pain and measles-like dermal eruptions [NLM 1992]. Pulmonary edema may occur after several hours, and high concentrations can cause death from corrosive burns of the lung [Parmeggiani 1983; Sittig 1985]. The inhalation LC_{Lo} in humans is 1,000 ppm [NIOSH 1991]. The lowest lethal oral dose is estimated to be 14 mg/kg [NIOSH 1991]. Ingestion of the liquid produces corrosive tissue burns, mouth and esophageal pain, vomiting, diarrhea, shock (hypotension, tachycardia, cyanosis), headache, dizziness, delirium, collapse, and stupor. Death can result from glottic or pulmonary

edema or aspiration pneumonia. Survivors can develop esophageal and pyloric stenoses [NLM 1992]. Regular exposure to 0.3 to 0.6 ppm for 1 year has induced headache, heart-area chest pain, irritability, anorexia, joint pain, and dyspepsia. Continued exposure for 5 to 6 years can cause loss of corneal reflexes, pharyngitis, vegetative disorders, thyroid hyperplasia and dysfunction, cardiovascular disorders (myocardial degeneration and hypotension), digestive tract secretory disorders, and inhibition of leucopoiesis and leucocytosis [NLM 1992].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to bromine can cause irritation or corrosion of contacted tissues, tearing, corneal clouding, dizziness, headache, pulmonary edema, dyspnea, nosebleeds, coughing, bronchopneumonia, central nervous system disturbances, abdominal pain, diarrhea, altered conditioned reflexes, delirium, collapse, and death. Survivors of ingestion incidents can develop esophageal and pyloric stenoses.

2. *Chronic exposure*: Chronic exposure to bromine can cause contact irritation, slow healing, painful acne-like skin eruptions, headache, heart pain, irritability, anorexia, joint pain, dyspepsia, loss of corneal reflexes, pharyngitis, vegetative disorders, thyroid dysfunction, and cardiovascular and digestive disorders.

- **Emergency procedures**

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Tissue destruction and blindness may result from exposure to concentrated solutions, vapors, mists, or aerosols of bromine! ***Immediately but gently*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Severe burns and skin corrosion may result! ***Immediately*** remove contaminated clothing! ***Immediately and gently*** wash skin for at least 15 min. Use soap and water if skin is intact; use only water if skin is not intact.

3. *Inhalation exposure*: If vapors, mists, or aerosols of bromine are inhaled, move the victim to fresh air ***immediately***. If the victim is not breathing, clean any chemical contamination from victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if bromine or a solution containing it is ingested:

—Do ***not*** induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water. Immediately after rinsing, have the victim drink one cup (8 oz) of fluid and ***no more***.

—Do ***not*** permit the victim to drink milk or carbonated beverages!

—Do ***not*** permit the victim to drink any fluid if more than 60 min have passed since initial ingestion.

NOTE: These instructions must be followed exactly. Drinking a carbonated beverage or more than one cup of fluid could create enough pressure to perforate already damaged stomach tissue. The tissue-coating action of milk can sometimes impede medical assessment of tissue damage. Ingestion of any fluid more than 60 min after initial exposure could further weaken damaged tissue and result in perforation.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve bromine and may result in worker exposures to this substance:

—Manufacture of ethylene dibromide, an anti-knock gasoline additive

—Use of bromine as a solvent

—Manufacture of pesticides

—Use of bromine in flame retardants for the plastics, fabric, and fiber industries

—Use of bromine as a sanitizing, disinfecting, bleaching, and water-purifying agent

—Manufacture of organic and inorganic compounds for use in photographic films and papers, sedatives, inks, anesthetics, hydraulic fluids, pharmaceuticals, fungicides, laboratory reagents, dyes and dyestuffs, war gases,

refrigerating and dehumidifying agents, and hair-waving preparations

—Use of bromine as a bleaching agent for silks and other fabrics, as a shrink-proofing agent for wool, as a desizing agent for cotton, and in gold extraction

The following methods are effective in controlling worker exposures to bromine, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

• Preplacement medical evaluation

Before a worker is placed in a job with a potential for exposure to bromine, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the skin and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to bromine at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with skin or respiratory system diseases.

• Periodic medical examinations and biological monitoring

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to bromine exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of bromine on the skin and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for bromine.

• Medical examinations recommended at the time of job transfer or termination

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job

placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne bromine is determined by using a midget fritted-glass bubbler containing 10 ml of a standard eluent carbonate-bicarbonate solution (0.003 M $NaHCO_3$ to 0.0024 M Na_2CO_3). Samples are collected at a maximum flow rate of 0.5 liter/min until a recommended air volume of 30 liters is collected. (Sampling may continue up to a maximum volume of 120 liters.) Analysis is conducted by ion chromatography. The limit of detection for this procedure is 6.7 $\mu g/m^3$ for a 30-liter sample. This method is described in Method ID-108 of the *OSHA Analytical Methods Manual* [OSHA 1985]. An alternate method uses a silver membrane filter for sample collection, and ion chromatography for analysis with a limit of detection of 1.6 µg of bromine per sample. This method is described in Method 6011 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If bromine contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min and then soak the affected areas in a 10% aqueous thiosulfate solution. Get medical help immediately.

Clothing and shoes contaminated with bromine should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of bromine, particularly its potential for being corrosive to the eyes, skin, and respiratory tract.

A worker who handles bromine should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where bromine or a solution containing bromine is handled, processed, or stored.

STORAGE

Bromine should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of bromine should be protected from physical damage and should be stored separately from combustibles, organic or other readily oxidizable materials, ammonia, aluminum, titanium, mercury, potassium, alkali hydroxides, arsenites, ferrous and mercurous salts, hypophosphites, heat, sparks, direct sunlight, and open flame. Bromine should be stored at temperatures above −6.7°C (19.9°F) to prevent freezing; heating containers of bromine above atmospheric temperatures may rupture the containers. Because containers that formerly contained bromine may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

Before bromine is handled in the workplace, an emergency plan for dealing with emergency spills or leaks of this substance must be developed. In the event of a spill or leak involving bromine, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.

2. Notify safety personnel.

3. Stay upwind of the spill or leak area to the extent possible.

4. Neutralize small liquid spills by pouring a hypo solution (sodium thiosulfate or limewater) over them; the spilled material can then be absorbed with sand or other noncombustible absorbent material and placed in a covered container for later disposal.

5. Neutralize large liquid spills with a solution of potassium carbonate, sodium carbonate, or sodium bicarbonate; or build a dike far ahead of the spill to contain the bromine for later reclamation or disposal.

6. Neutralize bromine vapors in air by carefully releasing anhydrous ammonia gas (do ***not*** use aqueous ammonia gas).

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

If 500 lb or more of bromine is present at a facility, the owner or operator must comply with EPA's emergency planning requirements [40 CFR 355.30].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is above the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for bromine is 1 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of bromine emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although bromine is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of bromine exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987c] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with bromine. Rubber boots, gloves, aprons, and full-body covering are recommended. Chemical protective clothing should be selected on the basis of available

performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Teflon® has been tested against permeation by bromine and may provide good-to-excellent resistance for more than 4 but fewer than 8 hr. Polyethylene and natural rubber have been tested against bromine and have demonstrated poor resistance to permeation by bromine.

If bromine is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which bromine might contact the eyes (e.g., through contact with the vapor or splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with bromine. Contact lenses should not be worn if the potential exists for bromine exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BROMOFORM

INTRODUCTION

This guideline summarizes pertinent information about bromoform for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$CHBr_3$

- **Synonyms**

Tribromomethane, methenyl tribromide, methyl tribromide

- **Identifiers**

1. CAS No.: 75-25-2
2. RTECS No.: PB5600000
3. DOT UN: 2515 58
4. DOT label: St. Andrew's Cross

- **Appearance and odor**

Bromoform is a nonflammable, colorless-to-dark-brown, fuming, volatile liquid with a suffocating chloroformlike odor; it may form hexagonal crystals at 6° to 7°C (43° to 45°F). The odor threshold is reported to be 1.3 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 252.8
2. Boiling point (at 760 mm Hg): 149° to 150°C (300.2° to 302°F)
3. Specific gravity (water = 1): 2.9 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of bromoform): 8.7
5. Melting point: 8.3°C (46.9°F)
6. Vapor pressure at 20°C (68°F): 5 mm Hg
7. Solubility: Slightly soluble in water; miscible with alcohol, benzene, chloroform, ether, petroleum ether, acetone, and oils
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: None
2. Incompatibilities: Fires and explosions may result from contact of bromoform with chemically active metals (sodium, potassium, powdered aluminum, zinc, magnesium, lithium), calcium, acetone, or strong caustics (such as potassium hydroxide).
3. Hazardous decomposition products: Toxic gases (such as carbon monoxide, bromine, hydrogen bromide, and bromine oxides) may be released in a fire involving bromoform.
4. Special precautions: Liquid bromoform attacks some coatings and some forms of plastic and rubber.

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to bromoform; this substance is not flammable.

1. Flash point: Not applicable
2. Autoignition temperature: Not applicable
3. Flammable limits in air (% by volume): Not applicable

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4. Extinguishant: Bromoform itself does not burn; use an extinguishant that is suitable for the material involved in the surrounding fire.

Fires involving bromoform should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving bromoform. Chemical protective clothing that is specifically recommended for bromoform may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by bromoform.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for bromoform is 0.5 ppm (5 mg/m^3) as an 8-hr time-weighted average (TWA). The OSHA PEL also bears a "Skin" notation, which indicates that the cutaneous route of exposure (including mucous membranes and eyes) contributes to overall exposure [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 0.5 ppm (5 mg/m^3) as an 8-hr TWA with a "Skin" notation [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned bromoform a threshold limit value (TLV) of 0.5 ppm (5.2 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek and a "Skin" notation [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of irritation and liver damage associated with exposure to bromoform.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to bromoform can occur through inhalation, ingestion, skin absorption, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Bromoform is an irritant of the eyes, skin, and respiratory tract; a central nervous system depressant; and a liver and kidney toxin. The application of undiluted bromoform to the eyes of rabbits caused moderate irritation that healed within 1 or 2 days. Rabbits also acutely exposed dermally to undiluted bromoform (2,000 mg/kg) developed moderate skin irritation but did not die [Clayton and Clayton 1981]. Rabbits exposed to 1,070 to 1,270 ppm for an unspecified duration developed narcosis [Clayton and Clayton 1981]. A dog exposed for 1 hr to approximately 7,000 ppm experienced deep narcosis followed by death [ACGIH 1991a]. The oral LD_{50}s for male and female rats were 1,388 and 1,147 mg/kg, respectively. Exposure of rabbits to 243 ppm for 10 days resulted in functional changes in the central nervous system, liver, and kidneys plus vascular and dystrophic changes [Clayton and Clayton 1981]. Rats exposed to 24 ppm for 4 hr/day for 2 months developed disorders in liver prothrombin synthesis and glycogenesis as well as reduced renal filtration capacity [NLM 1991]. Bromoform was mutagenic when tested in three strains of *Salmonella typhimurium* [ACGIH 1991a]. Carcinogenicity bioassays were performed with mice and rats treated by gavage with various doses of bromoform for 5 days/week during 103 weeks. Although the male and female rats in these bioassays showed an increased incidence of adenomatous polyps or adenocarcinomas of the large intestine, the mice were unaffected by treatment [NTP 1989]. Mice given repeated intraperitoneal injections of bromoform developed a significantly increased incidence of pulmonary adenomas [Theiss et al. 1977].

2. *Effects on Humans*: Bromoform has both narcotic and irritant effects in humans. Exposure to the vapor at unspecified concentrations causes irritation of the eyes, respiratory tract, pharnyx, and larnyx [Proctor et al. 1988]. Prolonged contact with the skin may lead to skin burns [NLM 1991]. Accidental ingestion of bromoform has produced central nervous system depression with coma and loss of reflexes; small doses have led to listlessness, headache, and vertigo [ACGIH 1991a].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to bromoform can cause irritation, tearing, headache, dizziness, vertigo, digestive symptoms, weight loss, excessive salivation, lethargy, sedation, amnesia, shock, convulsions, anesthesia, pulmonary edema, respiratory failure, and death.

2. *Chronic exposure*: No signs or symptoms of chronic bromoform exposure have been reported.

• **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of bromoform. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of bromoform are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if bromoform or a solution containing it is ingested:

—Do *not* induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of bromoform may result in worker exposures to this substance:

—Use as a reagent for graphite ore fractionation and as a heavy liquid flotation agent in mineral separation for sedimentary petrographical surveys, geological assays, and purification of materials such as quartz

—Use in the shipbuilding, aircraft, and aerospace industries

—Use as a solvent for waxes, greases, oils, and fats

—Use as an ingredient in fire-resistant chemicals and gauge fluids

—Use as an ingredient in pharmaceuticals and medicinal products such as antiseptics, sedatives, and cough suppressants

The following methods are effective in controlling worker exposures to bromoform, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to bromoform, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the central nervous system, liver, kidneys, and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to bromoform at or below the prescribed exposure limit. The health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with central nervous system, liver, kidney, or respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to bromoform exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of bromoform on the central nervous system, liver, kidneys, and respiratory tract. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. Inorganic bromide can be detected in the serum of bromine-exposed workers. Some sources suggest that the serum bromide concentration in bromoform-exposed workers should not exceed 15 to 30 mg/liter of serum. However, because few data correlate airborne exposure concentrations with serum bromide concentrations, no biological monitoring test acceptable for routine use has yet been developed for bromoform.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne bromoform is determined by using coconut shell charcoal tubes (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 10 liters is collected. The sample is then desorbed with carbon disulfide. Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is 5 μg per sample. This method is described in Method 1003 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If bromoform contacts the skin, workers should flush the affected areas immediately with plenty of water and then wash thoroughly with soap and water.

Clothing contaminated with bromoform should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of bromoform, particularly its potential for causing eye and respiratory tract irritation.

A worker who handles bromoform should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where bromoform or solutions containing bromoform are handled, processed, or stored.

STORAGE

Bromoform should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of bromoform should be protected from physical damage and should be stored separately from caustic alkalies, chemically active metals (such as sodium, potassium, powdered aluminum, zinc, magnesium, and lithium), calcium, acetone, heat, sparks, and open flame. Because containers that formerly contained bromoform may hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving bromoform, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.

2. Notify safety personnel.

3. Ventilate the area of the spill or leak.

4. Absorb small spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

5. For large spills, build dikes far ahead of the spill to contain the bromoform for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Bromoform is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is equal to or greater than the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal authorities.

The reportable quantity for bromoform is 100 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of bromoform per calendar year are required by EPA [40 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of bromoform emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Bromoform is listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.] and it has been assigned EPA Hazardous Waste No. U225. Bromoform is approved for land disposal as long as the concentration of bromoform in the waste or treatment residual does not exceed 15 mg/kg. Bromoform also may be disposed of in an organometallic or organic lab pack that meets the requirements of 40 CFR 264.316 or 265.316.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of bromoform exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require

entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with bromoform. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been tested against permeation by bromoform and have demonstrated protection for periods greater than 8 hr: polyvinyl alcohol and Viton®. Butyl rubber has demonstrated questionable resistance to permeation by bromoform. Natural rubber, neoprene, nitrile rubber, and polyvinyl chloride have demonstrated poor resistance to permeation by bromoform.

If bromoform is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which bromoform might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with bromoform. Contact lenses should not be worn if the potential exists for bromoform exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BUTADIENE (1,3-BUTADIENE)

INTRODUCTION

This guideline summarizes pertinent information about butadiene (1,3-butadiene) for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

C_4H_6

- **Structure**

$CH_2=CH\text{-}CH=CH_2$

- **Synonyms**

1,3-Butadiene, trans-butadiene, bivinyl, divinyl, erythrene, vinylethylene, biethylene, butadiene monomer, pyrrolylene, 1-methylallene

- **Identifiers**

1. CAS No.: 106-99-0
2. RTECS No.: EI9275000
3. DOT UN: 1010 17 (inhibited butadiene)
4. DOT label: Flammable Gas (inhibited butadiene)

- **Appearance and odor**

Butadiene is a colorless, flammable gas with a mild aromatic odor. It is shipped under its own vapor pressure as a liquefied gas. The odor threshold is reported to be 1.1 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 54.1
2. Boiling point (760 mm Hg): -4.4°C (24°F)
3. Specific gravity (water = 1): 0.62 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of butadiene): 1.9
5. Melting point: -108.9°C (-164.0°F)
6. Vapor pressure at 21°C (69.8°F): 1,840 mm Hg
7. Solubility: Insoluble in water; soluble in alcohol, ether, acetone, and benzene
8. Evaporation rate: Not applicable; butadiene is a gas.

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, or open flame. When exposed to air, butadiene may form explosive peroxides.

2. Incompatibilities: Fires, explosions, or hazardous polymerization may result from contact of butadiene with air, strong oxidizers, ozone, nitrogen dioxide, copper, copper alloys, phenol, chlorine dioxide, crotonaldehyde, or a free radical polymerization initiator such as hydroquinone.

3. Hazardous decomposition products: Toxic gases (such as carbon monoxide and carbon dioxide) may be released in a fire involving butadiene.

4. Special precautions: Butadiene is self-reactive. To prevent hazardous polymerization, an inhibitor must be added to the butadiene and the concentration of inhibitor (such as tert-butylcatechol) must be monitored to ensure that it remains at effective levels at all times.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 4 (extreme fire hazard) to butadiene.

1. Flash point: -156°F (105°C)
2. Autoignition temperature: 420°C (788°F)

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3. Flammable limits in air (% by volume): Lower, 2.0; upper, 12.0

4. Extinguishant: Butadiene is a flammable gas. To extinguish a fire involving this substance, the flow of gas must be stopped. Fires involving butadiene should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of butadiene may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving butadiene. Firefighters' protective clothing may not provide protection against permeation by butadiene.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for buta-diene is 1,000 ppm (2,200 mg/m^3) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A]. However, OSHA has published a proposed rule on occupational exposure to butadiene that would reduce the PEL to 2 ppm as a TWA and 10 ppm as a short-term exposure limit (STEL) [55 FR 32736, August 10, 1990]. A STEL is a 15-min TWA exposure that should not be exceeded at any time during a workday.

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has recommended that butadiene be considered a potential occupational carcinogen and that exposure be limited to the lowest feasible concentration [NIOSH 1984a, 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has designated butadiene an A2 substance (suspected human carcinogen) and has assigned butadiene a threshold limit value (TLV) of 10 ppm (22 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The current OSHA limit is based on the risk of irritation and narcosis associated with exposure to butadiene and does not take into account the possible carcinogenic effects of this substance. The proposed OSHA PEL and NIOSH REL are based on butadiene's potential occupational carcinogenicity and reproductive toxicity. The ACGIH TLV is based on potential occupational carcinogenicity.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to butadiene can occur through inhalation and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Butadiene is an irritant of the eyes and mucous membranes, and it is a narcotic at high concentrations. This substance is also a carcinogen and reproductive toxin in experimental animals. The 2-hr LC_{50} in rats is 270 g/m^3 (129,000 ppm) [NIOSH 1991]. Rabbits exposed for 8 to 10 min at 200,000 to 250,000 ppm were deeply anesthetized but recovered completely after exposure ceased. If the exposure was continued for 25 to 35 min, the animals died [ACGIH 1991a]. Inhalation of 625 or 1,250 ppm butadiene for 6 hr/day, 5 days/week for 6 weeks caused nonneoplastic effects in mice at several organ sites (ovaries, testes, nasopharynx, lung, and liver) [NIOSH 1984a]. Rats, guinea pigs, rabbits, and a dog exposed to butadiene concentrations ranging from 600 to 6,700 ppm for 7.5 hr/day, 6 days/week for 8 months developed no significant toxic effects [ACGIH 1991a; Proctor et al. 1988]. Inhalation exposure to butadiene at 200 ppm was toxic to pregnant rats and retarded embryonic growth and development; exposure at 8,000 ppm during pregnancy caused a significant increase in major skeletal abnormalities in the offspring [Proctor et al. 1988; ACGIH 1991a]. Butadiene has caused cancers in the mammary glands, uterus, ovaries, testes, thyroid gland, pancreas, liver, Zymbal gland, heart, lungs, lymph system, and hematopoietic system in rats and mice chronically exposed to this substance in inhalation bioassays [NIOSH 1984a]. On this basis, the International Agency for Research on Cancer (IARC) has concluded that butadiene is an animal carcinogen [IARC 1986].

2. *Effects on Humans*: Exposure to butadiene causes irritation of the eyes, mucous membranes, upper respiratory tract, and skin in exposed workers [Cralley and Cralley 1985; ACGIH 1991a]. Volunteers exposed to butadiene at 2,000 ppm experienced irritation of the eyes, nose, throat, and skin [NIOSH 1984a]. In contact with the skin, the liquid may cause frostbite [NIOSH 1984a]. Epidemiological studies of workers exposed to butadiene, styrene, and benzene at two styrene-butadiene rubber facilities (with average

butadiene exposures of 1.24 and 13.5 ppm, respectively) have shown an increased, but not statistically significant, risk of mortality from lymphatic and hematopoietic system cancer and from leukemia [NIOSH 1984a]. IARC has stated that evidence is insufficient to conclude that butadiene is a human carcinogen [IARC 1986].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to butadiene can cause irritation of the eyes, nose, and throat, with redness and tearing of the eyes, runny nose, and cough. Skin contact with butadiene in liquid form may cause burns or frostbite. At high concentrations, butadiene causes blurred vision, nausea, fatigue, headache, dizziness, rapid breathing, decreased blood pressure and pulse, diminished mental alertness, muscular incoordination, unconsciousness, respiratory paralysis, and death.

2. *Chronic exposure*: Prolonged or repeated skin contact with butadiene can induce dermatitis. On the basis of effects seen in animals, butadiene should be considered a potential carcinogen.

- **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of frostbite, toxicity, or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: If tissue is frozen, seek medical attention ***immediately***; if tissue is not frozen, ***immediately and thoroughly*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids. If irritation, pain, swelling, lacrimation, or photophobia persists, get medical attention as soon as possible.

2. *Skin exposure*: If frostbite has occurred, seek medical attention ***immediately***; do ***not*** rub the affected areas or flush them with water. If frostbite has ***not*** occurred, ***immediately and thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: Move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve butadiene and may result in worker exposures to this substance:

—Manufacture of styrene-butadiene-rubber (SBR) elastomer, polybutadiene elastomer, neoprene elastomer, nitrile elastomer, styrene-butadiene (SB) copolymer, and acrylonitrile-butadiene-styrene (ABS) resins, which are used as reinforcing and stiffening agents for rubbers

—Manufacture of high-impact polystyrene containing SBR/polybutadiene elastomer and of SBR foams

—Molding and vulcanizing operations that process synthetic rubber products from SBR

—Use of butadiene in latexes and resins to make carpet backing, paper coatings, high-impact-resistant pipes and parts for automobiles, appliances, business machines, telephones, and recreational vehicles

—Manufacture of tires, hoses, belts, gaskets, seals, and oil-resistant textile and paper products

—Manufacture of adiponitrile; cyclo-olefins; 1,4-hexadiene tetramethylene sulfone; tetrahydrophthalic anhydride; hexamethylenediamine; ethylidenenorbornene; and 1,5,9-cyclodecatriene

—Use of butadiene in the Diels-Alder condensation reaction for synthesis of compounds

—Use of butadiene in food wrappings, the latex paint industry, rocket fuels, pesticides, and fungicides

The following methods are effective in controlling worker exposures to butadiene, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to acrylic acid, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to acrylic acid at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with respiratory system or skin diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to butadiene exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of butadiene on the respiratory tract and skin. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for butadiene.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population. Because occupational exposure to butadiene may cause diseases with prolonged latent periods, the need for medical monitoring may extend well beyond the termination of employment.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne butadiene is determined by using charcoal tubes (100/50-mg sections, 20/40 mesh) coated with 10% (w/w) 4-tert-butylcatechol. Samples are collected at a maximum flow rate of 0.05 liter/min until a maximum air volume of 3 liters is collected. The sample is then treated with carbon disulfide to extract the butadiene. Analysis is conducted by gas chromatography using a flame ionization detector. The standard analytical error for this procedure is 0.11. The OSHA method is described in the OSHA Computerized Information System [OSHA 1990] and in Method 56 of the *OSHA Analytical Methods Manual*

[OSHA 1985]. NIOSH has a similiar method for butadiene [NIOSH 1984b]. OSHA Method 56 is compared with NIOSH Method 1024 in the NIOSH comments on the proposed rule for 1,3-butadiene [NIOSH 1990].

PERSONAL HYGIENE

If liquid butadiene contacts the skin, frostbite may occur. Workers should flush the affected areas immediately with plenty of tepid water and then wrap the affected part in a warm dressing. Medical aid should be obtained immediately.

Clothing contaminated with liquid butadiene should be removed immediately.

A worker who handles butadiene cylinders should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where butadiene cylinders are handled, processed, or stored.

STORAGE

Butadiene should be stored in a cool, dry, well-ventilated area in tightly sealed and pressurized containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Outside, isolated, or detached storage is preferred; inside storage should be in a noncombustible location. Containers of butadiene should be stored upright and should not be stacked. Containers of butadiene should be protected from physical damage and should be stored separately from oxygen, chlorine, phenol, chlorine dioxide, crotonaldehyde, copper, copper alloys, oxidizers, heat, sparks, and open flame. The manufacturer's recommendations regarding shelf life, rotation of inventory, and monitoring of levels of inhibitor should be followed rigorously. Only nonsparking tools may be used to handle butadiene. To prevent static sparks, containers should be grounded and bonded for transfers. Because containers that formerly contained butadiene may hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving butadiene, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Isolate the area until the gas has dispersed.
5. If butadiene gas is leaking, stop the flow of gas if it is possible to do so without risk.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Butadiene is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of butadiene; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of butadiene per calendar year are required by EPA [40 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of butadiene emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although butadiene is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in

Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of butadiene exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with butadiene. Protective gloves and clothing are recommended for workers handling this material. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been tested against permeation by butadiene and have demonstrated good-to-excellent resistance for periods of greater than 8 hr: butyl rubber and Viton®. Natural rubber, neoprene, and polyvinyl chloride have demonstrated poor resistance to permeation by butadiene.

If butadiene is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which butadiene might contact the eyes (e.g., through splashes of the liquid). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with liquid butadiene. Contact lenses should not be worn if the potential exists for butadiene exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR 2-BUTOXYETHANOL

INTRODUCTION

This guideline summarizes pertinent information about 2-butoxyethanol for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_6H_{14}O_2$

- **Structure**

$CH_3(CH_2)_3OCH_2CH_2OH$

- **Synonyms**

2-Butoxy-1-ethanol; beta-butoxyethanol; o-butyl ethylene glycol; butyl glycol; butyl oxitol; ethylene glycol monobutyl ether; glycol butyl ether; monobutyl ether of ethylene glycol; n-butoxyethanol; Butyl Cellosolve; Dowanol EB; Ektasolve EB; Gafcol EB; Jeffersol EB; Poly-solv EB; EGBE

- **Identifiers**

1. CAS No.: 111-76-2
2. RTECS No.: KJ8575000
3. DOT UN: 2369 26
4. DOT labels: St. Andrew's Cross; Flammable Liquid

- **Appearance and odor**

2-Butoxyethanol is a clear, colorless liquid with a pleasant, etherlike odor. The odor threshold is reported to be 0.35 part per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 118.2
2. Boiling point (760 mm Hg): 171°C (340°F)
3. Specific gravity (water = 1): 0.90 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of 2-butoxyethanol): 4.1
5. Melting point: -70°C (-94°F)
6. Vapor pressure at 20°C (68°F): 0.8 mm Hg
7. Solubility: Miscible in water, alcohol, ether, mineral oil, and most organic solvents
8. Evaporation rate (butyl acetate = 1): 0.07

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame
2. Incompatibilities: Fires and explosions may result from contact of 2-butoxyethanol with strong oxidizers or caustics.
3. Hazardous decomposition products: Toxic gases (such as carbon monoxide) may be released in a fire involving 2-butoxyethanol.
4. Special precautions: 2-Butoxyethanol attacks some coatings and some forms of plastic and rubber; at high temperatures, this substance may attack metallic aluminum.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 2 (moderate fire hazard) to 2-butoxyethanol.

1. Flash point: 62°C (143°F) (closed cup)
2. Autoignition temperature: 238°C (460°F)
3. Flammable limits in air (% by volume): Lower, 1.1 at 93°C (200°F); upper, 12.7 at 135°C (275°F)

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Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

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Occupational Safety and Health Administration

4. Extinguishant: Use alcohol foam, carbon dioxide, dry chemical, Halon®, water spray, or fog to fight fires involving 2-butoxyethanol. Do *not* use a solid stream of water because it will scatter and spread the fire.

Fires involving 2-butoxyethanol should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of 2-butoxyethanol may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving 2-butoxyethanol. Firefighters' protective clothing may not provide protection against permeation by 2-butoxyethanol.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for 2-butoxyethanol is 25 ppm (120 mg/m3) as an 8-hr time-weighted average (TWA). The OSHA PEL also bears a "Skin" notation, which indicates that the cutaneous route of exposure (including mucous membranes and eyes) contributes to overall exposure [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 5 ppm (24 mg/m^3) as a 10-hr TWA for a 40-hr workweek; the REL also bears a "Skin" notation [NIOSH 1990, 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned 2-butoxyethanol a threshold limit value (TLV) of 25 ppm (120 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek. The ACGIH also assigns a "Skin" notation to 2-butoxyethanol [ACGIH 1991b].

• Rationale for limits

The OSHA and ACGIH limits are based on the risk of hematologic and other systemic effects associated with exposure to 2-butoxyethanol. The NIOSH limit is based on tissue irritation, CNS depression, and adverse effects of exposure on the blood and hematopoietic systems.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to 2-butoxyethanol can occur through inhalation, ingestion, skin absorption, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: 2-Butoxyethanol is an irritant of the eyes, mucous membranes, and skin; it also causes hemolysis, kidney damage, reproductive effects, immunotoxicity, and embryotoxicity in animals. 2-Butoxyethanol caused severe corneal injury in rabbits [Tyler 1984]. When applied to the skin of rabbits for 4 hr, 2-butoxyethanol caused only mild irritation; extending the period of skin contact increased the degree of irritation [Tyler 1984]. Repeated application of this substance to rabbit skin caused systemic toxicity manifested as reduced body weight gain [Tyler 1984]. The oral LD_{50} is about 530 mg/kg in rats and 490 mg/kg in rabbits [NIOSH 1991]. At autopsy, acutely-poisoned animals exhibited kidney damage, narcotic effects, and breathing difficulty before death [Proctor et al. 1988]. Rats exposed to 245 ppm in air for 6 hr/day for 9 days showed significant depressions in red blood cell counts and hemoglobin concentrations and increases in nucleated erythrocytes, reticulocytes, and lymphocytes [Dodd et al. 1983]. Exposure of rats to 77 ppm in air for 30 hr/week for 90 days caused mild hematologic alterations. Fourteen days after exposure ceased, these hematologic effects were no longer evident [Dodd et al. 1983]. Male rats given 500 or 1,000 mg/kg per day for 4 days by oral gavage showed leukopenia and anemia; testicular atrophy was apparent in animals in the 500-mg/kg group [Grant et al. 1985]. Rats given 222, 443, or 885 mg/kg of 2-butoxyethanol by gavage for 6 weeks (5 days/week) showed a dose-dependent decrease in hemoglobin concentration and red blood cell count; these changes were apparent at all dose levels [Krasavage 1986; Ghanayem et al. 1990]. Teratogenicity studies have shown that 2-butoxyethanol to cause maternal, embryonic, and fetal toxicity in rats at 100 or 200 ppm, and maternal and embryonic toxicity in rabbits at 200 ppm [Tyl et al. 1984].

2. *Effects on Humans*: 2-Butoxyethanol is an irritant of the eyes and upper respiratory tract in humans. After an 8-hr exposure to 195 ppm, volunteers reported eye, nose, and throat discomfort; at 113 ppm for 4 hr, milder symptoms were experienced [Proctor et al. 1988]. Although humans appear to be less sensitive to the hematologic effects of 2-butoxyethanol than rats and mice, human red blood cells exposed in vitro showed increased fragility [Carpenter et al. 1956]. In one case report, a worker experienced two separate episodes of hematuria after being exposed to unspecified concentrations of 2-butoxyethanol and diethylene glycol monobutyl ether [Browning 1971].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to 2-butoxyethanol can cause irritation of the eyes, nose, and throat, with pain and tearing of the eyes, runny nose, and cough; skin irritation with redness and cracking; and narcotic effects with difficult breathing.

2. *Chronic exposure*: Chronic exposure to 2-butoxyethanol can cause dermatitis and hematuria.

- **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of 2-butoxyethanol. ***Immediately and thoroughly*** flush eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation or absorption of toxic amounts may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water for at least 15 min.

3. *Inhalation exposure*: If vapors, mists, or aerosols of 2-butoxyethanol are inhaled, move the victim to fresh air *immediately*.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if 2-butoxyethanol or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of 2-butoxyethanol may result in worker exposures to this substance:

—Use as a solvent for nitrocellulose resins and enamels, spray lacquers, quick-drying lacquers, varnishes, varnish removers, grease, oil, albumin, and dry cleaning compounds

—Use as a solvent for paints, printing inks, and dyestuffs and as an ingredient in agricultural chemicals, nonvolatile herbicides, brake oils, detergents for the automobile industry, penetrants, and softeners

—Use as a solvent for "soluble" mineral oils to hold soap in solution and to improve emulsifying properties

—Use as a solvent for protective coatings and metal cleaners

—Use as an agent to prevent spotting in textile printing and dyeing

—Use in production of acetate esters and phthalate and stearate plasticizers

—Use as a stabilizing agent in metal cleaners, textile lubricants, oils, hydraulic fluids, and liquid household cleaners

The following methods are effective in controlling worker exposures to 2-butoxyethanol, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to 2-butoxyethanol, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the skin, kidneys, liver, respiratory system, and blood. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to 2-butoxyethanol at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with skin, kidney, liver, respiratory system, or blood diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to 2-butoxyethanol exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of 2-butoxyethanol on the skin, kidney, liver, respiratory system, and blood. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. Although butoxy acetic acid (BAA), a metabolite of 2-butoxyethanol, can be detected in the urine of exposed individuals, excreted levels of butoxy acetic acid do not correlate with airborne concentrations of 2-butoxyethanol. Therefore, no biological monitoring test acceptable for routine use has yet been developed for

2-butoxyethanol. However, NIOSH has recommended guidelines for biological monitoring of BAA [NIOSH 1990].

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne 2-butoxyethanol is determined by using coconut shell charcoal tubes (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.05 liter/min until a maximum air volume of 10 liters is collected. The sample is then treated with methylene chloride/methanol (95:5) to extract the 2-butoxyethanol. Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is 0.01 to 0.02 mg per sample. This method is described in Method 1403 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984]. A similar method for sampling and analyzing 2-butoxyethanol is included in Method 83 of the *OSHA Analytical Methods Manual* [OSHA 1990].

PERSONAL HYGIENE

2-Butoxyethanol can be absorbed through the skin in toxic amounts. Therefore, if 2-butoxyethanol contacts the skin, workers should immediately flush the skin with large amounts of water and then wash with soap and water.

Clothing and shoes contaminated with 2-butoxyethanol should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of 2-butoxyethanol, particularly its potential for being absorbed through the skin in toxic amounts.

A worker who handles 2-butoxyethanol should thoroughly wash hands with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where 2-butoxyethanol is handled, processed, or stored.

STORAGE

2-Butoxyethanol should be stored in a cool, dry, dark, well-ventilated area in tightly sealed, resin-coated, stainless steel containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. This substance should not be stored in aluminum containers. Electrical service in the storage area must be of explosionproof design. Containers of 2-butoxyethanol should be protected from physical damage and should be stored separately from strong oxidizers, strong caustics, heat, sparks, and open flame. Only nonsparking tools should be used to handle this substance. To prevent static sparks, all containers and equipment used to transfer 2-butoxyethanol must be bonded and grounded. Because containers that formerly contained 2-butoxyethanol may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving 2-butoxyethanol, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.

2. Notify safety personnel.

3. Remove all sources of heat and ignition.

4. Ventilate potentially explosive atmospheres with maximally explosionproof ventilation.

5. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

6. For large liquid spills, build dikes far ahead of the spill to contain the 2-butoxyethanol for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore

advised to determine periodically whether new information is available.

- **Emergency planning requirements**

2-Butoxyethanol is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of 2-butoxyethanol; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of 2-butoxyethanol emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although 2-butoxyethanol is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of 2-butoxyethanol exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with 2-butoxyethanol. Gloves, aprons, guantlets, boots, and other protective clothing should be worn as necessary. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Butyl rubber and Saranex® have been recommended for use against permeation by 2-butoxyethanol and may provide protection for periods greater than 8 hr. Natural rubber, polyvinyl alcohol, and polyvinyl chloride have demonstrated poor resistance to permeation by 2-butoxyethanol.

If 2-butoxyethanol is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which 2-butoxyethanol might contact the eyes (e.g., through dust particles or splashes of solution). Eyewash fountains and emergency showers should be

available within the immediate work area whenever the potential exists for eye or skin contact with 2-butoxyethanol. Contact lenses should not be worn if the potential exists for 2-butoxyethanol exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR n-BUTYL ACETATE

INTRODUCTION

This guideline summarizes pertinent information about n-butyl acetate for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_6H_{12}O_2$

- **Structure**

$CH_3COO(CH_2)_3CH_3$

- **Synonyms**

n-Butyl acetate; butyl ethanoate; acetic acid, n-butyl ester; 1-butyl acetate

- **Identifiers**

1. CAS No.: 123-86-4
2. RTECS No.: AF7350000
3. DOT UN: 1123 26
4. DOT label: Flammable Liquid

- **Appearance and odor**

n-Butyl acetate is a clear, colorless, flammable liquid with a fruity odor. The odor threshold is reported to be 0.7 part per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 116.2
2. Boiling point (at 760 mm Hg): 126°C (258°F)
3. Specific gravity (water = 1): 0.88 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of n-butyl acetate): 4.0
5. Melting point: -77.9°C (-108.2°F)
6. Vapor pressure at 20°C (68°F): 10 mm Hg
7. Solubility: Slightly soluble in water; miscible with alcohol, ether, and most hydrocarbons
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame
2. Incompatibilities: Fires may result from contact of n-butyl acetate with potassium-tert-butoxide, nitrates, strong oxidizers, strong alkalies, and strong acids.
3. Hazardous decomposition products: Toxic gases and vapors (such as partial oxidation products, carbon dioxide, and carbon monoxide) may be released in a fire involving n-butyl acetate.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 3 (severe fire hazard) to n-butyl acetate.

1. Flash point: 22°C (72°F) (closed cup)
2. Autoignition temperature: 425°C (797°F)
3. Flammable limits in air (% by volume): Lower, 1.7; upper, 7.6
4. Extinguishant: Use dry chemical, alcohol foam, or carbon dioxide to fight fires involving n-butyl acetate. A stream of water should not be used to extinguish fires involving this substance because the water will scatter and spread the fire.

Fires involving n-butyl acetate should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of n-butyl acetate may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving n-butyl acetate. Firefighters' protective clothing may not provide protection against permeation by n-butyl acetate.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for n-butyl acetate is 150 ppm (710 mg/m^3) as an 8-hr time-weighted average (TWA) concentration and 200 ppm (950 mg/m^3) as a short-term exposure limit (STEL). A STEL is a 15-min TWA exposure that should not be exceeded at any time during a workday [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 150 ppm (710 mg/m^3) as an 8-hr TWA and 200 ppm (950 mg/m^3) as a STEL [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned n-butyl acetate a threshold limit value (TLV) of 150 ppm (713 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek and a STEL of 200 ppm (950 mg/m^3) for periods not to exceed 15 min [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of sensory irritation associated with exposure to n-butyl acetate.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to n-butyl acetate can occur through inhalation, ingestion, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: n-Butyl acetate causes moderate to severe irritation of the eyes, skin, and upper respiratory tract in animals; at high concentrations, it can cause narcosis and death from respiratory failure. In rabbits, n-butyl acetate caused moderate skin irritation after 24 hr of exposure and severe eye irritation after instillation [NIOSH 1991]. Guinea pigs exposed to 3,300 ppm showed signs of eye irritation; exposure to 7,000 ppm for 11 hr caused narcosis [Proctor et al. 1988]. In rats, the oral LD_{50} is 14 g/kg, and the LC_{50} is 2,000 ppm for 4 hr [NIOSH 1991]. Nearly saturated vapor (10,000 ppm) was fatal to six rats following an 8-hr exposure. Mice exposed to n-butyl acetate at concentrations ranging from 3,100 to 4,200 ppm 6 hr/day for 6 days showed signs of fatigue, weight loss, and an increase in formed elements in the blood and in hemoglobin levels [NLM 1991]. When administered during pregnancy, n-butyl acetate was embryotoxic in mice and rats [NIOSH 1991; NLM 1991].

2. *Effects on Humans*: n-Butyl acetate is an irritant of the eyes, nose, respiratory tract, and skin in exposed workers. Volunteers exposed to n-butyl acetate at 200 ppm reported upper respiratory tract irritation; at 300 ppm, this irritation was reported to be severe [ACGIH 1991a]. Humans exposed to concentrations as high as 3,300 ppm experienced lacrimation and conjunctival redness [Grant 1986]. Vacuolar keratitis occurred in workers exposed to a mixture of butyl acetate and isobutyl alcohol. Hepatotoxicity has also been reported. Repeated skin contact with n-butyl acetate caused dermatitis in a pharmaceutical plant worker [NLM 1991].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to n-butyl acetate can cause contact irritation, headache, muscle weakness, giddiness, dizziness, ataxia, confusion, delirium, CNS and respiratory depression, coma, and death from respiratory failure.

2. *Chronic exposure*: Chronic exposure to n-butyl acetate can cause eye irritation and dryness, redness, scaling, and cracking of the skin.

• Emergency procedures

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of n-butyl acetate. ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of n-butyl acetate are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if n-butyl acetate or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve n-butyl acetate and may result in worker exposures to this substance:

—Use of n-butyl acetate as a solvent and thinner for gums, oil, fats, waxes, pitch, lacquers, enamels, nitrocellulose, camphor, ethyl cellulose acetate, pyroxylin, chlorinated rubber, artificial leathers, ester-soluble dyes, airplane dopes, perfumes, natural gums, synthetic resins, and vinyl, polystyrene, and methacrylate plastics

—Application of nitrocellulose lacquers by spraying, brushing, or dipping and of surface coatings other than nitrocellulose lacquers, including paper coatings, lamp coatings, and airplane dope enamels

—Use of n-butyl acetate as a dehydrating agent

—Production of protective coatings in the automobile industry, flavorings, perfumes, safety glass, plastics, cosmetics, adhesives, shoe polishes, stain removers, photographic films, penicillin, and larvicides

The following methods are effective in controlling worker exposure to n-butyl acetate, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to n-butyl acetate, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the skin and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to n-butyl acetate at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with skin or respiratory disease.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to n-butyl acetate exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of n-butyl acetate on the skin and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for n-butyl acetate.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne n-butyl acetate is determined by using coconut shell charcoal tubes (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 10 liters is collected. The sample is then treated with carbon disulfide or carbon disulfide/dimethylformamide to extract the n-butyl acetate. Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is 0.02 mg per sample. This method is described in Method No. 1450 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If n-butyl acetate contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min and then wash with soap and water.

Clothing contaminated with n-butyl acetate should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of n-butyl acetate, particularly its potential to be irritating to the skin.

A worker who handles n-butyl acetate should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where n-butyl acetate or a solution containing n-butyl acetate is handled, processed, or stored.

STORAGE

n-Butyl acetate should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. This substance is an OSHA IB flammable liquid and must be handled accordingly. Containers of n-butyl acetate should be protected from physical damage

and should be stored separately from potassium tert-butoxide, strong oxidizers, nitrates, strong alkalies, strong acids, explosives, heat, sparks, open flame, and materials that are readily impregnable by odor. Only nonsparking tools may be used to handle n-butyl acetate. To prevent static sparks, containers and equipment should be grounded and bonded for transfers. Because containers that formerly contained n-butyl acetate may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving n-butyl acetate, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.
6. For large liquid spills, build dikes far ahead of the spill to contain the n-butyl acetate for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities for hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

n-Butyl acetate is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is equal to or greater than the reportable quantity for that chemical, employers are required by EPA regulations resulting from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal authorities.

The reportable quantity for n-butyl acetate is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Reponse Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of n-butyl acetate emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although n-butyl acetate is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of n-butyl acetate are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

• **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of n-butyl acetate exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

• **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent skin contact with n-butyl acetate. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been tested against permeation by n-butyl acetate and have demonstrated protection for more than 4 but fewer than 8 hr: polyvinyl alcohol, Teflon®, and polyethylene/ethylene vinyl alcohol. Butyl rubber has demonstrated questionable protection from permeation. Natural rubber, neoprene, nitrile rubber, polyethylene, polyvinyl chloride, and Viton® have demonstrated poor resistance to permeation by n-butyl acetate.

If n-butyl acetate is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which n-butyl acetate might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with n-butyl acetate. Contact lenses should not be worn if the potential exists for n-butyl acetate exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR sec-BUTYL ACETATE

INTRODUCTION

This guideline summarizes pertinent information about sec-butyl acetate for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_6H_{12}O_2$

- **Structure**

$CH_3COOCH(CH_3)(C_2H_5)$

- **Synonyms**

Acetic acid, 1-methylpropyl ester; acetic acid, 2-butoxy ester; sec-butyl alcohol acetate; acetic acid, sec-butyl ester; 2-butyl acetate; 1-methylpropylacetate; 2-butanol acetate; acetic acid, secondary butyl ester

- **Identifiers**

1. CAS No.: 105-46-4
2. RTECS No.: AF7380000
3. DOT UN: 1123 26
4. DOT label: Flammable Liquid

- **Appearance and odor**

sec-Butyl acetate is a flammable, colorless liquid with a mild fruity odor. The odor threshold is reported to be below 200 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 116.2
2. Boiling point (at 760 mm Hg): 112°C (233.6°F)
3. Specific gravity (water = 1): 0.88 at 16°C (60.8°F)
4. Vapor density (air = 1 at boiling point of sec-butyl acetate): 4.0
5. Melting point: -99°C (-146°F)
6. Vapor pressure at 20°C (68°F): 10 mm Hg
7. Solubility: Slightly soluble in water; miscible with common solvents
8. Evaporation rate (butyl acetate = 1): 2.0

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame
2. Incompatibilities: Fires and explosions may result from contact of sec-butyl acetate with nitrates, strong oxidizers, strong alkalies, or strong acids.
3. Hazardous decomposition products: Toxic gases and particulates (such as carbon monoxide, acrid smoke, and irritating fumes) may be released when sec-butyl acetate decomposes.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 3 (severe fire hazard) to sec-butyl acetate.

1. Flash point: 31°C (88°F) (open cup)
2. Autoignition temperature: Data not available
3. Flammable limits in air (% by volume): Lower, 1.7; upper, 9.8

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

4. Extinguishant: Use alcohol foam, carbon dioxide, dry chemical, or Halon® to fight fires involving sec-butyl acetate. Water may be ineffective for extinguishing fires, but it may be used to cool fire-exposed containers.

Fires involving sec-butyl acetate should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of sec-butyl acetate may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving sec-butyl acetate. Firefighters' protective clothing may not provide protection against permeation by sec-butyl acetate.

EXPOSURE LIMITS

• **OSHA PEL**

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for sec-butyl acetate is 200 ppm (950 mg/m^3) as an 8-hr time-weighted average (TWA) [29 CFR 1910.1000, Table Z-1-A].

• **NIOSH REL**

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 200 ppm (950 mg/m^3) as an 8-hr TWA [NIOSH 1992].

• **ACGIH TLV®**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned sec-butyl acetate a threshold limit value (TLV) of 200 ppm (950 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• **Rationale for limits**

The limits are based on the risk of eye and upper respiratory tract irritation associated with exposure to sec-butyl acetate.

HEALTH HAZARD INFORMATION

• **Routes of exposure**

Exposure to sec-butyl acetate can occur through inhalation, ingestion, and eye or skin contact.

• **Summary of toxicology**

1. *Effects on Animals*: sec-Butyl acetate is an irritant of the eyes, skin, and upper respiratory tract. On the basis of effects seen in animals exposed to other acetates, it is likely that sec-butyl acetate will cause narcosis in animals exposed to high concentrations [Proctor et al. 1988].

2. *Effects on Humans*: sec-Butyl acetate is an irritant of the eyes and upper respiratory tract. Based on effects seen in humans exposed to chemically similar substances, sec-butyl acetate is likely to cause narcosis at high concentrations [Proctor et al. 1988].

• **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to sec-butyl acetate can cause redness and tearing of the eyes, runny nose, and sore throat. In contact with the skin, sec-butyl acetate may cause redness, defatting, and cracking. At high concentrations, workers may experience headache, fatigue, drowsiness, dizziness, or other symptoms of central nervous system depression and narcosis.

2. *Chronic exposure*: No signs or symptoms of chronic exposure to sec-butyl acetate have been reported; however, prolonged exposure may increase the severity of the acute dermal effects noted above.

• **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of sec-butyl acetate. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of sec-butyl acetate are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if sec-butyl acetate or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of sec-butyl acetate may result in worker exposures to this substance:

—Use as a general solvent

—Use as a solvent for nitrocellulose, artificial leather, thinners, and nail enamels

The following methods are effective in controlling worker exposures to sec-butyl acetate, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to sec-butyl acetate, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the skin and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to sec-butyl acetate at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable

medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with skin or respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to sec-butyl acetate exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of sec-butyl acetate on the skin and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for sec-butyl acetate.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne sec-butyl acetate is determined by using coconut shell charcoal tubes (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 10 liters is collected. The sample is then treated with carbon disulfide to extract the sec-butyl acetate. Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is 0.2 mg/sample. This method is described in Method 1450 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If sec-butyl acetate contacts skin, workers should wash the affected areas with soap and water.

Clothing and shoes contaminated with sec-butyl acetate should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of sec-butyl acetate, particularly its potential for irritating the skin.

A worker who handles sec-butyl acetate should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where sec-butyl acetate or a solution containing it is handled, processed, or stored.

STORAGE

sec-Butyl acetate should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Electrical service in the storage area must meet requirements for an OSHA Class IB flammable liquid. To prevent static sparks, containers of sec-butyl acetate must be grounded and bonded. Containers also should be protected from physical damage and should be stored separately from direct sunlight, nitrates, strong oxidizers, strong alkalies, strong acids, heat, sparks, and open flames. Drums used to store sec-butyl acetate must be equipped with self-closing valves, pressure-vacuum bungs, and flame arresters. Only nonsparking tools may be used to transfer or handle sec-butyl acetate. Because containers that formerly contained sec-butyl acetate may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving sec-butyl acetate, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate the area of the spill or leak.
5. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

6. For large liquid spills, build dikes far ahead of the spill to contain the sec-butyl acetate for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

sec-Butyl acetate is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is above the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.4] to notify the proper Federal, State, and local authorities.

The reportable quantity for sec-butyl acetate is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center *immediately* at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of sec-butyl acetate emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although sec-butyl acetate is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of sec-butyl acetate exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator*

Decision Logic [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent skin contact with sec-butyl acetate. Gloves, aprons, and other protective clothing are recommended as necessary. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following material is recommended for use against permeation by sec-butyl acetate: polyvinyl alcohol.

If sec-butyl acetate is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which sec-butyl acetate might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with sec-butyl acetate. Contact lenses should not be worn if the potential exists for sec-butyl acetate exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR tert-BUTYL ACETATE

INTRODUCTION

This guideline summarizes pertinent information about tert-butyl acetate for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_6H_{12}O_2$

- **Structure**

$CH_3COOC(CH_3)_3$

- **Synonyms**

t-Butyl acetate; acetic acid, tert-butyl ester; acetic acid, 1,1-dimethyl ethyl ester; Texaco Lead Appreciator; TLA

- **Identifiers**

1. CAS No.: 540-88-5
2. RTECS No.: AF7400000
3. DOT UN: 1123 26
4. DOT label: Flammable Liquid

- **Appearance and odor**

tert-Butyl acetate is a flammable, colorless liquid with a fruity odor.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 116.2
2. Boiling point (at 760 mm Hg): 97° to 98°C (206.6° to 208.4°F)
3. Specific gravity (water = 1): 0.87 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of tert-butyl acetate): 4.0
5. Melting point: Data not available
6. Vapor pressure at 20°C (68°F): Data not available
7. Solubility: Insoluble in water; soluble in alcohol and ether
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame
2. Incompatibilities: Fire and explosions may result from contact of tert-butyl acetate with nitrates, strong oxidizers, strong alkalies, and strong acids.
3. Hazardous decomposition products: Toxic gases (such as carbon monoxide) may be released in a fire involving tert-butyl acetate.
4. Special precautions: tert-Butyl acetate may soften or dissolve plastics.

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to tert-butyl acetate; however, other sources rate this substance's fire hazard potential as severe.

1. Flash point: Between 16.6° and 22°C (62° and 72°F) (closed cup)
2. Autoignition temperature: Data not available
3. Flammable limits in air (% by volume): Lower, 1.5; upper, data not available

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

4. Extinguishant: Use alcohol foam, carbon dioxide, dry chemical, water spray, or Halon® to fight fires involving tert-butyl acetate.

Fires involving tert-butyl acetate should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of tert-butyl acetate may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing, including a self-contained breathing apparatus, when fighting fires involving tert-butyl acetate. Firefighters' protective clothing may not provide protection against permeation by tert-butyl acetate.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for tert-butyl acetate is 200 ppm (950 mg/m^3) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 200 ppm (950 mg/m^3) as an 8-hr TWA [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned tert-butyl acetate a threshold limit value (TLV) of 200 ppm (950 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991a].

• Rationale for limits

The limits are based on the risk of eye and respiratory tract irritation associated with exposure to tert-butyl acetate.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to tert-butyl acetate can occur through inhalation, ingestion, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: tert-Butyl acetate has not been tested for toxicity in animals. However, by analogy with the effects of other acetate esters, tert-butyl acetate is likely to cause eye, nose, and skin irritation and, at high concentrations, narcosis [Proctor et al. 1988].

2. *Effects on Humans*: Exposure to tert-butyl acetate causes eye, skin, and respiratory irritation in workers. By analogy with the effects of similar esters, tert-butyl acetate is likely to cause narcosis at high concentrations [ACGIH 1991a].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to tert-butyl acetate can cause itchy or inflamed eyes and irritation of the nose and upper respiratory tract. Exposure to high concentrations of tert-butyl acetate may cause headache, drowsiness, and other narcotic effects.

2. *Chronic exposure*: No chronic effects of exposure to tert-butyl acetate have been reported; however, prolonged exposure may increase the severity of the acute dermal effects noted above.

• Emergency procedures

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of tert-butyl acetate. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of tert-butyl acetate are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if tert-butyl acetate or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do *not* force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of tert-butyl acetate may result in worker exposures to this substance:

—Use as a solvent

—Use as an additive to improve the antiknock properties of motor fuels

The following methods are effective in controlling worker exposures to tert-butyl acetate, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to tert-butyl acetate, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to tert-butyl acetate at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with eye, skin, or respiratory tract diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced

occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to tert-butyl acetate exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of tert-butyl acetate on the eyes, skin, and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for tert-butyl acetate.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne tert-butyl acetate is determined by using coconut shell charcoal tubes (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 10 liters is collected. The sample is then desorbed with carbon disulfide. Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is 0.02 mg per sample. This method is described in Method 1450 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If tert-butyl acetate contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min and then wash with soap and water.

Clothing contaminated with tert-butyl acetate should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of tert-butyl acetate, particularly its potential to be irritating to the eyes and skin.

A worker who handles tert-butyl acetate should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where tert-butyl acetate is handled, processed, or stored.

STORAGE

tert-Butyl acetate should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of tert-butyl acetate should be protected from physical damage and should be stored separately from nitrates, strong oxidizers, strong acids, strong alkalies, heat, sparks, and open flame. Because containers that formerly contained tert-butyl acetate may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a leak involving tert-butyl acetate, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. Use water spray to reduce vapors, but be aware that the spray may not prevent ignition in closed spaces.
6. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.
7. For large liquid spills, build dikes far ahead of the spill to contain the tert-butyl acetate for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

tert-Butyl acetate is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is equal to or greater than the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal authorities.

The reportable quantity for tert-butyl acetate is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of the SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of tert-butyl acetate emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although tert-butyl acetate is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of tert-butyl acetate are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of tert-butyl acetate exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information about the selection and use of respirators and the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent skin contact with tert-butyl acetate. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to permeation by tert-butyl acetate; however, the following materials have been tested against permeation by a chemically similar substance (n-butyl acetate) and have demonstrated protection for more than 4 but fewer than 8 hr: polyvinyl alcohol, polyethylene/ethylene vinyl alcohol, and Teflon®. Natural rubber, neoprene, nitrile rubber,

polyethylene, polyvinyl chloride, and Viton® have demonstrated poor resistance to permeation by n-butyl acetate. Since specific test data are not available for tert-butyl acetate, the information provided here should be considered as a guideline only. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to tert-butyl acetate.

If tert-butyl acetate is dissolved in an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which tert-butyl acetate might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with tert-butyl acetate. Contact lenses should not be worn if the potential exists for tert-butyl acetate exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR n-BUTYL ALCOHOL

INTRODUCTION

This guideline summarizes pertinent information about n-butyl alcohol for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_4H_{10}O$

- **Structure**

$CH_3CH_2CH_2CH_2OH$

- **Synonyms**

1-Butanol, n-butanol, n-propyl carbinol, NBA, butyl hydroxide, butyric alcohol, normal primary butyl alcohol, methylal propane, propylmethanal, 1-hydroxybutane

- **Identifiers**

1. CAS No.: 71-36-3
2. RTECS No.: EO1400000
3. DOT UN: 1120 26
4. DOT label: Flammable Liquid

- **Appearance and odor**

n-Butyl alcohol is a flammable, colorless liquid with a mild, wine-like odor. The odor threshold is reported to be between 0.12 and 11.0 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 74.1
2. Boiling point (at 760 mm Hg): 117° to 118°C (243° to 244°F)
3. Specific gravity (water = 1): 0.81 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of n-butyl alcohol): 2.6
5. Melting point: -90°C (-130°F)
6. Vapor pressure at 20°C (68°F): 6 mm Hg
7. Solubility: Slightly soluble in water; miscible with alcohol, ether, and many other organic solvents
8. Evaporation rate (butyl acetate = 1): 0.46

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame
2. Incompatibilities: Fires and explosions may result from contact of n-butyl alcohol with strong oxidizers, strong mineral acids, alkali metals, or halogens.
3. Hazardous decomposition products: Toxic gases (such as carbon monoxide) may be released in a fire involving n-butyl alcohol.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 3 (severe fire hazard) to n-butyl alcohol.

1. Flash point: 37°C (98°F) (closed cup)
2. Autoignition temperature: 343°C (650°F)
3. Flammable limits in air (% by volume): Lower, 1.4; upper, 11.3
4. Extinguishant: Use carbon dioxide, dry chemical, or alcohol foam to fight fires involving n-butyl alcohol. Water may be ineffective, but it may be used to cool fire-exposed containers.

Fires involving n-butyl alcohol should be fought upwind and from the maximum distance possible. Isolate the hazard area

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and should ventilate closed spaces before entering. Containers of n-butyl alcohol may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving n-butyl alcohol. Firefighters' protective clothing may not provide protection against permeation by n-butyl alcohol.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for n-butyl alcohol is 50 ppm (150 mg/m^3) as a ceiling limit. A worker's exposure to n-butyl alcohol shall at no time exceed this limit. The OSHA PEL also bears a "Skin" notation, which indicates that the cutaneous route of exposure (including mucous membranes and eyes) contributes to overall exposure [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 50 ppm (150 mg/m^3) as a ceiling limit with a "Skin" notation [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned n-butyl alcohol a ceiling limit of 50 ppm (152 mg/m^3), which should not be exceeded during any part of the working exposure. The ACGIH has also assigned n-butyl alcohol a "Skin" notation [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of possible vestibular and auditory nerve injury as well as headaches and irritation associated with exposure to n-butyl alcohol.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to n-butyl alcohol can occur through inhalation, ingestion, skin absorption, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: n-Butyl alcohol is an irritant of the eyes, skin, and respiratory tract in animals; at high concentrations, exposure causes narcosis. In rabbits, n-butyl alcohol causes moderate skin irritation upon contact and severe corneal irritation when instilled into the eyes [NIOSH 1991]. The dermal LD_{50} in rabbits ranges from 3,400 to 5,300 mg/kg [NIOSH 1991; IPCS 1987]. The oral LD_{50}s in rats ranges from 700 to 2,100 mg/kg [IPCS 1987]. The 4-hr LC_{50} for rats is 8,000 ppm [NIOSH 1991]. Death also occurred in two of six female rats that inhaled 9,000 ppm for 7 hr. Half of another group of female rats that inhaled 8,000 ppm for 7 hr also developed narcosis. However, females that inhaled 6,000 ppm were asymptomatic throughout and after the 7-hr exposure period [Nelson et al. 1989]. Mice exposed to 3,300 ppm for 7 hr showed no effects, and 6,600 ppm caused giddiness within 1 hr, prostration within 2 hr, and loss of reflexes after 3 hr, with respiratory failure, deep narcosis, and death in some animals [Clayton and Clayton 1981]. Guinea pigs exposed to 100 ppm for 4 hr/day, 6 days/week for a total of 64 exposures showed lymphocytopenia and erythropenia; at autopsy, lung hemorrhage and degeneration of the liver and kidneys were seen [Clayton and Clayton 1981]. Groups of female rats were exposed to 8,000, 6,000, 3,500, or 0 ppm sec-butyl alcohol for 7 hr/day on gestation days 1 through 19. Absorbed daily doses for each of these exposure concentrations were theorized to be 800, 600, 350, or 0 mg/kg, respectively. Two of 18 dams exposed at 8,000 ppm died. Fetal weights were slightly depressed at 8,000 and 6,000 ppm. A slight but statistically significant increase in skeletal malformations (primarily rudimentary cervical ribs) occurred in pups obtained from 8,000-ppm-exposed dams who exhibited the presence of maternal toxicity (reduced weight gain and food consumption) [Nelson et al. 1989]. n-Butyl alcohol was not mutagenic when tested with in vitro assays [IPCS 1987]. Two long-term n-butyl alcohol tests have been performed but were considered inadequate for assessment of carcinogenic activity [IPCS 1987].

2. *Effects on Humans*: n-Butyl alcohol causes eye, skin, and upper respiratory tract irritation in exposed workers. Volunteers reported mild irritation of the eyes, nose, and throat when exposed to 25 ppm. Unacclimatized subjects exposed to 50 ppm experienced pronounced throat irritation, and several of them developed delayed onset headaches [ACGIH 1991a]. Workers chronically exposed to 100 ppm rarely complained of eye irritation, where as previous exposures to 200 ppm or more caused corneal inflammation, an ocular burning sensation, blurred vision, lacrimation, and photophobia [ACGIH 1991a]. Repeated or prolonged contact of n-butyl alcohol with the skin causes defatting and contact dermatitis, and this substance can be absorbed through the skin in toxic amounts [Proctor et al. 1988].

Vertigo and auditory nerve and vestibular system damage have been reported in Mexican and French workers exposed both to n-butyl alcohol and workplace noise, but the relative contribution of the alcohol to these effects has not been determined [ACGIH 1991a; Proctor et al. 1988].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to n-butyl alcohol can cause redness and tearing of the eyes, scratchy throat, itching and redness of the skin, headache, ataxia, prostration, deep narcosis, respiratory failure, and death.

2. *Chronic exposure*: Chronic exposure to n-butyl alcohol can cause photophobia, blurred vision, corneal vacuoles, and defatting and itching of the skin. Chronic exposure to n-butyl alcohol can cause vertigo and may increase the extent of hearing loss among workers exposed to both noise and n-butyl alcohol.

- **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of n-butyl alcohol. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of n-butyl alcohol are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if n-butyl alcohol or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve n-butyl alcohol and may result in worker exposures to this substance:

—Formulation of nitrocellulose lacquers, latexes, rayon detergents, esters, other butyl compounds, and plastic and rubber cements

—Use of n-butyl alcohol as a solvent or diluent in brake fluids, perfumes, detergents, adhesives, denatured alcohol, surface coatings, fats, waxes, natural and synthetic paints, resins, shellac, varnishes, gums, vegetable oils, dyes, camphor, and alkaloids

—Manufacture of artificial leather, safety glass, derivatives of butyl alcohol (including chemicals, herbicides, flotation agents, and urea and melamine formaldehyde resins), pharmaceuticals (including antibiotics, hormones, and vitamins), and bactericides for veterinary use

—Use of n-butyl alcohol during photographic processing operations and in the manufacture of photographic film

—Use of n-butyl alcohol in textile making as a swelling agent, dye ingredient, and waterproofing agent

—Use of n-butyl alcohol as an azeotropic dehydration agent and blending agent in laboratory analysis and in microscopy to prepare paraffin imbedding materials

The following methods are effective in controlling worker exposures to n-butyl alcohol, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to n-butyl alcohol, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory tract. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to n-butyl alcohol at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with eye, skin, or respiratory tract diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to n-butyl alcohol exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of n-butyl alcohol on the eyes, skin, and respiratory tract. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for n-butyl alcohol.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne n-butyl alcohol is determined by using charcoal tubes (100/50-mg sections, 20/40 mesh). To determine TWA concentrations, samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 10 liters is collected; to determine ceiling limit concentrations, samples are collected for a minimum of

5 min. The sample is desorbed with carbon disulfide/isopropanol (99:1) or carbon disulfide/dimethylformamide (99:1). Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is 0.01 mg per sample. This method is described in Method No. 1401 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If n-butyl alcohol contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min and then wash with soap and water.

Clothing and shoes contaminated with n-butyl alcohol should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of n-butyl alcohol, particularly its potential to be absorbed through the skin.

A worker who handles n-butyl alcohol should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where n-butyl alcohol or a solution containing n-butyl alcohol is handled, processed, or stored.

STORAGE

n-Butyl alcohol should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. All electrical service in the storage area must meet OSHA requirements for Class IC flammable liquids [29 CFR 1910.106]. Small amounts of n-butyl alcohol should be stored in metal safety cans in OSHA-approved safety cabinets or storerooms. Containers of n-butyl alcohol should be protected from physical damage and should be stored separately from oxidizing agents, strong mineral acids, alkali metals, halogens, explosives, organic peroxides, radioactive materials, heat, sparks, and open flame. Drums must be equipped with self-closing valves, pressure vacuum bungs, and flame arrestors. Only nonsparking tools may be used to handle n-butyl alcohol. To prevent static sparks, containers should be grounded and bonded for transfers. Because containers that formerly contained n-butyl alcohol may hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving n-butyl alcohol, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup has been completed. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.
6. For large liquid spills, build dikes far ahead of the spill to contain the n-butyl alcohol for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities for hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

n-Butyl alcohol is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is above the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for n-butyl alcohol is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center *immediately* at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of n-butyl alcohol per calendar year are required by EPA [40 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of n-butyl alcohol emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. n-Butyl alcohol is listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.] and has been assigned EPA Hazardous Waste No. U031. This chemical is approved for land disposal as long as the concentration in the waste or treatment residual does not exceed 2.6 mg/kg. n-Butyl alcohol also may be disposed of in an organometallic or organic lab pack that meets the requirements of 40 CFR 264.316 or 265.316.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of n-butyl alcohol exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. If the use of respirators is necessary, the only respirators permitted are those approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with n-butyl alcohol. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Teflon® has been recommended for use against permeation by n-butyl alcohol and may provide protection for periods greater than 8 hr. Materials that may withstand permeation for more than 4 but fewer than 8 hr are butyl rubber, neoprene, nitrile rubber, polyethylene, and polyethylene/ethylene vinyl alcohol. Polyvinyl alcohol and polyvinyl chloride provide questionable protection from permeation, and natural rubber has demonstrated poor resistance to permeation by n-butyl alcohol.

If n-butyl alcohol is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which n-butyl alcohol might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with n-butyl alcohol. Contact lenses should not be worn if the potential exists for n-butyl alcohol exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR sec-BUTYL ALCOHOL

INTRODUCTION

This guideline summarizes pertinent information about sec-butyl alcohol for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_4H_{10}O$

- **Structure**

$CH_3CH_2CH(OH)CH_3$

- **Synonyms**

2-Butanol, sec-butanol, 2-butyl alcohol, methyl ethyl carbinol, butylene hydrate, 2-hydroxybutane

- **Identifiers**

1. CAS No.: 78-92-2
2. RTECS No.: EO1750000
3. DOT UN: 1120 26
4. DOT label: Flammable Liquid

- **Appearance and odor**

sec-Butyl alcohol is a colorless, flammable, volatile liquid with a strong, winelike odor. The odor threshold is reported to be between 0.4 and 2.5 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 74.1
2. Boiling point (760 mm Hg): 99.5°C (211.1°F)
3. Specific gravity (water = 1): 0.81 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of sec-butyl alcohol): 2.55
5. Melting point: −115°C (−175°F)
6. Vapor pressure at 20°C (68°F): 12 mm Hg
7. Solubility: Moderately soluble in water; miscible with alcohol, ether, and most organic solvents
8. Evaporation rate (butyl acetate = 1): 1.3

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame. sec-Butyl alcohol auto-oxidizes to form an explosive peroxide.
2. Incompatibilities: Fires and explosions may result from contact of sec-butyl alcohol with strong oxidizers, organic peroxides, or perchloric or permonosulfuric acid. sec-Butyl alcohol ignites on contact with chromium trioxide.
3. Hazardous decomposition products: Toxic gases (such as carbon monoxide) may be released when sec-butyl alcohol decomposes.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 3 (dangerous fire hazard) to sec-butyl alcohol.

1. Flash point: 24°C (75°F)
2. Autoignition temperature: 405°C (761°F)

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Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

3. Flammable limits in air at 100°C (212°F) (% by volume): Lower, 1.7; upper, 9.8

4. Extinguishant: Use alcohol foam, carbon dioxide, or dry chemical to fight fires involving sec-butyl alcohol. Water may be ineffective, but it may be used to cool fire-exposed containers. If a leak or spill has not ignited, water spray may be used to disperse vapors and to protect persons attempting to stop the leak.

Fires involving sec-butyl alcohol should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Vapors may travel to a source of ignition and flash back. Vapor explosion hazards may occur indoors, outdoors, or in sewers. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of sec-butyl alcohol may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving sec-butyl alcohol. Firefighters' protective clothing may not provide protection against permeation by sec-butyl alcohol.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for sec-butyl alcohol is 100 ppm (305 mg/m^3) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 100 ppm (305 mg/m^3) as an 8-hr TWA and 150 ppm (455 mg/m^3) as a short-term exposure limit (STEL). A STEL is a 15-min TWA exposure that should not be exceeded at any time during a workday [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned sec-butyl alcohol a threshold limit value (TLV) of 100 ppm (303 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The limits are based on the risks of narcosis and irritation associated with exposure to sec-butyl alcohol.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to sec-butyl alcohol can occur through inhalation, ingestion, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: In animals, sec-butyl alcohol is an eye irritant and, at high concentrations, a narcotic. Although it is not an irritant when in contact with rabbit skin, it can induce severe corneal injury when directly instilled into the eyes of rabbits [Grant 1986; NLM 1991]. Five of six rats died following an exposure of 16,000 ppm for 4 hr [Clayton and Clayton 1981]. Death also occurred in all five female rats that inhaled 10,000 ppm for 7 hr. Another group of female rats exposed to 7,000 ppm for 7 hr did not die and had not completely recovered from the induced narcosis on the day following exposure. Female rats exposed to 5,000 ppm also had impaired motor activity and developed narcosis [Nelson et al. 1989]. Inhalation of 10,670 ppm for 225 min or 16,000 ppm for 160 min was fatal to exposed mice [Clayton and Clayton 1981]. Mice that inhaled exposures ranging from 3,300 ppm for 5 hr to 19,800 ppm for 40 min developed restlessness, ataxia, prostration, and narcosis but did not die [NLM 1991]. Mice were unaffected by exposure to 1,650 ppm for 7 hr [ACGIH 1991a]. The oral LD_{50} in the rat is 6.5 g/kg [NIOSH 1991]. Mice exposed repeatedly to a sec-butyl alcohol concentration of 5,330 ppm for a total of 117 hr developed narcosis but survived the exposure [Clayton and Clayton 1981]. Groups of female rats were exposed to 7,000, 5,000, 3,500, or 0 ppm sec-butyl alcohol for 7 hr/day on gestation days 1 through 19. Absorbed daily doses for each of these respective exposure concentrations were theorized to be 700, 500, 350, or 0 mg/kg. No deaths occurred, but weight gain and food consumption were depressed for dams at each sec-butyl alcohol exposure concentration. The number of live fetuses was significantly reduced, resorptions increased, and the fetal weights were slightly depressed at 7,000 and 5,000 ppm [Nelson et al. 1989]. In two mutagenicity assays, *Schizosaccharomyces pombe* (yeast) and V-79 Chinese hamster cells, sec-butyl alcohol was nonmutagenic [IPCS 1987].

2. *Effects on Humans*: sec-Butyl alcohol has a defatting effect on the skin [Proctor et al. 1988]. Workers repeatedly exposed to 100 ppm have not developed signs or symptoms

of toxicity or irritation [Proctor et al. 1988]. However, two patients who had become sensitized to primary alcohols tested positive when challenged with sec-butyl alcohol [NLM 1991]. Excessive exposure may result in headache, dizziness, drowsiness, and narcosis [IPCS 1987].

• **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to sec-butyl alcohol can cause eye, nose, and throat irritation, with redness and tearing of the eyes, runny nose, defatting of skin, and cough. Exposure to high concentrations of sec-butyl alcohol is likely to cause headache, fatigue, nausea, dizziness, and narcosis.

2. *Chronic exposure*: Chronic exposure to sec-butyl alcohol can cause dermatitis in chronically exposed workers and may cause intense dermal sensitization in some exposed individuals.

• **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of sec-butyl alcohol. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of sec-butyl alcohol are inhaled, move the victim to fresh air *immediately*.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if sec-butyl alcohol or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve sec-butyl alcohol and may result in worker exposures to this substance:

—Use of sec-butyl alcohol as an adhesive in the manufacture of plywood and as a chemical intermediate in the production of methyl ethyl ketone, sec-butyl acetate, and xanthate

—Use of sec-butyl alcohol as a solvent for natural resins, linseed oil, castor oil, lacquer, paint removers, and adhesives

—Manufacture of flotation agents, hydraulic fluids, flavors, perfumes, dyestuffs, wetting agents, paint removers, industrial cleaners, and polishes

—Use of sec-butyl alcohol as a dehydrating agent, an antifoaming agent, and an ingredient in dewaxing paraffin

The following methods are effective in controlling worker exposures to sec-butyl alcohol, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to sec-butyl alcohol, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory tract. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to sec-butyl alcohol at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with eye, skin, and respiratory tract diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to sec-butyl alcohol exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of sec-butyl alcohol on the eyes, skin, and respiratory tract. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for sec-butyl alcohol.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne sec-butyl alcohol is determined by using coconut shell charcoal tubes (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 10 liters is collected. The samples are desorbed either with carbon disulfide/isopropanol (99:1) or carbon disulfide/dimethylformamide (99:1). Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is 0.01 mg/sample. This method is described in Method No. 1401 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If sec-butyl alcohol contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min and then wash with soap and water.

Clothing and shoes contaminated with sec-butyl alcohol should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of sec-butyl alcohol, particularly its potential to be irritating to the eyes and skin.

A worker who handles sec-butyl alcohol should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where sec-butyl alcohol is handled, processed, or stored.

STORAGE

sec-Butyl alcohol should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. The storage area must meet OSHA requirements for Class IC flammable liquids. Drums must be equipped with self-closing valves, pressure-vacuum bungs, and flame arrestors. Containers of sec-butyl alcohol should be protected from physical damage and should be kept separate from oxidizing agents, explosives, heat, sparks, and open flame. Small amounts of this substance may be stored in metal safety cans in OSHA-approved safety cabinets or storage rooms. Only nonsparking tools may be used to handle sec-butyl alcohol. To prevent static sparks, containers should be grounded and bonded during transfers. Because containers that formerly contained sec-butyl alcohol may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving sec-butyl alcohol, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.

2. Notify safety personnel.

3. Remove all sources of heat and ignition.

4. Ventilate potentially explosive atmospheres.

5. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

6. For large liquid spills, build dikes far ahead of the spill to contain the sec-butyl alcohol for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

sec-Butyl alcohol is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of sec-butyl alcohol; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of sec-butyl alcohol per calendar year are required by EPA [40 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of sec-butyl alcohol emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although sec-butyl alcohol is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local

authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of sec-butyl alcohol exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent skin contact with sec-butyl alcohol. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been recommended for use against permeation by sec-butyl alcohol and may withstand permeation for more than 4 but fewer than 8 hr: butyl rubber and polyethylene/ethylene vinyl alcohol.

If sec-butyl alcohol is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which sec-butyl alcohol might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with sec-butyl alcohol. Contact lenses should not be worn if the potential exists for sec-butyl alcohol exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR tert-BUTYL ALCOHOL

INTRODUCTION

This guideline summarizes pertinent information about tert-butyl alcohol for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_4H_{10}O$

- **Structure**

$(CH_3)_3COH$

- **Synonyms**

tert-Butanol; 2-methyl-2-propanol; TBA; t-butyl hydroxide; 1,1-dimethylethanol; trimethylmethanol; trimethylcarbinol

- **Identifiers**

1. CAS No.: 75-65-0
2. RTECS No.: EO1925000
3. DOT UN: 1120 26
4. DOT label: Flammable Liquid

- **Appearance and odor**

tert-Butyl alcohol is a colorless, crystalline solid or a volatile liquid (above 77°F) that has a camphorlike odor. The odor threshold is reported to be below 0.8 part per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 74.1
2. Boiling point (760 mm Hg): 82.4°C (180°F)
3. Specific gravity (water = 1): 0.79 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of tert-butyl alcohol): 2.55
5. Melting point: 25.6°C (78.1°F)
6. Vapor pressure at 20°C (68°F): 31 mm Hg
7. Solubility: Soluble in water; miscible with alcohol and ether
8. Evaporation rate (butyl acetate = 1): 1.05

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame
2. Incompatibilities: Fires and explosions may result from contact with oxidizing agents, strong mineral acids, or strong hydrochloric acid.
3. Hazardous decomposition products: Toxic gases (such as carbon monoxide or isobutylene) may be released when tert-butyl alcohol decomposes in contact with strong mineral acids.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 3 (dangerous fire hazard) to tert-butyl alcohol.

1. Flash point: 11°C (52°F) (closed cup)
2. Autoignition temperature: 478°C (892°F)

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Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
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3. Flammable limits in air (% by volume): Lower, 2.4; upper, 8.0

4. Extinguishant: Use dry chemical, carbon dioxide, alcohol foam, or water fog to fight fires involving tert-butyl alcohol. Blanket the fire to smother it. Water may be ineffective in extinguishing the fire, but a water spray may be used to cool fire-exposed containers. If a leak or spill has not ignited, water spray may be used to disperse vapors and to dilute spills to a nonflammable mixture.

Fires involving tert-butyl alcohol should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapors may travel to a source of ignition and then flash back. Vapor explosions may occur indoors, outdoors, or in sewers. Containers of tert-butyl alcohol may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving tert-butyl alcohol. Firefighters' protective clothing may not provide protection against permeation by tert-butyl alcohol.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for tert-butyl alcohol is 100 ppm (300 mg/m^3) as an 8-hr time-weighted average (TWA) concentration and 150 ppm (450 mg/m^3) as a 15-min short-term exposure limit (STEL). A STEL is a 15-min TWA concentration that should not be exceeded at any time during a workday [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 100 ppm (300 mg/m^3) as an 8-hr TWA and 150 ppm (450 mg/m^3) as a STEL [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned tert-butyl alcohol a threshold limit value (TLV) of 100 ppm (303 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek with a STEL of 150 ppm (455 mg/m^3) for periods not to exceed 15 min [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of narcotic effects associated with exposure to tert-butyl alcohol.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to tert-butyl alcohol can occur through inhalation, ingestion, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: tert-Butyl alcohol causes narcosis in animals exposed to high concentrations. The oral LD_{50} in rats is 3,500 mg/kg [NIOSH 1991]. Prolonged contact of tert-butyl alcohol with the skin of rabbits caused no irritation [Clayton and Clayton 1981]. When six female rats were exposed to 10,000 ppm for 7 hr, all developed severe narcosis and five died. Female rats in another group that inhaled 5,000 ppm for 7 hr also developed ataxia and narcosis but did not die. A 2,000-ppm exposure resulted in ataxia alone [Nelson et al. 1989]. Compared with other butyl alcohols, tert-butyl alcohol is reported to have a stronger narcotic effect on mice and rats [ACGIH 1991a; Nelson et al. 1989]. Rats given nontoxic oral doses of tert-butyl alcohol (0.0163 mol/kg) showed a marked decline in motor performance test scores; tert-butyl alcohol caused a narcotic effect estimated to be 4.8 times greater than that of ethanol [Clayton and Clayton 1981]. In a teratology study, groups of pregnant rats were exposed to 5,000, 3,500, 2,000, or 0 ppm tert-butyl alcohol for 7 hr/day during gestation days 1 through 19. Absorbed daily doses for each of these respective exposure levels were theorized to be 500, 350, 200, or 0 mg/kg. Depressed maternal weight gain and food consumption were induced only at 5,000 ppm. Fetal weights were statistically depressed in a dose-related fashion for all three alcohol exposures, and skeletal variations were statistically increased only at 5,000 and 3,500 ppm [Nelson et al. 1989]. The effect of prenatal ethanol or tert-butyl alcohol exposure on postnatal development was studied in mice. Daily ingestion of a diet deriving 1% of its calories from tert-butyl alcohol reduced maternal weight gain and food consumption and increased the number of stillborn pups. The authors concluded that this compound was five times more potent than ethanol in producing developmental delay in postnatal physiologic and psychomotor performance [Daniel and Evans 1982]. Ethanol and tert-butyl alcohol exposures were also compared for their potential to induce microcephaly in neonatal rats. Using an artificial rearing technique and exposures during developmental

days 4 through 7, microcephaly was induced by both of these alcohols [Grant and Sampson 1982]. This compound has been tested in a wide variety of mutagenicity assays, all of which confirm it to be a nonmutagen [IPCS 1987]. The National Toxicology Program (NTP) has completed one carcinogenicity study in mice and rats administered tert-butyl alcohol in drinking water. However, they judged this study to be inadequate for publication. The NTP has also completed subchronic tert-butyl alcohol inhalation studies in mice and rats and intends to conduct a set of inhalation carcinogenicity studies in these species [NTP 1992].

2. *Effects on Humans*: tert-Butyl alcohol causes eye and mucous membrane irritation. In contact with the skin of humans, tert-butyl alcohol caused slight redness, hyperemia, and irritation; prolonged skin contact may cause contact dermatitis [Clayton and Clayton 1981; NLM 1991]. A positive patch test was found in an individual who had an allergic skin reaction to a skin screen that contained tert-butyl alcohol [ACGIH 1991a]. Exposure to excessive (not further specified) concentrations caused eye, nose, and throat irritation, headache, nausea, fatigue, dizziness, and narcosis in humans [Clayton and Clayton 1981].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to tert-butyl alcohol can cause irritation and redness of the eyes, runny nose, scratchy throat, headache, nausea, fatigue, dizziness, and redness and drying of the skin.

2. *Chronic exposure*: Chronic exposure to tert-butyl alcohol can cause defatting of the skin and dermatitis.

- **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of tert-butyl alcohol. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of tert-butyl alcohol are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if tert-butyl alcohol or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve tert-butyl alcohol and may result in worker exposures to this substance:

—Use of tert-butyl alcohol as a solvent for paints, lacquers, varnishes, natural and synthetic resins, gums, vegetable oils, dyes, camphor, and alkaloids, and as an octane booster in unleaded gasoline

—Manufacture of artificial leather, safety glass, rubber and plastic cements, shellac, raincoats, photographic films, flotation agents, fruit essences, perfumes, cellulose esters, lacquers, paint removers, and plastics

—Use of tert-butyl alcohol as a denaturant for alcohol and as a chemical intermediate in the manufacture of methyl methacrylate and pharmaceuticals

The following methods are effective in controlling worker exposures to tert-butyl alcohol, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to tert-butyl alcohol, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory tract. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to tert-butyl alcohol at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with eye, skin, or respiratory tract diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to tert-butyl alcohol exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of tert-butyl alcohol on the eyes, skin, and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for tert-butyl alcohol.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne tert-butyl alcohol is determined by using charcoal tubes (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 10 liters is collected (for TWA monitoring) or a maximum air volume

of 3 liters is collected (for STEL monitoring). The sample is then desorbed with carbon disulfide/2-butanol (99:1) or with carbon disulfide/dimethylformamide (99:1) to extract the tert-butyl alcohol. Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is 0.01 mg per sample. This method is described in the OSHA Computerized Information System [OSHA 1990] and in Method 1400 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If tert-butyl alcohol contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min and then wash with soap and water.

Clothing and shoes contaminated with tert-butyl alcohol should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of tert-butyl alcohol, particularly its potential for irritating the skin.

A worker who handles tert-butyl alcohol should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where tert-butyl alcohol is handled, processed, or stored.

STORAGE

tert-Butyl alcohol should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of tert-butyl alcohol should be protected from physical damage and should be stored separately from strong oxidizers, strong mineral acids, strong hydrochloric acid, heat, sparks, and open flame. Drums must be equipped with self-closing valves, pressure-vacuum bungs, and flame arrestors. Only nonsparking tools and equipment may be used to handle tert-butyl alcohol. To prevent static sparks, containers of tert-butyl alcohol should be grounded and bonded for transfers. Because containers that formerly contained tert-butyl alcohol may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving tert-butyl alcohol, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. Use water spray to reduce vapors, but be aware that the spray may not prevent ignition in closed spaces.
6. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.
7. For large liquid spills, build dikes far ahead of the spill to contain the tert-butyl alcohol for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know; and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

tert-Butyl alcohol is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of tert-butyl alcohol; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of tert-butyl alcohol per calendar year are required by EPA [40 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of tert-butyl alcohol emitted or released from their facility annually.

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EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although tert-butyl alcohol is not specifically listed as a hazardous waste under the Resource Conservation and

Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

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- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent skin contact with tert-butyl alcohol. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Butyl rubber has been tested against permeation by tert-butyl alcohol and has demonstrated good-to-excellent resistance for periods greater than 8 hr. Polyethylene ethylene/vinyl alcohol may withstand permeation for more than 4 but fewer than 8 hr.

If tert-butyl alcohol is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which tert-butyl alcohol might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with tert-butyl alcohol. Contact lenses should not be worn if the potential exists for tert-butyl alcohol exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BUTYLAMINE

INTRODUCTION

This guideline summarizes pertinent information about butylamine for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_4H_{11}N$

- **Structure**

$CH_3CH_2CH_2CH_2NH_2$

- **Synonyms**

1-Butylamine, n-butylamine, 1-aminobutane, 1-butanamine, Norvalamine, mono-n-butylamine

- **Identifiers**

1. CAS No: 109-73-9
2. RTECS No.: EO2975000
3. DOT UN: 1125 68
4. DOT label: Flammable Liquid

- **Appearance and odor**

Butylamine is a colorless, volatile, flammable liquid with an ammonialike odor; the liquid tends to yellow on standing. The odor threshold is reported to be 1.8 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 73.1
2. Boiling point (760 mm Hg): 78°C (172°F)
3. Specific gravity (water = 1): 0.74 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of butylamine): 2.5
5. Melting point: -50°C (-58°F)
6. Vapor pressure at 20°C (68°F): 82 mm Hg
7. Solubility: Miscible with water, alcohol, and ether
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame
2. Incompatibilities: Fires and explosion may result from contact of butylamine with strong oxidizers or strong acids.
3. Hazardous decomposition products: Toxic gases (such as oxides of nitrogen and carbon monoxide) may be released in a fire involving butylamine.
4. Special precautions: In the presence of moisture, butylamine corrodes some metals on contact.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 3 (dangerous fire hazard) to butylamine.

1. Flash point: -12°C (10°F) (closed cup)
2. Autoignition temperature: 312°C (594°F)
3. Flammable limits in air (% by volume): Lower, 1.7; upper, 9.8
4. Extinguishant: Use dry chemical, alcohol foam, or carbon dioxide to fight fires involving butylamine. Water may be an ineffective extinguishant, but it may be used to cool

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fire-exposed containers. If a leak or spill has not ignited, water spray may be used to disperse vapors and to protect persons attempting to stop the leak.

Fires involving butylamine should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of butylamine may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving butylamine. Firefighters' protective clothing may not provide protection against permeation by butylamine.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for butylamine is 5 ppm (15 mg/m^3) as a ceiling limit. A worker's exposure to butylamine shall at no time exceed this ceiling limit. The OSHA PEL also bears a "Skin" notation, which indicates that the cutaneous route of exposure (including mucous membranes and eyes) contributes to overall exposure [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 5 ppm (15 mg/m^3) as a ceiling limit with a "Skin" notation [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned butylamine a ceiling limit of 5 ppm (15 mg/m^3), which should not be exceeded during any part of the working exposure. The ACGIH also assigns a "Skin" notation to butylamine [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of eye, skin, and respiratory tract irritation associated with exposure to butylamine.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to butylamine can occur through inhalation, ingestion, eye or skin contact, and by skin absorption.

• Summary of toxicology

1. *Effects on Animals*: Butylamine vapor is an irritant of the eyes, nose, respiratory tract, and skin; contact of liquid butylamine with the eyes or skin causes corrosive burns. The oral LD_{50} in rats is 366 mg/kg, the LC_{50} in rats is 4,000 ppm for 4 hr, and the dermal LD_{50} in rabbits is 850 mg/kg [NIOSH 1991]. Rats exposed for an unspecified time to butylamine at concentrations of 3,000 to 5,000 ppm exhibited signs of severe irritation of the respiratory tract, developed pulmonary edema, and died within minutes or hours of the exposure [Clayton and Clayton 1981]. When applied to the skin of guinea pigs, butylamine caused necrosis [ACGIH 1991a]. Butylamine caused severe damage to the eyes of rabbits [ACGIH 1991a].

2. *Effects on Humans*: Exposure to butylamine vapor causes eye, nose, and upper respiratory tract irritation, and contact of the skin or eyes with liquid butylamine causes severe irritation, corrosive burns, and possibly blindness [Clayton and Clayton 1981]. Workers exposed to butylamine concentrations at 5 to 10 ppm or higher experience eye and upper respiratory tract irritation, and exposure to butylamine concentrations at 10 to 25 ppm for more than a few minutes is considered intolerable by some workers [Clayton and Clayton 1981; Proctor et al. 1988].

• Signs and symptoms of exposure

1. *Acute exposure*: The signs and symptoms of acute exposure to butylamine include redness and tearing of the eyes, runny nose, scratchy throat, headache, facial flushing, increased pulse and respiratory rates, shortness of breath, and (if the exposure is severe) hyperactive reflexes, cyanosis, pulmonary edema, convulsions, and coma. If absorbed through the skin in toxic amounts, butylamine can cause nausea, vomiting, and shock. Direct eye or skin contact with the liquid can result in deep second-degree burns, blistering, corrosion, and possible blindness. Oral administration of near-lethal doses of butylamine to rats and rabbits resulted in hyperactivity of the reflexes, an increase in pulse and respiratory rates, shortness of breath, convulsions, cyanosis, and coma [ACGIH 1991a]. Some workers exposed to this substance at 5 to 10 ppm also experienced headache and facial flushing [Proctor et al. 1988].

2. *Chronic exposure*: No signs or symptoms of chronic exposure to butylamine have been reported.

• **Emergency procedures**

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Tissue destruction and blindness may result from exposure to concentrated solutions, vapors, mists or aerosols of butylamine! ***Immediately but gently*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Severe burns, skin corrosion, and absorption of toxic amounts may result! ***Immediately*** remove all contaminated clothing! ***Immediately and gently*** wash skin for at least 15 min. Use soap and water if skin is intact; use only water if skin is not intact.

3. *Inhalation exposure*: If vapors, mists, or aerosols of butylamine are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if butylamine or a solution containing it is ingested:

—Do ***not*** induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water. Immediately after rinsing, have the victim drink one cup (8 oz) of fluid and ***no more***.

—Do ***not*** permit the victim to drink milk or carbonated beverages!

—Do ***not*** permit the victim to drink any fluid if more than 60 min have passed since initial ingestion.

NOTE: These instructions must be followed exactly. Drinking a carbonated beverage or more than one cup of fluid could create enough pressure to perforate already damaged stomach tissue. The tissue-coating action of milk may impede medical assessment of tissue damage. Ingestion of any fluid more than 60 min after initial exposure could further weaken damaged tissue and result in perforation.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve butylamine and may result in worker exposures to this substance:

—Use of butylamine as a vulcanizing accelerator and reaction initiator in the rubber and polymer industries

—Use of butylamine as a chemical intermediate in the production of emulsifying agents, rubber chemicals, synthetic tanning agents, and special soaps

—Manufacture of photographic developers, pharmaceuticals, dyes, gasoline antioxidants, insecticides, and textile desizing agents

—Use of butylamine as a flavoring ingredient in alcoholic beverages, ice cream, ices, candy, baked goods, gelatins, and puddings

The following methods are effective in controlling worker exposures to butylamine, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to butylamine, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to butylamine at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with eye, skin, or respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to butylamine exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of butylamine on the eyes, skin, and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. However, no biological monitoring test acceptable for routine use has yet been developed for butylamine.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne butylamine is determined by using sulfuric-acid-coated silica gel tubes (150/75-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 1 liter/min until a maximum air volume of 15 liters is collected. The samples are desorbed with methanol/water (50:50). Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is not known. This method is described in Method No. S138 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

Butylamine causes severe burns on contact with the skin; this substance can also be absorbed through the skin in toxic amounts. Therefore, if butylamine contacts the skin, workers should flush the affected areas immediately with plenty of water for at least 15 min and then wash with soap and water. Get medical attention immediately.

Clothing and shoes contaminated with butylamine should be removed immediately, and provisions should be made for

safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of butylamine, particularly its potential to be absorbed through the skin and to cause eye and skin burns.

A worker who handles butylamine should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where butylamine or a solution containing butylamine is handled, processed, or stored.

STORAGE

Butylamine should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Outside or detached storage is preferred; inside storage should be in a standard storage area or room for flammable liquids. All ventilation systems and electrical equipment in storage areas should be of explosionproof design. Containers of butylamine should be protected from physical damage and should be stored separately from strong oxidizers and strong acids, heat, sparks, and open flame. To prevent static sparks, all containers and equipment used in shipping, transferring, or receiving operations should be bonded and grounded. Because containers that formerly contained butylamine may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving butylamine, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. Use water spray to cool fire-exposed containers and to reduce vapors; such spraying may not prevent ignition in closed spaces.
6. Absorb small spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.
7. For large spills, build dikes far ahead of the spill to contain the butylamine for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Butylamine is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is equal to or greater than the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal authorities.

The reportable quantity for butylamine is 1,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of butylamine emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reac-

tivity, or toxicity as defined in 40 CFR 261.21-261.24. Although butylamine is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of butylamine exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with butylamine. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Teflon® has been recommended for use against permeation by butylamine and may withstand permeation for more than 4 but fewer than 8 hr. Butyl rubber, natural rubber, neoprene, nitrile rubber, polyvinyl alcohol, polyvinyl chloride, and Viton® have demonstrated poor resistance to permeation by butylamine.

If butylamine is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which butylamine might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with butylamine. Contact lenses should not be worn if the potential exists for butylamine exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR p-tert-BUTYLTOLUENE

INTRODUCTION

This guideline summarizes pertinent information about p-tert-butyltoluene for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_{11}H_{16}$

- **Synonyms**

1-Methyl-4-tert-butylbenzene; 1-tert-butyl-4-methylbenzene; 4-tert-butyltoluene; 1-(1,1-dimethyl)-4-methylbenzene; p-methyl-tert-butylbenzene; TBT; p-TBT

- **Identifiers**

1. CAS No.: 98-51-1
2. RTECS No.: XS8400000
3. DOT UN (for butyltoluenes): 2667 27
4. DOT label (for butyltoluenes): St. Andrew's Cross

- **Appearance and odor**

p-tert-Butyltoluene is a clear, colorless, combustible liquid with a gasoline-like odor. The odor threshold is reported to be 5 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 148.3
2. Boiling point (at 760 mm Hg): 192.8°C (379°F)
3. Specific gravity (water = 1): 0.86 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of p-tert-butyltoluene): 4.6
5. Melting point: −55°C (−67°F)
6. Vapor pressure at 25°C (77°F): 0.65 mm Hg
7. Solubility: Insoluble in water; slightly soluble in alcohol; very soluble in ether; miscible with most common industrial solvents
8. Evaporation rate (butyl acetate = 1): Very low

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame
2. Incompatibilities: Fires and explosions may result from contact of p-tert-butyltoluene with oxidizing materials.
3. Hazardous decomposition products: Toxic gases (such as carbon monoxide and carbon dioxide) may be released when p-tert-butyltoluene decomposes.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to p-tert-butyltoluene. Other sources rate p-tert-butyltoluene's fire hazard as moderate.

1. Flash point: 68°C (155°F) (closed cup)
2. Autoignition temperature: Data not available
3. Flammable limits in air: Data not available
4. Extinguishant: Use carbon dioxide, dry chemical, foam, or water fog to fight fires involving p-tert-butyltoluene. Do not use a solid stream of water because the stream will scatter and spread the fire.

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EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for p-tert-butyltoluene is 10 ppm (60 mg/m^3) as an 8-hr time-weighted average (TWA) concentration and 20 ppm (120 mg/m^3) as a short-term exposure limit (STEL). A STEL is a 15-min TWA exposure that should not be exceeded at any time during a workday [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 10 ppm (60 mg/m^3) as an 8-hr TWA and 20 ppm (120 mg/m^3) as a STEL [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned p-tert-butyltoluene a threshold limit value (TLV) of 10 ppm (61 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek, and a STEL of 20 ppm (121 mg/m^3) for periods not to exceed 15 min [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of irritation, nausea, and central nervous system and cardiovascular effects associated with exposure to p-tert-butyltoluene.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to p-tert-butyltoluene can occur through inhalation, ingestion, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: p-tert-Butyltoluene is a mild eye, skin, and respiratory tract irritant and a central nervous system depressant in animals acutely exposed; chronic exposure causes lung, brain, liver, and kidney damage. p-tert-Butyltoluene caused slight and transient eye irritation in rats and mild skin irritation in rabbits [NIOSH 1991; Grant 1986]. The dermal LD_{50} in rabbits is 19,600 mg/kg, and the LC_{50} in rats is 934 ppm for 1 hr [NIOSH 1991]. The oral LD_{50} in rats is 1,800 mg/kg. Acutely poisoned animals showed signs of eye and respiratory tract irritation and central nervous system effects including convulsions before death [Hine et al. 1954]. Rats repeatedly inhaling 25 or 50 ppm for 1 to 7 hr showed an increase in hemoglobin and a decrease in both erythrocyte and leukocyte counts [Clayton and Clayton 1981]. Repeated exposure of rats to 50 ppm caused liver and kidney changes and lesions of the brain and spinal cord [Hine et al. 1954]. Rats repeatedly exposed to 850 ppm for 1 hr progressively showed tremor, clonic movements, and flexor paralysis; pulmonary edema and pneumonia were the most frequent causes of death in animals after 10 such exposures [NLM 1990].

2. *Effects on Humans*: p-tert-Butyltoluene causes eye, skin, and upper respiratory tract irritation and central nervous system effects in humans. The irritant dose for the human eye is 5 ppm for 2 hr [NIOSH 1991]. The lowest acute toxic concentration in humans is 20 ppm for 5 min; central nervous system effects are seen at this concentration. Volunteers exposed for 5 min to p-tert-butyltoluene at concentrations ranging from 5 to 160 ppm reported experiencing nausea, upper respiratory tract irritation, and a metallic taste in the mouth. Volunteers exposed to the 160-ppm concentration became giddy and had increased pulse rates [Hine et al. 1954]. Workers chronically exposed to concentrations that were generally below 10 ppm reported anxiety and experienced decreased blood pressure, increased pulse rate, tremor, hematologic changes, and skin irritation [Hine et al. 1954].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to p-tert-butyltoluene can cause contact irritation, runny nose, scratchy throat, headache, tiredness, giddiness, anxiety, nausea, metallic taste, weakness, tremor, ataxia, increased pulse rate, decreased blood pressure, dizziness, confusion, hallucinations, dysarthria, convulsions, dyspnea, increased breathing effort, temporary loss of consciousness, and death from possible respiratory failure [NLM 1990].

2. *Chronic exposure*: Repeated or prolonged contact of p-tert-butyltoluene causes defatting and irritation of the skin. It can also cause tremor, decreased blood pressure, elevated pulse rate, and blood changes.

• Emergency procedures

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of p-tert-butyltoluene. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of p-tert-butyltoluene are inhaled, move the victim to fresh air ***immediately***. Have the victim blow his or her nose to remove residues from nostrils.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if p-tert-butyltoluene or a solution containing it is ingested:

—Do ***not*** induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve p-tert-butyltoluene and may result in worker exposures to this substance:

—Production of resins

—Use of p-tert-butyltoluene as a primary intermediate and as a solvent in the chemical and pharmaceutical industries

The following methods are effective in controlling worker exposures to p-tert-butyltoluene, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to p-tert-butyltoluene, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, respiratory system, blood, and central nervous system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to p-tert-butyltoluene at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable

medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with eye, skin, respiratory system, blood, or central nervous system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to p-tert-butyltoluene exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of p-tert-butyltoluene on the eyes, skin, respiratory system, blood, and central nervous system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for p-tert-butyltoluene.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population. Because occupational exposure to p-tert-butyltoluene may cause diseases with prolonged latent periods, the need for medical monitoring may extend well beyond the termination of employment.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne p-tert-butyltoluene is determined by using charcoal tubes (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 29 liters is collected. The samples are desorbed with carbon disulfide. Analysis is conducted by gas chromatography using a flame ionization detector. The limit of detection for this procedure is 0.001 to 0.01 mg per sample. This method is described in Method No. 1501 of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If p-tert-butyltoluene contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min, followed by washing with soap and water.

Clothing and shoes contaminated with p-tert-butyltoluene should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of p-tert-butyltoluene, particularly its potential for causing irritation of the eyes and skin.

A worker who handles p-tert-butyltoluene should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where p-tert-butyltoluene or a solution containing p-tert-butyltoluene is handled, processed, or stored.

STORAGE

p-tert-Butyltoluene should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. The storage area must meet OSHA requirements for a Class IIIA flammable liquid [29 CFR 1910.106]. Ventilation fans and other electrical service must be of explosionproof design. Containers of p-tert-butyltoluene should be protected from physical damage and should be stored separately from oxidizers, heat, sparks, and open flame. Containers of p-tert-butyltoluene should be routinely inspected for leaks. To prevent static sparks, metal containers and equipment must be grounded and bonded during transfers. Because containers that formerly contained p-tert-butyltoluene may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving p-tert-butyltoluene, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.

5. Use water spray to reduce vapors, but be aware that the spray may not prevent ignition in closed spaces.

6. Use only nonsparking tools for cleanup.

7. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

8. For large liquid spills, build dikes far ahead of the spill to contain the p-tert-butyltoluene for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

p-tert-Butyltoluene is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of p-tert-butyltoluene; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of p-tert-butyltoluene emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although p-tert-butyltoluene is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of p-tert-butyltoluene exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent prolonged or repeated skin contact with p-tert-butyltoluene. Gloves, aprons, boots, and other protective clothing and equipment should be used as necessary to prevent skin contact. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been tested against

permeation by p-tert-butyltoluene and have demonstrated good-to-excellent resistance for periods greater than 8 hr: polyvinyl alcohol and Viton®. Nitrile rubber may withstand permeation for more than 4 but fewer than 8 hr. Butyl rubber, natural rubber, and neoprene have demonstrated poor resistance to permeation by p-tert-butyltoluene.

If p-tert-butyltoluene is dissolved in an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which p-tert-butyltoluene might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with p-tert-butyltoluene. Contact lenses should not be worn if the potential exists for exposure to p-tert-butyltoluene.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ACETYLSALICYLIC ACID

INTRODUCTION

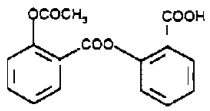
This guideline summarizes pertinent information about acetylsalicylic acid for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$CH_3COOC_6H_4COOH$

- **Structure**



- **Synonyms**

Aspirin, ASA, acetol, salicylic acid acetate, 2-acetoxybenzoic acid, acetophen, acetosalic acid, acetal, acetylin, acetylsal, acidum acetylsalicylicum, Asagran, Aspirdrops, Entericin, Caprin, Colfarit, Duramax, Empirin, Measurin, Novid, Rhodine, Saletin, Solpyron

- **Identifiers**

1. CAS No.: 50-78-2
2. RTECS No.: VO0700000
3. DOT UN: None
4. DOT label: None

- **Appearance and odor**

Acetylsalicylic acid is a noncombustible, crystalline, colorless to white powder. This substance is odorless; on contact with moisture, it develops the vinegarlike odor of acetic acid.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 180.2
2. Boiling point (at 760 mm Hg): 140°C (284°F) (decomposes)
3. Specific gravity (water = 1): 1.4 at 20°C (68°F)
4. Vapor density: Not applicable
5. Melting point: 135°C (275°F)
6. Vapor pressure at 20°C (68°F): Negligible
7. Solubility: Soluble in water, alcohol, chloroform, and ether; less soluble in absolute ether
8. Evaporation rate: Not applicable

- **Reactivity**

1. Conditions contributing to instability: None
2. Incompatibilities: Fires or explosions may result from contact of acetylsalicylic acid with strong oxidizers. Contact with alkali hydroxides or carbonates may cause decomposition.
3. Hazardous decomposition products: When heated to decomposition, toxic vapors and gases (such as partially oxidized hydrocarbons, carbon monoxide, and carbon dioxide) may be released.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to acetylsalicylic acid; this substance is not combustible.

1. Flash point: Not applicable
2. Autoignition temperature: Not applicable
3. Flammable limits in air: Not applicable

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

4. Extinguishant: Acetylsalicylic acid will not burn. Use an extinguishant that is suitable for the materials involved in the surrounding fire.

Dispersed in air, the dust of acetylsalicylic acid is a serious explosion hazard. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires resulting from acetylsalicylic acid explosions.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for acetylsalicylic acid is 5 mg/m^3 of air as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for acetylsalicylic acid of 5 mg/m^3 as an 8-hr TWA [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned acetylsalicylic acid a threshold limit value (TLV) of 5 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of respiratory and gastric irritation associated with exposure to acetylsalicylic acid.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to acetylsalicylic acid can occur through inhalation, ingestion, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Acetylsalicylic acid can damage the stomach lining and interfere with blood clotting; it is also fetotoxic and teratogenic in animals [Klaassen et al. 1986; NIOSH 1991]. Cats were orally administered total daily doses of either 33 to 63 mg/kg or 81 to 130 mg/kg for up to 35 days. The lowest dose induced toxic hepatitis in the treated animals, but both doses induced anorexia, weight loss, vomiting, depression, and death. Only animals receiving the high doses had hyperpnea (increased rate and depth of breathing), hyperthermia, and disturbances in their acid-base balance [NLM 1991]. Dogs administered oral daily doses of 100 to 300 mg/kg for 1 to 4 weeks vomited bloody emesis and had gastritis and gastric perforations [NLM 1991]. The oral LD_{50} in rats ranges from 1,360 to 1,750 mg/kg [NLM 1991]. Acetylsalicylic acid has been shown to be a developmental toxin in five species of animals; this substance also causes reproductive effects in both males and females [NIOSH 1991]. Teratogenic effects occurred when 125 mg/kg acetylsalicylic acid was administered orally to rats on day 12 of pregnancy; damage to the testes, epididymis, and sperm duct was observed in male rats dosed orally with 2.1 g/kg acetylsalicylic acid for 14 days [NIOSH 1991]. When administered orally or subcutaneously to pregnant rats, mice, rabbits, cats, and dogs, acetylsalicylic acid was fetotoxic or teratogenic [NIOSH 1991]. Chronic administration of a 300-mg/kg dose of acetylsalicylic acid inhibited ovulation in rats by depressing prostaglandin synthesis [NLM 1991].

2. *Effects on Humans*: In the occupational environment, acetylsalicylic acid is a systemic allergen and an irritant of the eyes, mucous membranes, upper respiratory tract, and skin. When in contact with the eyes, this substance causes irritation, conjunctival ulceration, and corneal injury [ACGIH 1991a; Grant 1986]. Aspirin-intolerant individuals develop hives, rhinorrhea, and bronchospasm when exposed to this substance; some persons (e.g., those who are glucose-6-phosphate dehydrogenase deficient) may be especially sensitive to aspirin's effects [Klaassen et al. 1986; Gosselin et al. 1984]. Ingestion of acetylsalicylic acid causes an increased tendency to bleed by interfering with platelet aggregation; this effect has been seen after the ingestion of as little as 150 mg of acetylsalicylic acid [ACGIH 1991a]. Acetylsalicylic acid produces an allergy-like response in about 0.2% of individuals; although aspirin intolerance mimics a true allergic response, this reaction is not believed to be immunologically based [Klaassen et al. 1986].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to acetylsalicylic acid can cause redness and tearing of the eyes, runny nose, scratchy throat, and redness and swelling of the skin.

2. *Chronic exposure*: Chronic exposure to acetylsalicylic acid can cause headache, dizziness, and ringing in the ears; in aspirin-intolerant individuals, it can induce pseudoallergic responses (hives, runny nose, wheezing, and difficult breathing) and a permanent intolerance to this substance. Ingestion of aspirin may lead to an increase in clotting time.

• Emergency procedures

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Irritation may result! ***Immediately*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Irritation may result. Wash contaminated skin with soap and water.

3. *Inhalation exposure*: If a large amount of acetylsalicylic acid is inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if a large amount of acetylsalicylic acid is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The manufacture, handling, and packaging of aspirin tablets or related pharmaceutical products may result in worker exposures to this substance.

The following methods are effective in controlling worker exposures to acetylsalicylic acid, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to acetylsalicylic acid, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and upper respiratory tract. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific

job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to acetylsalicylic acid at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with drug allergies or aspirin intolerance or of diseases of the eyes, skin, or upper respiratory system; individuals using anticoagulant medications may also be at increased risk.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to acetylsalicylic acid exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of acetylsalicylic acid on the eyes, skin, or upper respiratory tract or on blood clotting time. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for acetylsalicylic acid.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne acetylsalicylic acid is determined by using a 37-mm glass fiber filter. Samples are collected at a maximum flow rate of 1.0 liter/min until a maximum air volume of 120 liters is collected. Analysis is conducted by high-performance liquid chromatography using an ultraviolet detector. This method is included in the OSHA Laboratory In-House Methods File [OSHA 1989].

PERSONAL HYGIENE

If acetylsalicylic acid contacts the skin, workers should immediately wash the affected areas with soap and water.

Clothing contaminated with acetylsalicylic acid should be removed immediately, and provisions should be made for safely removing this chemical from these articles.

A worker who handles acetylsalicylic acid should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where acetylsalicylic acid or a solution containing acetylsalicylic acid is handled, processed, or stored.

STORAGE

Acetylsalicylic acid should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of acetylsalicylic acid should be protected from physical damage and should be stored separately from strong oxidizers, alkali hydroxides, carbonates, moisture, and heat. Because containers that formerly contained acetylsalicylic acid may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving acetylsalicylic acid, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Collect spilled material in the most convenient and safe manner and place the material in a covered container for reclamation or later disposal in an approved facility.

2. Absorb liquid containing acetylsalicylic acid in vermiculite, dry sand, earth, or similar material.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Acetylsalicylic acid is not subject to EPA emergency planning requirements [40 CFR 355.30].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of acetylsalicylic acid; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA [42 USC 11022] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of acetylsalicylic acid emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although acetylsalicylic acid is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for the waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of acetylsalicylic acid exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent prolonged or repeated skin contact with acetylsalicylic acid; protective gloves are recommended when handling this substance. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to acetylsalicylic acid permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to acetylsalicylic acid.

If acetylsalicylic acid is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which acetylsalicylic acid might contact the eyes (e.g., through dust particles). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with acetylsalicylic acid. Contact lenses should not be worn if the potential exists for acetylsalicylic acid exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ACRYLIC ACID

INTRODUCTION

This guideline summarizes pertinent information about acrylic acid for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_3H_4O_2$

- **Structure**

$CH_2=CHCO_2H$

- **Synonyms**

Propenoic acid, acroleic acid, ethylenecarboxylic acid, propene acid, vinylformic acid, glacial acrylic acid, 2-propenoic acid

- **Identifiers**

1. CAS No.: 79-10-7
2. RTECS No.: AS4375000
3. DOT UN: 2218 29
4. DOT label: Corrosive

- **Appearance and odor**

Acrylic acid is a colorless, corrosive, combustible liquid with a distinctive and acrid odor. The odor threshold is reported to be 1.0 part per million (ppm) parts of air. Acrylic acid is available commercially in the United States in two forms: the technical grade (which contains 94% acrylic acid) and glacial acrylic acid (which contains 98% acrylic acid).

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 72.1
2. Boiling point (760 mm Hg): 141°C (221.8°F)
3. Specific gravity (water = 1): 1.06 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of acrylic acid): 2.5
5. Melting point: 14°C (57.2°F)
6. Vapor pressure at 20°C (68°F): 3.1 mm Hg
7. Solubility: Miscible with water, alcohol, ether, acetone, and benzene
8. Evaporation rate (butyl acetate = 1): Greater than 1

- **Reactivity**

1. Conditions contributing to instability: The vapor forms an explosive mixture in contact with the air. Heat, sparks, open flame, oxygen, high temperature, and pressure.
2. Incompatibilities: Fires and explosion may result from contact of acrylic acid with oxydizing agents, amines, alkalis, ammonium hydroxide, chlorosulfonic acid, ethylene diamine, ethyleneimine, oleum, or 2-aminoethanol.
3. Hazardous decomposition products: Toxic gases (such as carbon dioxide and carbon monoxide) may be released in a fire involving acrylic acid.
4. Special precautions: Acrylic acid corrodes carbon steel and other metals.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 2 (moderate fire hazard) to acrylic acid.

1. Flash point: 50°C (122°F) (open cup)
2. Autoignition temperature: 438°C (820°F)
3. Flammable limits in air (% by volume): Lower, 2.4; upper, 8.0
4. Extinguishant: Use dry chemical, water spray, alcohol foam, or carbon dioxide to fight fires involving acrylic acid.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Water may be ineffective, but it may be used to cool fire-exposed containers. If a leak or spill has not ignited, water spray may be used to disperse vapors and to protect persons attempting to stop the leak.

Fires involving acrylic acid should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of acrylic acid may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving acrylic acid. Firefighters' protective clothing may not provide protection against permeation by acrylic acid.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for acrylic acid is 10 ppm (30 mg/m^3) as an 8-hr time-weighted average (TWA) concentration. The OSHA PEL also bears a "Skin" notation, which indicates that the cutaneous route of exposure (including mucous membranes and eyes) contributes to overall exposure [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 2 ppm (6 mg/m^3) as an 8-hr TWA with a "Skin" notation [NIOSH 1988, 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned acrylic acid a threshold limit value (TLV) of 2 ppm (5.9 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991]. The ACGIH TLV also bears a "Skin" notation.

• Rationale for limits

The OSHA limit was established to protect workers from the risk of eye and nasal irritation. The NIOSH and ACGIH limits were based on recent studies demonstrating degeneration of nasal mucosa at 5 ppm, changes in pulmonary function, teratogenicity and embryotoxicity in rats at low doses, and skin absorption in animals.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to acrylic acid can occur through inhalation, ingestion, eye or skin contact, and absorption through the skin.

• Summary of toxicology

1. *Effects on Animals*: Acrylic acid is dermally absorbed and is corrosive to the eyes, nose, and mucous membranes in animals. Application of glacial acrylic acid to the eyes of rabbits caused irreversible corneal injury graded 9 on an ascending severity scale of 1 to 10 [Grant 1986]. Application of a 1% solution to the eye of a rabbit caused severe burns and eye injury [ACGIH 1991a; NIOSH 1991; Proctor et al. 1988]. Irreversible eye and skin damage resulted following exposure of rats to 1,200 ppm for 4 hr [NLM 1992]. Applied to rabbit skin, acrylic acid caused severe irritation [Proctor et al. 1988]. Three of five guinea pigs became dermally sensitized when exposed to acrylic acid by injection and subsequently challenged with this substance [Clayton and Clayton 1981]. The dermal LD_{50} in rabbits is 290 mg/kg [NLM 1992]. Saturated atmospheres have been reported to range from 420 ppm at 20° to 760 ppm at 30° [NLM 1992]. Although exposure of rats to polymerized saturated vapors (room temperature) for 8 hr did not induce deaths [Smyth et al. 1962], a 1-hr exposure to unpolymerized saturated vapor was the maximum duration tolerated without death [Carpenter et al. 1974]. Vapor concentrations approaching saturation killed half of a group of rats exposed for 3.5 hr [NLM 1992]. However, 4-hr exposures of rats at 2,000 or 4,000 ppm were nonlethal [NLM 1992; Carpenter et al. 1974]. The 4-hr LC_{50} in rats is 1,200 ppm [NLM 1992]. Exposure of rats to irritant concentrations of acrylic acid caused decreased respiratory rates and tidal and minute volumes [ACGIH 1991a]. In addition, four rats exposed once to 6,333 ppm of acrylic acid for 5 hr developed eye and nose irritation, respiratory difficulties, and unresponsivness; one animal died. At autopsy, these animals showed lung, liver, and kidney damage [ACGIH 1991a]. The oral LD_{50} in rats was variable: 357, 1,250, or 2,722 mg/kg [NLM 1992; Smyth et al. 1962]. Rats exposed to acrylic acid at 80 ppm for 6 hr/day, 5 days/week for 4 weeks showed no adverse effects, and rats exposed to 300 ppm on the same regimen experienced nose irritation, lethargy, and decreased weight

gain. Rats exposed to 1,500 ppm acrylic acid for shorter intervals showed damage to the liver, kidneys, and lungs at autopsy [ACGIH 1991a]. However, rats that inhaled 233 ppm for 4 hr/day, 5 days/week for 4 weeks developed gastric mucosal lesions and pulmonary inflammation [NLM 1992]. In rats exposed to the vapors of acrylic acid at 5, 25, or 75 ppm for 6 hr/day, 5 days/week for 13 weeks, terminal pathology was normal in the 5- or 25-ppm group; however, slight degenerative lesions of the olfactory mucosa were present in the high-dose group [ACGIH 1991a]. Similarly exposed mice were more sensitive than rats as they developed lesions of the nasal mucosa for all three exposure concentrations [ACGIH 1991a]. Intraperitoneal or intra-amniotic injections of acrylic acid caused embryotoxicity and gross abnormalities in the offspring of treated pregnant rats [Proctor et al. 1988; NLM 1992].

2. *Effects on Humans*: Acrylic acid is corrosive on contact with the eyes, skin, mucous membranes, and upper respiratory tract of humans, and its vapor causes severe irritation of these organs. Acute industrial exposure to this substance has caused eye and skin burns ranging in intensity from moderate to severe [Proctor et al. 1988]. Absorption of acrylic acid through the skin has been reported to cause systemic illness, and inhalation of the mist or vapor of acrylic acid may cause lung injury as well as nasal irritation and tearing of the eyes [Genium 1989]. Based on effects seen in animals, acrylic acid may cause skin sensitization [ACGIH 1991a].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to acrylic acid can cause redness, swelling, and tearing of the eyes, runny nose, scratchy throat, coughing, and difficult breathing. Contact of the liquid with the eyes or skin can cause corneal injury, irritation, burns, and destruction of the tissue.

2. *Chronic exposure*: Chronic exposure to acrylic acid may cause lethargy, irritation, and skin sensitization reactions.

- **Emergency procedures**

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Tissue destruction and blindness may result from exposure to concentrated solutions, vapors, mists or aerosols of acrylic acid. ***Immediately but gently*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Severe burns, skin corrosion, and absorption of lethal amounts may result! ***Immediately*** remove contaminated clothing! ***Immediately, continuously, and gently*** wash skin for at least 15 min. Use soap and water if skin is intact; use only water if skin is not intact.

3. *Inhalation exposure*: If vapors, mists, or aerosols of acrylic acid are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if acrylic acid or a solution containing it is ingested:

—Seek medical attention ***immediately***.

—Do ***not*** induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water. Immediately after rinsing, have the victim drink one cup (8 oz) of fluid and ***no more***.

—Do ***not*** permit the victim to drink milk or carbonated beverages!

—Do ***not*** permit the victim to drink any fluid if more than 60 min have passed since initial ingestion.

NOTE: These instructions must be followed exactly. Drinking a carbonated beverage or more than one cup of fluid could create enough pressure to perforate already damaged stomach tissue. The tissue-coating action of milk may impede medical assessment of tissue damage. Ingestion of any fluid more than 60 min after initial exposure could further weaken damaged tissue and result in perforation.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve acrylic acid and may result in worker exposures to this substance:

—Manufacture of acrylic resins, especially the acrylates

—Use of acrylic acid in acrylic polymeric emulsions for leather, textile, and paper coatings

—Use of acrylic acid in paints, floor polishes, adhesives, general finishes, and binders

—Manufacture of plastics, molding powder for signs, construction units, decorative emblems, and insignia

—Use of acrylic acid in dentistry and medicine

The following methods are effective in controlling worker exposures to acrylic acid, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to acrylic acid, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to acrylic acid at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with eye, skin, or respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to acrylic acid exposure. The interviews, examinations, and medical screening tests should focus on identifying

the adverse effects of acrylic acid on the eyes, skin, and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for acrylic acid.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne acrylic acid is determined by using two XAD-8 tubes connected in series. Samples are collected at a maximum flow rate of 0.1 liter/min until a maximum air volume of 24 liters is collected. The sample is then treated with methanol and water (1:1) to extract the acrylic acid. Analysis is conducted by high-performance liquid chromatography using an ultraviolet detector. This method has a sampling and analytical error of 0.12 and is found in OSHA Method No. 28, *OSHA Analytical Methods Manual* [OSHA 1985].

PERSONAL HYGIENE

If acrylic acid contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min, followed by washing with soap and water.

Clothing contaminated with acrylic acid should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of acrylic acid, particularly its potential to cause skin burns.

A worker who handles acrylic acid should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where acrylic acid or a solution containing acrylic acid is handled, processed, or stored.

STORAGE

Acrylic acid is explosive unless (1) an inhibitor has been added to it before it is stored, or (2) it is stored at temperatures below its melting point. Acrylic acid should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Outside or detached storage is preferred; the storage area must meet the requirements for an OSHA Class II combustible liquid. Explosionproof exhaust ventilation and sparkproof fans must be used in storage areas. Storage tanks should be made of stainless steel or aluminum. Containers of acrylic acid should be protected from physical damage and should be stored separately from oxidizers, amines, alkalies, other incompatible substances, heat, sparks, and open flame. Only nonsparking tools may be used to handle acrylic acid. To prevent static sparks, containers should be grounded and bonded for transfers. Because containers that formerly contained acrylic acid may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving acrylic acid, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.

2. Notify safety personnel.

3. Remove all sources of heat and ignition.

4. Ventilate potentially explosive atmospheres.

5. Use water spray to reduce vapors, but the spray may not prevent ignition in closed spaces.

6. Use nonsparking tools for cleanup.

7. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

8. For large liquid spills, build dikes far ahead of the spill to contain the acrylic acid for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Acrylic acid is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is equal to or greater than the reportable quantity for that chemical, employers are required by EPA regulation resulting from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal, State, and local authorities.

The reportable quantity for acrylic acid is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center *immediately* at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of acrylic acid per calendar year are required by EPA [49 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of acrylic acid emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Acrylic acid is listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.] and has been assigned EPA Hazardous Waste No. U008. This substance has been banned from land disposal and may be treated by fuel substitution or incineration. Acrylic acid may also be disposed of in an organometallic or organic lab pack that meets the requirements of 40 CFR 264.316 or 265.316.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of acrylic acid exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an

evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective gloves and clothing should be worn to prevent any possibility of skin contact with acrylic acid. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been tested against permeation by acrylic acid and have demonstrated good-to-excellent resistance for periods greater than 8 hr: butyl rubber and Saranex®. Materials that may withstand permeation for more than 4 hr but fewer than 8 hr: Teflon® and Viton®. Natural rubber, neoprene, nitrile rubber, polyethylene, and polyvinyl chloride have demonstrated poor resistance to permeation by acrylic acid.

If acrylic acid is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which acrylic acid might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with acrylic acid. Contact lenses should not be worn if the potential exists for acrylic acid exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ALLYL PROPYL DISULFIDE

INTRODUCTION

This guideline summarizes pertinent information about allyl propyl disulfide for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_6H_{12}S_2$

- **Structure**

$CH_2{=}CHCH_2S_2C_3H_7$

- **Synonyms**

2-Propenyl propyl disulfide; onion oil; 4,5-dithia-1-octene; propyl allyl disulfide

- **Identifiers**

1. CAS No.: 2179-59-1
2. RTECS No.: JO0350000
3. DOT UN: None
4. DOT label: None

- **Appearance and odor**

Allyl propyl disulfide is a pale yellow, combustible liquid with a strong, pungent, irritating odor. It is the chief volatile constituent of onion oil.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 148.3
2. Boiling point (13 mm Hg): 78° to 80°C (172.4° to 176°F)
3. Specific gravity (water = 1): 0.93 at 15°C (59°F)
4. Vapor density: (air = 1 at boiling point of allyl propyl disulfide) 5.12
5. Melting point: Solidifies at −15°C (5°F)
6. Vapor pressure at 20°C (68°F): Data not available; however, this substance is known to be volatile.
7. Solubility: Insoluble in water; soluble in ether, carbon disulfide, and chloroform
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame
2. Incompatibilities: Fires and explosions may result from contact of allyl propyl disulfide with oxidizers.
3. Hazardous decomposition products: Toxic gases (such as sulfur oxides) may be released in a fire involving allyl propyl disulfide.
4. Special precautions: None known

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to allyl propyl disulfide. Other sources rate allyl propyl disulfide as a moderate fire hazard.

1. Flash point: Data not available
2. Autoignition temperature: Data not available
3. Flammable limits in air: Data not available
4. Extinguishant: Use foam, carbon dioxide, or dry chemical to fight fires involving allyl propyl disulfide. Water may be ineffective, but it may be used to cool fire-exposed containers. If a leak or spill has not ignited, water spray may be used to disperse vapors and to protect persons attempting to stop the leak.

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EXPOSURE LIMITS

• **OSHA PEL**

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for allyl propyl disulfide is 2 ppm (12 mg/m^3) as an 8-hr time-weighted average (TWA) concentration and 3 ppm (18 mg/m^3) as a short-term exposure limit (STEL). A STEL is a 15-min TWA exposure that should not be exceeded at any time during a workday [29 CFR 1910.1000, Table Z-1-A].

• **NIOSH REL**

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 2 ppm (12 mg/m^3) as an 8-hr TWA and 3 ppm (18 mg/m^3) as a STEL [NIOSH 1992].

• **ACGIH TLV®**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned allyl propyl disulfide a threshold limit value (TLV) of 2 ppm (12 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek and a STEL of 3 ppm (18 mg/m^3) for periods not to exceed 15 min [ACGIH 1991b].

• **Rationale for limits**

The limits are based on the risk of eye, nose, and upper respiratory tract irritation associated with exposure to allyl propyl disulfide.

HEALTH HAZARD INFORMATION

• **Routes of exposure**

Exposure to allyl propyl disulfide can occur through inhalation and eye or skin contact.

• **Summary of toxicology**

1. *Effects on Animals*: No studies are available on the toxicity of allyl propyl disulfide in animals.

2. *Effects on Humans*: Allyl propyl disulfide irritates the eyes, nose, throat, and mucous membranes [Proctor et al. 1988]. Allyl propyl disulfide is reported to cause lacrimation at concentrations of 2 to 3 ppm and above [Grant 1986]. Workers in an onion dehydration plant who were exposed to allyl propyl disulfide at 3.4 ppm experienced eye, nose, and throat irritation [ACGIH 1991a].

• **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to allyl propyl disulfide can cause tearing eyes, runny nose, and throat irritation.

2. *Chronic exposure*: No signs or symptoms of chronic exposure to allyl propyl disulfide have been reported.

• **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to the liquid or vapors, mists, or aerosols of allyl propyl disulfide. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operation may involve allyl propyl disulfide and may result in worker exposures to this substance:

—Slicing of onions

The following methods are effective in controlling worker exposures to allyl propyl disulfide, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to allyl propyl disulfide, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the respiratory system and skin. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to allyl propyl disulfide at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with diseases of the respiratory system or skin.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to allyl propyl disulfide exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of allyl propyl disulfide on the respiratory system and skin. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for allyl chloride.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne allyl propyl disulfide is determined by using a Chromosorb 106 tube (100/50-mg sections, 60/80 mesh). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 10 liters is collected. The sample is then treated with trichloroethylene to extract the allyl propyl disulfide. Analysis is conducted by gas chromatography using a flame photometric detector. This method has a sampling and analytical error of 0.09 and is described in the OSHA Laboratory In-House Methods File [OSHA 1991].

PERSONAL HYGIENE

If allyl propyl disulfide contacts the skin, workers should wash the affected areas with soap and water.

Clothing contaminated with allyl propyl disulfide should be removed.

A worker who handles allyl propyl disulfide should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where allyl propyl disulfide is handled, processed, or stored.

STORAGE

Allyl propyl disulfide should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of allyl propyl disulfide should be protected from physical damage and should be stored separately from oxidizers, heat, sparks, and open flame. Because containers that formerly contained allyl propyl disulfide may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving allyl propyl disulfide, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Notify safety personnel.
2. Remove all sources of heat and ignition.
3. Ventilate the area of the spill or leak.
4. Absorb spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Allyl propyl disulfide is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [40 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of allyl propyl disulfide; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of allyl propyl disulfide emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although allyl propyl disulfide is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of allyl propyl disulfide exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements

of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Safety glasses, goggles, or face shields should be worn during operations in which allyl propyl disulfide might contact the eyes (e.g., through splashes of solution).

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR AMITROLE

INTRODUCTION

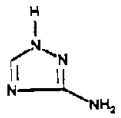
This guideline summarizes pertinent information about amitrole for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_2H_4N_4$

- **Structure**



- **Synonyms**

3-Amino-s-triazole; 2-amino-1,3,4-triazole; 3AT; ATA; aminotriazole; 3-amino-1H-1,2,4-triazole; Amitril; Amizol; Cytrol; Weedazol; Azaplant; Azolan; Diurol; Domatol; Elmasil; Emisol; Fenamine; Kleer-Lot; Orga-414; Radoxone TL; X-All Liquid; Fenavar; Ramizol; Vorox

- **Identifiers**

1. CAS No.: 61-82-5
2. RTECS No.: XZ3850000
3. DOT UN: None
4. DOT label: None

- **Appearance and odor**

Amitrole is a nonflammable, colorless-to-white, crystalline solid that is odorless when pure. The use of amitrole on food crops is now banned in the United States; however, this substance is still imported for use as a specialty herbicide (e.g., brush killer) and as a preharvest and postharvest herbicide on selected crops.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 84.1
2. Boiling point (760 mm Hg): Data not available
3. Specific gravity (water = 1): 1.14 at 20°C (68°F)
4. Vapor density: Not applicable
5. Melting point: 159°C (318.2°F)
6. Vapor pressure at 20°C (68°F): Not applicable
7. Solubility: Soluble in water, alcohol, and chloroform; sparingly soluble in ethyl acetate; insoluble in acetone, diesel oil, ether, and kerosene
8. Evaporation rate: Not applicable

- **Reactivity**

1. Conditions contributing to instability: Heat and light
2. Incompatibilities: Amitrole in aqueous solution is neutral, but the compound acts as a weak base to form salts in contact with acids. This substance is also mildly corrosive to iron, aluminum, copper, and copper alloys.
3. Hazardous decomposition products: Toxic gases (such as oxides of nitrogen) may be released in a fire involving amitrole.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to amitrole; this substance is not flammable.

1. Flash point: Not applicable

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2. Autoignition temperature: Not applicable

3. Flammable limits in air: Not applicable

4. Extinguishant: Use an extinguishant that is suitable for the materials involved in the surrounding fire.

Firefighters should wear a full set of protective clothing, including a self-contained breathing apparatus, when fighting fires involving amitrole.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for amitrole is 0.2 mg/m^3 of air as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 0.2 mg/m^3 as an 8-hr TWA. NIOSH has also recommended that amitrole be considered a potential occupational carcinogen and that exposure be limited to the lowest feasible concentration [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned amitrole a threshold limit value (TLV) of 0.2 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The OSHA and NIOSH limits are based on the risk of cancer associated with exposure to amitrole, and the ACGIH limit is based on the risk of systemic and reproductive (fetotoxicity) effects associated with exposure to amitrole.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to amitrole can occur through inhalation, ingestion, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Amitrole is a potent antithyroid agent and an animal carcinogen. Amitrole is slightly irritating to the eyes and skin of exposed rabbits [ACGIH 1991a]. Acute dermal exposure of rats and rabbits to 10,000 mg/kg did not induce toxicity. Exposure of rats to 439 mg/m^3 for 4 hr did not induce eye or respiratory tract irritation or toxicity [ACGIH 1991a]. The oral LD_{50} for mice and rats ranges from 11,000 to 14,000 mg/kg [ACGIH 1991a; Clayton and Clayton 1982]; however, a 25,000-mg/kg LD_{50} has also been cited for rats [ACGIH 1991a; NIOSH 1991]. When administered to young rabbits (dose and route not specified), amitrole produced cataracts and reduced the catalase activity within the lens [Grant 1986]. A number of subchronic studies via oral routes of administration have established the thyroid as the primary target organ of amitrole toxicity. In rats, the no observable effect level (NOEL) based on normal iodine 131 uptake was 0.5 ppm amitrole in the diet consumed during 13 weeks of exposure. Decreased thyroid function required 1.0 ppm in the diet for 29 days. Induction of increased thyroid weights required a minimum of 10 ppm in the diet for 13 weeks [ACGIH 1991a]. In addition, rats fed amitrole in drinking water (12 to 14 mg/day) developed goiter and showed histologic evidence of thyroid pathology at autopsy [Clayton and Clayton 1981]. Dietary exposure of breeding pairs of rats to amitrole caused reduced growth and viability of offspring [IARC 1986], and oral administration to pregnant mice caused fetotoxicity [NLM 1991]. In vitro mammalian test systems indicate that amitrole is also mutagenic [NIOSH 1991]. Amitrole has been tested for carcinogenicity in mice (by oral administration, skin application, and transplacental exposure), in rats (by oral and subcutaneous administration), and in hamsters (by oral administration). Orally, this substance produced thyroid tumors, liver carcinomas, and benign and malignant liver tumors in mice of both sexes; it also caused benign and malignant (adenocarcinomas) thyroid tumors in rats of both sexes, and benign pituitary tumors in female rats [IARC 1987]. On the basis of these studies, the International Agency for Research on Cancer (IARC) has concluded that the evidence for the carcinogenicity of amitrole in animals is sufficient [IARC 1987].

2. *Effects on Humans*: Amitrole is a thyroid toxin in humans. On the basis of effects seen in animals, this substance is also a potential occupational carcinogen. There have been no reports of signs or symptoms in exposed individuals, but extrapolations from animal data suggest that dyspnea, muscle spasms, fasciculations, ataxia, anorexia, salivation, and increased body temperature could occur [NLM 1991]. A single oral dose of 100 mg of amitrole given to volunteers inhibited thyroid iodine uptake for 24 hr after administration; the volunteers included healthy persons as well as individuals with hyperthyroidism [ACGIH 1991a]. Ingestion of 20 mg/kg of a commercial preparation (30% amitrole) by a 39-year-old woman did not induce signs or symptoms of toxicity [NLM 1991]. A small cohort study of Swedish railroad workers exposed for 45 days or more to amitrole, other pesticides, and organic and inorganic chemicals revealed an excess number of deaths from cancer. A subgroup of these workers exposed both to amitrole and chlorophenoxy herbicides had an increase in cancer mortality that was statistically significant; however, in the subgroup exposed primarily to amitrole alone, no

significant excess was seen [IARC 1987]. On the basis of this study, IARC has concluded that the evidence for the carcinogenicity of amitrole in humans is inadequate [IARC 1987].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Other than mild irritation, no signs or symptoms of acute exposure to amitrole have been reported.

2. *Chronic exposure*: On the basis of effects seen in animals, the signs and symptoms of chronic exposure to amitrole could include dyspnea, muscle spasms, ataxia, anorexia, salivation, and increased body temperature; or lassitude, skin dryness, depression, and other effects indicative of thyroid function suppression.

- **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to particulates or concentrated solutions, vapors, mists, or aerosols of amitrole. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If particulates or vapors, mists, or aerosols of amitrole are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if amitrole or any material containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses involve amitrole and may result in worker exposures to this substance:

—Use in the formulation of herbicides

—Use as a herbicide for hardwood nursery stock, aquatic weeds, and nonselective weed control along highways and railroads

—Use as a cotton defoliant and as a reagent in photography

—Use as a herbicide on poison ivy and poison oak

—Use as a herbicide on food crops (now banned in the United States)

The following methods are effective in controlling worker exposures to amitrole, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to amitrole, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the thyroid gland, and they should include measurement of the individual's pre-exposure level of thyroid activity.

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to amitrole at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with diseases of the thyroid gland.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to amitrole exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of amitrole on the thyroid gland. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for amitrole.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population. Because occupational exposure to amitrole may cause diseases with prolonged latent periods, the need for medical monitoring may extend well beyond the termination of employment.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne amitrole is determined by using a midget impinger containing 10 ml of distilled water. Samples are collected at a maximum flow rate of 1.0 liter/min until a maximum air volume of 60 liters is collected. Analysis is conducted by high performance liquid chromatography using ultraviolet detection. The limit of detection for this procedure is 0.004 mg/m^3. This method is described in the OSHA Computerized Information System [OSHA 1988] and in the OSHA Laboratory In-House Methods File [OSHA 1991].

PERSONAL HYGIENE

If amitrole contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min and then wash with soap and water.

Clothing and shoes contaminated with amitrole should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of amitrole.

A worker who handles amitrole should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where amitrole or a solution containing amitrole is handled, processed, or stored.

STORAGE

Amitrole should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of amitrole should be protected from physical damage and should be stored separately from acids, heat, and light. Because containers that formerly contained amitrole may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving amitrole, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material.

2. For small dry spills, use a clean shovel and place the material in a clean, dry container; cover and remove the container from the spill area.

3. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

4. For large liquid spills, build dikes far ahead of the spill to contain the amitrole for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Amitrole is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is above the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal, State or local authorities.

The reportable quantity for amitrole is 1 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center ***immediately*** at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of amitrole emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21–261.24. Amitrole is listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.] and has been assigned EPA Hazardous Waste No. U011. This substance has been banned from land disposal and may be treated by incineration. Amitrole also may be disposed of in an organometallic or organic lab pack that meets the requirements of 40 CFR 264.316 or 265.316.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

• **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of amitrole exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

• **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective gloves and clothing should be worn to prevent any possibility of skin contact with amitrole. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to amitrole permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to amitrole.

If amitrole is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which amitrole might contact the eyes (e.g., through dust particles or splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with amitrole. Contact lenses should not be worn if the potential exists for amitrole exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR AMMONIUM CHLORIDE FUME

INTRODUCTION

This guideline summarizes pertinent information about ammonium chloride fume for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

NH_4Cl

- **Synonyms**

Amchlor fume, ammoneric fume, ammonium muriate fume, darammon fume, sal ammonia fume, salammoniac fume, salammonite fume, salmiac fume

- **Identifiers**

1. CAS No.: 12125-02-9
2. RTECS No.: BP4550000
3. DOT UN: 9085 31
4. DOT label: None

- **Appearance and odor**

Ammonium chloride is a noncombustible, white, crystalline solid. It is odorless and somewhat hygroscopic. Ammonium chloride fume is the finely divided particulate form of this substance.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 53.5
2. Boiling point (760 mm Hg): 520°C (968°F)
3. Specific gravity (water = 1): 1.52 at 25°C (77°F)
4. Vapor density: Not applicable
5. Melting point: 350°C (662°F) sublimes
6. Vapor pressure at 160.4°C (320.7°F): 1 mm Hg
7. Solubility: Soluble in water, liquid ammonia, methanol, and ethanol; practically insoluble in acetone, ether, and ethyl acetate
8. Evaporation rate (butyl acetate = 1): Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat
2. Incompatibilities: Violent reactions may result from contact of ammonium chloride fume with boron trifluoride, boron pentafluoride, iodine heptafluoride, or potassium chlorate. In the presence of alkalies, ammonia is evolved; in the presence of acids, hydrogen chloride is evolved. Ammonium chloride is also incompatible with the salts of lead or silver.
3. Hazardous decomposition products: Toxic gases and vapors (such as ammonia and hydrochloric acid) may be released in a fire involving ammonium chloride fume.
4. Special precautions: At fire temperatures, ammonium chloride fume corrodes metals.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 0 (no fire hazard) to ammonium chloride fume. This substance is not combustible.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

1. Flash point: Not applicable

2. Autoignition temperature: Not applicable

3. Flammable limits in air: Not applicable

4. Extinguishant: Use water spray to reduce the fumes and irritant gases produced in a fire involving ammonium chloride. For small fires, use dry chemical, Halon®, water spray, foam, or other noncombustible material suitable for the materials involved in the surrounding fire.

Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving ammonium chloride fume.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) for ammonium chloride fume are 10 mg/m^3 of air as an 8-hr time-weighted average (TWA) and 20 mg/m^3 as a short-term exposure limit (STEL)—the 15-min TWA that should not be exceeded at any time during a workday [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 10 mg/m^3 as an 8-hr TWA and 20 mg/m^3 as a STEL (15-min TWA) [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned ammonium chloride fume a threshold limit value (TLV) of 10 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek and 20 mg/m^3 as a STEL (15-min TWA) [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of respiratory system irritation associated with exposure to ammonium chloride fume.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to ammonium chloride fume can occur through inhalation and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Ammonium chloride is a tissue irritant and metabolic acidifying agent. Topical administration of 100 or 500 mg onto the eyes of rabbits caused severe or mild irritation, respectively [NIOSH 1991]. No animal data are available on the toxic effects of inhalation exposure to the fume of ammonium chloride. The acute oral LD_{50} in rats is 1,650 mg/kg [NIOSH 1991]. An acute lethal intravenous dose to mice induced hyperventilation, convulsions, coma, and death [NLM 1991]. During a 13-week subchronic study, 10 male rats ingested a purified diet containing 5% ammonium chloride. This metabolic acidifying agent depressed food consumption and weight. Necropsy of an animal that died during week 10 revealed hemorrhagic abdominal fluid, a blood clot in the enlarged urinary bladder, inflammation of the seminal vesicles and prostate, and haemothorax. Terminal relative kidney weights were also increased. Histopathology of selected organs demonstrated only a diffuse hyperplasia of the urinary bladders in 4 of 10 rats treated with ammonium chloride. Two males had a moderate hyperplasia, and two other males had severe hyperplasia with small papillary protrusions [NIOSH 1991; de Groot et al. 1988].

2. *Effects on Humans*: Ammonium chloride fume is a mild irritant of the eyes, nose, throat, lungs, and skin in humans. Repeated inhalation of ammonium chloride fumes (concentration unspecified) during welding also caused pulmonary sensitization in some workers [Genium 1991]. A 50-year-old woman ingested 6 g of ammonium chloride per day as a urine acidifying agent for the treatment of renal stone disease, air hunger, and profound metabolic acidosis [NLM 1991]. Ingestion of large doses of this chemical induced nausea, gastric irritation and distress, vomiting, thirst, headache, hyperventilation, progressive drowsiness, anorexia, bradycardia, mental confusion, phases of excitement, calcium-deficient tetany, tremors, hyperreflexia, and coma. Clinical chemistry analyses revealed the following adverse alterations: profound metabolic acidosis, hypokalemia, hyperchloremia, hyperglycemia, and glycosuria. EEG abnormalities have also been reported [NLM 1991].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to ambient ammonium chloride can cause irritation of contacted tissues. Ingestion exposure can cause nausea, gastric irritation and distress, vomiting, thirst, headache, hyperventilation, progressive drowsiness, anorexia, bradycardia, mental confusion, phases of excitement, calcium-deficient tetany, tremors, hyperreflexia, and coma.

2. *Chronic exposure*: Chronic exposure to ammonium chloride fume can cause difficult breathing, wheezing, and coughing in sensitized individuals.

• **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Irritation may result! ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Irritation may result. ***Immediately and thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: Move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of ammonium chloride may result in worker exposures to ammonium chloride fume:

—Use as a flux for coating sheet iron with zinc, in tinning, and in soldering

—Use in dry and Leclanche batteries

—Use in electroplating and welding

—Use in cleaning soldering irons

The following methods are effective in controlling worker exposures to ammonium chloride fume, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

• **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to ammonium chloride fume, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the respiratory tract and skin. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific

job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to ammonium chloride fume at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with allergies or with respiratory tract or skin diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to ammonium chloride fume exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of ammonium chloride fume on the respiratory tract and skin. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for ammonium chloride fume.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne ammonium chloride fume is determined by using a tared, low-ash polyvinyl chloride filter (5-micron). Samples are collected at a maximum flow rate of 2 liters/min until a maximum air volume of 960 liters is collected. Analysis is conducted by gravimetric measurement (weighing). This method has a sampling and analytical error of 0.10 and is described in the *OSHA Industrial Hygiene Technical Manual* [OSHA 1985].

PERSONAL HYGIENE

If ammonium chloride fume contacts the skin, workers should immediately wash the affected areas with soap and water.

Clothing and shoes contaminated with ammonium chloride fume should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of ammonium chloride fume, particularly its potential for causing irritation.

A worker who handles ammonium chloride fume should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where ammonium chloride fume is generated.

RELEASES

In the event of a large release of ammonium chloride fume, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a release:

1. Notify safety personnel.
2. Remove all sources of heat and ignition.
3. Ventilate potentially explosive atmospheres.
4. Use cleanup procedures such as vacuuming and wet mopping to minimize dust generation.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Ammonium chloride is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

A hazardous substance release is defined by EPA as any spilling, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment (including the abandonment or discarding of contaminated containers). In the event of a release that is above the reportable quantity for that chemical, employers are required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the proper Federal authorities.

The reportable quantity for ammonium chloride fume is 5,000 lb. If an amount equal to or greater than this quantity is released within a 24-hr period in a manner that will expose persons outside the facility, employers are required to do the following:

—Notify the National Response Center *immediately* at (800) 424-8802 or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6].

—Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40].

—Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of ammonium chloride fume emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although ammonium chloride fume is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of ammonium chloride fume exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing (gloves, boots, aprons, and gauntlets, as appropriate) should be worn to prevent skin contact with ammonium chloride fume. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Chlorinated polyethylene is recommended for protection against ammonium chloride.

Safety glasses, goggles, or face shields should be worn during operations in which ammonium chloride fume might

contact the eyes. Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with ammonium chloride fume. Contact lenses should not be worn if the potential exists for exposure to ammonium chloride fume.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ATRAZINE

INTRODUCTION

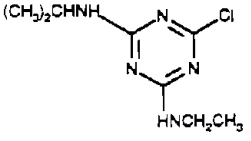
This guideline summarizes pertinent information about atrazine for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_8H_{14}ClN_5$

- **Structure**



- **Synonyms**

Aatrex; Atranex; Atratol A; Atred; 2-chloro-4-ethylamino-6-isopropylamino-s-triazine; 6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine; Crisatrina; Fenamin; Gesaprim; Griffex; Hungazin; Inakor; Primatol; Radazin; Shell Atrazine Herbicide; Strazine; Triazine A1294; Vectral; Weedex A; Zeazine

- **Identifiers**

1. CAS No.: 1912-24-9
2. RTECS No.: XY5600000
3. DOT UN: 2763 53
4. DOT label: Poison

- **Appearance and odor**

Atrazine is an odorless, nonflammable, colorless or white, crystalline solid. This chemical is a triazine herbicide that is available commercially as a wettable powder or a liquid emulsion and is often combined with other herbicides.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 215.72
2. Boiling point (760 mm Hg): Not applicable
3. Specific gravity (water = 1): 1.19 at 20°C (68°F)
4. Vapor density: Data not available
5. Melting point: 171° to 174°C (339.8° to 345.2°F)
6. Vapor pressure at 20°C (68°F): 0.0000003 mm Hg
7. Solubility: Slightly soluble in water; soluble in diethyl ether, methanol, chloroform, dimethyl sulfoxide, ethyl acetate, and n-pentane
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat. Atrazine is very stable; it has a shelf life of several years but is slightly sensitive to natural light and extreme temperatures.
2. Incompatibilities: None
3. Hazardous decomposition products: Toxic gases and vapors (such as carbon monoxide, hydrogen chloride, and oxides of nitrogen) may be released in a fire involving atrazine.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to atrazine; this substance is not flammable.

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1. Flash point: Not applicable

2. Autoignition temperature: Not applicable

3. Flammable limits in air: Not applicable

4. Extinguishant: Use an extinguishant that is suitable for the materials involved in the surrounding fire.

Fires involving atrazine should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving atrazine. Firefighters' protective clothing may not provide protection against permeation by atrazine.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for atrazine is 5 mg/m^3 of air as an 8-hr time-weighted average (TWA) [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 5 mg/m^3 as an 8-hr TWA [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned atrazine a threshold limit value (TLV) of 5 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The OSHA and NIOSH limits are based on the risk of neuropathic and metabolic effects associated with exposure to atrazine. The ACGIH limit is based on the acute effects of exposure to atrazine.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to atrazine can occur through inhalation, ingestion, or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Atrazine is an irritant of the eyes and skin in animals; at high doses, it causes nervous system effects. Eyelid edema and conjunctivitis occurred after application of atrazine to the eyes of guinea pigs, cats, and rabbits [NLM 1991]. In separate studies, it also induced severe eye irritation when applied to the eyes of rabbits [NIOSH 1991] and caused mild irritation when applied to their skin [NIOSH 1991]. The dermal LD_{50} in rabbits is 7,500 mg/kg [NIOSH 1991]. When applied to the skin of rats, atrazine caused marked erythema but no systemic toxicity [Hayes 1982]. Groups of rats that inhaled atrazine aerosol concentrations (80% wettable powder) ranging from 1,800 to 4,900 mg/m^3 for 1 hr developed no signs or symptoms of toxicity [NLM 1991]. The LC_{50} in rats is 5,200 mg/m^3 for 4 hr [NIOSH 1991]. The oral LD_{50} in mice is 1,750 mg/kg [NLM 1991]. The oral LD_{50} in rats ranges from 672 mg/kg [NIOSH 1991] to 3,080 mg/kg [NLM 1991]. Oral administration of a large amount of atrazine to rats caused them to develop muscular weakness, hypoactivity, ptosis, dyspnea, and prostration [NLM 1991]. The effects induced in rats following oral administration of the LD_{100} (3,000 mg/kg) included depression, reduced respiratory rate, motor incoordination, clonic/tonic convulsions, hypothermia, and central nervous system lesions (undefined) [NLM 1991]. Rats receiving atrazine by gavage (100, 200, or 400 mg/kg per day for 7 or 14 days) showed a dose-dependent increase in liver weight and histopathological changes in the liver [NLM 1991]. Forty percent of rats that received 20 mg/kg per day for 6 months developed bronchitis, peribronchitis, respiratory distress, pericapillary edema, and dystrophy of the brain before death [NLM 1991]. In addition, rats receiving either 10 or 50 mg/kg per day for 6 months by gavage had inhibited growth rates, leukopenia, and disturbances in vitamin metabolism [NLM 1991]. Atrazine is embryotoxic at high, maternally toxic oral doses [NLM 1991]. Some carcinogenicity bioassays with atrazine have been positive [NLM 1991]. Atrazine is mutagenic in several mammalian test systems, including human fibroblasts [NIOSH 1991; NLM 1991]. Oral administration of atrazine for up to 2 yr did not induce cancers in treated mice or rats [ACGIH 1991a; NLM 1991].

2. *Effects on Humans*: In humans, atrazine causes skin irritation [NLM 1991]. No toxicity resulted when a child ingested 800 mg or when an adult ingested 4 mg/kg [NLM 1991]. A farmer who sprayed an atrazine formulation reported a case of severe contact dermatitis; he had red, swollen hands and bloody blisters between the fingers. A patch test later showed the farmer to be sensitized to atrazine [Hayes 1982]. Atrazine may also be mutagenic in humans: lymphocytes of agricultural workers exposed to atrazine showed a statistically significant increase in the incidence of chromosomal aberrations during the spraying season [EPA 1987]. Some evidence suggests that exposure to triazine herbicides increases the risk of ovarian cancer in exposed women [NLM 1991].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to atrazine can cause severe irritation of the eyes and mild skin irritation. Mus-

cular weakness, hypoactivity, ptosis, dyspnea, prostration, depression, reduced respiratory rate, motor incoordination, clonic/tonic convulsions, and hypothermia have also been reported in atrazine-exposed animals.

2. *Chronic exposure*: Chronic exposure of animals to atrazine has produced tissue irritation and inhibited growth rates.

- **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to particulates or concentrated solutions, vapors, mists, or aerosols of atrazine. ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result! ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If particulates, vapors, mists, or aerosols of atrazine are inhaled, move the victim to fresh air *immediately*.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if atrazine or any material containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Induce vomiting by having the victim touch the back of the throat with a finger until productive vomiting ceases. Do ***not*** give syrup of ipecac because of possible onset of seizures.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of atrazine may result in worker exposures to this substance:

—Use in the manufacture, formulation, or application of herbicides

—Use as a selective herbicide for control of broadleaf and grassy weeds in corn, sorghum, sugarcane, pineapple, asparagus, tomato, and potato fields; macadamia orchards; conifer reforestation sites; Christmas tree plantations; and grass seed fields

—Use as a nonselective herbicide (at higher concentrations) for industrial and commercial noncropped sites such as railroads, storage yards, and highways

—Use as an algicide in lakes and ponds

—Use as a turf grass sod herbicide

The following methods are effective in controlling worker exposures to atrazine, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease.

The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to atrazine, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the skin and on a history of skin allergies.

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to atrazine at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with skin diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to atrazine exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of atrazine on the skin. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for atrazine.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne atrazine is determined by using a glass fiber filter. Samples are collected at a maximum flow rate of 1 liter/min until a maximum air volume of 240 liters is collected. Analysis is conducted by high-pressure liquid chromatography using an ultraviolet detector. This method is described in the OSHA Computerized Information System [OSHA 1990] and in the OSHA Laboratory In-House Methods File [OSHA 1991].

PERSONAL HYGIENE

If atrazine contacts the skin, workers should immediately wash the affected areas with soap and water.

Clothing and shoes contaminated with atrazine should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of atrazine, particularly its potential for causing skin irritation.

A worker who handles atrazine should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where atrazine or a solution containing atrazine is handled, processed, or stored.

STORAGE

Atrazine should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of atrazine should be protected from physical damage and should be stored separately from heat, sparks, and open flame. Because containers that formerly

contained atrazine may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving atrazine, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Ventilate the area of the spill or leak.
4. For small dry spills, use a clean shovel and place the material in a clean, dry container; cover and remove the container from the spill area.
5. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.
6. For large liquid spills, build dikes far ahead of the spill to contain the atrazine for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Atrazine is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of atrazine; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of the SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of atrazine emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although atrazine is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of atrazine exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For

additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Gloves and protective clothing should be worn to prevent skin contact with atrazine. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use.

No reports have been published on the resistance of various protective clothing materials to permeation by atrazine formulations. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to atrazine.

If atrazine is dissolved in an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which atrazine might contact the eyes (e.g., through dust particles or splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with atrazine. Contact lenses should not be worn if the potential exists for atrazine exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BARIUM SULFATE

INTRODUCTION

This guideline summarizes pertinent information about barium sulfate for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$BaSO_4$

- **Synonyms**

Actybaryte; artificial barite; artificial heavy spar; bakontal; baridol; barite; barosperse; barotrast; baryta white; barytes; bayrites; citobaryum; colonatrast; finemeal; liquibarine; macropaque; neobar; oratrast; permanent white; precipitated barium sulphate; raybar; redi-flow; solbar; sulfuric acid, barium salt (1:1); supramike; travad; unibaryt

- **Identifiers**

1. CAS No.: 7727-43-7
2. RTECS No.: CR0600000
3. DOT UN: None
4. DOT label: None

- **Appearance and odor**

Barium sulfate is a heavy, noncombustible, white or yellowish, odorless powder or crystalline solid. It occurs naturally as the mineral barite and can also be manufactured. Barium sulfate is available in several commercial grades, including technical, dry, pulp, bleached, ground, floated, natural, pharmaceutical, and X-ray.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 233.42
2. Boiling point (760 mm Hg): Not applicable
3. Specific gravity (water = 1): 4.25 to 4.50 at 20°C (68°F)
4. Vapor density: Not applicable.
5. Melting point: 1,580°C (2,876°F); decomposes above 1,600°C (2,912°F)
6. Vapor pressure at 20°C (68°F): Not applicable
7. Solubility: Almost insoluble in water, dilute acids, or alcohol; soluble in hot concentrated sulfuric acid
8. Evaporation rate: Not applicable

- **Reactivity**

1. Conditions contributing to instability: None
2. Incompatibilities: Explosions may result from contact of barium sulfate with aluminum in the presence of heat.
3. Hazardous decomposition products: Toxic gases and particulates (such as sulfur oxides or barium fumes) may be released in a fire involving barium sulfate.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to barium sulfate; this substance is not combustible.

1. Flash point: Not applicable
2. Autoignition temperature: Not applicable
3. Flammable limits in air: Not applicable
4. Extinguishant: Use an extinguishant that is suitable for the materials involved in the surrounding fire.

Fires involving barium sulfate should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of barium sulfate may

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explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. Do not scatter this material. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving barium sulfate. Chemical protective clothing that is specifically recommended for barium sulfate may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by barium sulfate.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for barium sulfate is 10 mg/m^3 of air (total dust) and 5 mg/m^3 (respirable fraction) as 8-hr time-weighted average (TWA) concentrations [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 10 mg/m^3 of air (total dust) and 5 mg/m^3 (respirable fraction) as 8-hr TWA concentrations [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned barium sulfate a threshold limit value (TLV) of 10 mg/m^3 (total dust) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of eye, nose, and upper respiratory tract irritation and pneumoconiosis associated with exposure to barium sulfate.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to barium sulfate can occur through inhalation and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Barium sulfate dust is a mechanical irritant. Rats exposed to a 40-mg/m^3 concentration of barium sulfate dust for 5 hr/day during a 2-month period did not show adverse effects [ACGIH 1991a]. In another study, rats inhaling barium sulfate dust (concentration not specified) developed a reversible pneumoconiosis without fibrosis [NLM 1991]. Intratracheal injection of radioactive barium sulfate caused bronchogenic carcinomas in rats [Clayton and Clayton 1981].

2. *Effects on Humans*: Inhalation of barium sulfate causes physical irritation and a benign pneumoconiosis (known as baritosis) in humans. In Italy, Germany, Czechoslovakia, and the United States, workers exposed to the fine dust of barium sulfate have developed a benign, noncollagenous form of pneumoconiosis that generally disappears when exposure ceases. Although chronic bronchial irritation occasionally persists after termination of exposure, no adverse effects on pulmonary function have been reported [Clayton and Clayton 1981; NLM 1991].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to barium sulfate can cause redness and itching of the eyes and nose and a scratchy throat. No other acute effects have been reported.

2. *Chronic exposure*: Chronic exposure to barium sulfate can cause radiographic evidence of disseminated, discrete nodular opacities in the lung fields; in most cases, these opacities disappear after cessation of exposure. Chronic bronchial irritation has been reported occasionally in baritotic workers.

• Emergency procedures

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Irritation may result! ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Wash contaminated skin with soap and water.

3. *Inhalation exposure*: Move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Seek medical attention if signs and symptoms of toxicity develop, or take the following steps if a large amount of barium sulfate is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a fluid such as water.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve barium sulfate and may result in worker exposures to this substance:

—Mining, grinding, and bagging of barite and manufacture of barium sulfate

—Use of barium sulfate in oil-drilling muds, as a filler and delustrant for textiles, and as an expander in battery plate pastes

—Manufacture of lithopane, a white pigment

—Use of barium sulfate as a source of other barium compounds

—Manufacture of photographic papers, glass, ceramics, artificial ivory, cellophane, filler for rubber, linoleum, oil cloth, polymeric fibers and resins, and lithographic inks

—Use of barium sulfate as a diagnostic aid and X-ray contrast medium

—Use of barium sulfate as a watercolor pigment for colored paper and wallpaper, as an agent for modifying the colors of other pigments, and as an ingredient in the heavy concrete used for radiation shielding

The following methods are effective in controlling worker exposures to barium sulfate, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to barium sulfate, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to barium sulfate at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to barium sulfate exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of barium sulfate on the respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for barium sulfate.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne barium sulfate is determined by using a tared, low-ash polyvinyl chloride (LAPVC) filter (5-micron) to measure both total dust and the respirable fraction (a 10-mm nylon cyclone must be used for collecting the respirable fraction). Samples are collected at a maximum flow rate of 2 liters/min (total dust) or 1.7 liters/min (respirable fraction) until a maximum air volume of 960 liters (total dust) or 816 liters (respirable fraction) is collected. Gravimetric analysis is conducted by weighing the filters. This method has a sampling and analytical error of 0.10 and is described in the *OSHA Industrial Hygiene Technical Manual* [OSHA 1985] and in the OSHA Computerized Information System (respirable fraction and total dust) [OSHA 1990]. A similar method is described in Method 500 (Nuisance dust, total) and Method 600 (Nuisance dust, respirable) of the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

If barium sulfate contacts the skin, workers should immediately wash the affected areas with soap and water.

Clothing contaminated with barium sulfate should be removed to prevent physical irritation of the skin.

A worker who handles barium sulfate should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where barium sulfate is handled, processed, or stored.

STORAGE

Barium sulfate should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of barium sulfate should be protected from physical damage and should be stored separately from aluminum, heat, sparks, and open flame. Because containers that formerly contained barium sulfate may still hold product residues, they should be handled appropriately.

SPILLS

In the event of a spill involving barium sulfate, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate the area of the spill or leak.

5. For small, dry spills, use a clean shovel and place the material into a clean, dry, covered container; remove the container from the spill area.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Barium sulfate is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.30] to notify the National Response Center of an accidental release of barium sulfate; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Facilities in SIC codes 20 to 39 who employ 10 or more workers and who manufacture more than 25,000 lb of barium compounds (including barium sulfate) per calendar year or who use more than 10,000 lb of barium compounds per calendar year are required to comply with EPA requirements in 40 CFR 372 that mandate the submission of Toxic Chemical Release Inventory Forms.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although barium sulfate is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing more information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of barium sulfate exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn if necessary to prevent skin contact with barium sulfate (gloves, boots, aprons, and gauntlets).

Safety glasses, goggles, or face shields should be worn during operations in which barium sulfate might contact the eyes (e.g., through dust particles). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with barium sulfate. Contact lenses should not be worn if the potential exists for barium sulfate exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BENOMYL

INTRODUCTION

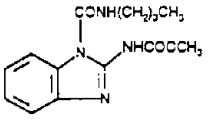
This guideline summarizes pertinent information about benomyl for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_{14}H_{18}N_4O_3$

- **Structure**



- **Synonyms**

1-(Butylcarbamoyl)-2-benzimidazolecarbamic acid; methyl ester; 1-(butylcarbamoyl)-2-benzimidazol-methylcarbamat; 1-(n-butylcarbamoyl)-2-(methyoxy-carboxamido)-benzimidazol; carbamic acid; methyl 1-(butylcarbamoyl)-2-benzimidazole ester; Benlate; Arilate; BBC; Benlate 50; Benomyl 50W; BNM; Fundasol; Fungicide 1991; MBC; Tersan 1991

- **Identifiers**

1. CAS No.: 17804-35-2

2. RTECS No.: DD6475000

3. DOT UN: 2757 55 (carbamate pesticide, solid, not otherwise specified)

4. DOT label: Poison or St. Andrew's Cross (depending on quantity shipped)

- **Appearance and odor**

Benomyl is a noncombustible, white, crystalline solid that decomposes without melting. It has a faint, acrid odor.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 290.32

2. Boiling point (760 mm Hg): Not applicable

3. Specific gravity: Data not available

4. Vapor density: Data not available

5. Melting point: Decomposes without melting above 300°C (572°F)

6. Vapor pressure at 20°C (68°F): Less than 0.1 mm Hg

7. Solubility: Very slightly soluble in water; soluble in ethanol, heptane, xylene, acetone, dimethylformamide, and chloroform

8. Evaporation rate: Not applicable

- **Reactivity**

1. Conditions contributing to instability: Heat, water, strong acids, and strong alkalies can cause benomyl to decompose.

2. Incompatibilities: None reported

3. Hazardous decomposition products: Toxic gases (such as oxides of nitrogen) may be released in a fire involving benomyl.

4. Special precautions: None reported

- **Flammability**

The National Fire Protection Association has not assigned a fire hazard rating to benomyl; this substance is not combustible.

1. Flash point: Not applicable

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

2. Autoignition temperature: Not applicable

3. Flammable limits in air: Not applicable

4. Extinguishant: Use an extinguishant that is suitable for the materials involved in the surrounding fire.

Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving benomyl.

EXPOSURE LIMITS

• OSHA PEL

The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for benomyl is 10 mg/m^3 of air (total dust) and 5 mg/m^3 (respirable fraction) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has no recommended exposure limit (REL) for benomyl [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned benomyl a threshold limit value (TLV) of 10 mg/m^3 (0.84 ppm) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The OSHA limit is based on the risk of physical irritation, erythema, and potential reproductive effects associated with exposure to benomyl; the ACGIH limit is based on the low toxicity of this substance.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to benomyl can occur through inhalation and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: Benomyl is a skin sensitizer, reproductive toxin, and teratogen in animals. When instilled into the eyes of rabbits, dry benomyl powder (50%) or 0.1 ml of a 10% benomyl solution produced only temporary, mild irritation of the conjunctiva [ACGIH 1991a]. When applied to the intact, shaved skin of guinea pigs, a benomyl concentration of 25% in a 50% wettable powder produced reddened skin in 1 of 10 animals; lower concentrations of benomyl did not cause skin irritation [ACGIH 1991a]. Benomyl caused mild to moderate skin sensitization in guinea pigs injected intradermally with benomyl and then challenged by topical application [Clayton and Clayton 1981]. The dermal LD_{50} in rabbits is greater than 10 g/kg [ACGIH 1991a]. The LC_{50} in rats is greater than 2,000 mg/m^3 for 4 hr. The oral LD_{50} in rats is 10 g/kg [NIOSH 1991]. Rats exposed to 100 mg/m^3 for 4 hr/day, 5 days/week for 3 weeks developed neither clinical or histopathological effects [NLM 1991]. Rats exposed to technical-grade benomyl at 10, 50, or 200 mg/m^3 for 6 hr/day, 5 days/week for 14 weeks had suppressed food consumptions and body weight gains at the highest level. Only the 50- and 200-mg/m^3 exposures induced any effect (a degeneration of the olfactory epithelium) after 45 days. Oral administration of benomyl (2,500 mg/kg in the diet) to rats for 90 days did not cause toxicity, but rats and dogs fed benomyl for 2 years exhibited a low order of toxicity (undefined) [NLM 1991].

A number of studies [Barnes et al. 1983; Carter et al. 1984; Ellis et al. 1987] have demonstrated benomyl's reproductive and teratogenic effects. Adult rats fed benomyl for 70 days showed significant depressions in sperm count and testicular weight and had lowered fertility indexes [Barnes et al. 1983]. Similar effects were elicited in rats given benomyl during or after puberty [Carter et al. 1984]. Rats intubated with benomyl doses ranging from 125 to 500 mg/kg per day during the first 20 days of pregnancy produced offspring with dose-related increases in the rates of skull and central nervous system anomalies [NLM 1991]. In addition, pregnant mice administered 1,100 mg/kg benomyl on days 7 to 17 of pregnancy had offspring with similar abnormalities [NIOSH 1991]. In another study, the offspring of rats given 31.2, 62.5, or 125 mg/kg by gavage on days 7 to 21 of gestation showed a dose-dependent increase in the incidence of craniocerebral and systemic malformations; an increase in fetal resorptions and late fetal deaths also occurred in the offspring of animals in the high-dose group [Ellis et al. 1987]. Although benomyl is mutagenic in bacterial test systems [NIOSH 1991], it did not induce cancer in either rats or dogs fed the compounds for two years [NLM 1991].

2. *Effects on Humans*: Benomyl is an irritant and skin sensitizer in humans. A recent U.S. study showed that two migrant workers in a group of farm workers with dermatitis had positive responses to 0.1% benomyl solutions in patch tests, indicating that they had become sensitized to this substance [Schuman and Dobson 1985]. A field study in Japanese farmers showed that 20% of women farmers had positive patch tests to benomyl as well as cross-sensitivities to other pesticides [Matsushita and Aoyama 1981]. Irritation, erythema, salivation, sweating, lassitude, reproductive effects, muscular incoordination, nausea, vomiting, abdominal cramps, angina pectoris, central nervous system depression, and cholinesterase inhibition have been reported [NLM 1991]. Benomyl is mutagenic in human in vitro test systems [NIOSH 1991].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to benomyl dust can cause irritation, erythema, salivation, sweating, lassitude, reproductive effects, muscular incoordination, nausea, vomiting, abdominal cramps, angina pectoris, central nervous system depression, and cholinesterase inhibition.

2. *Chronic exposure*: Chronic exposure to benomyl may cause skin sensitization with irritation, redness, and cholinesterase inhibition.

- **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to particulates or concentrated solutions, vapors, mists, or aerosols of benomyl. ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If particulates or vapors, mists, or aerosols of benomyl are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if benomyl or any material containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve benomyl and may result in worker exposures to this substance:

—Manufacture and formulation of pesticides containing benomyl

—Use of benomyl as a systemic fungicide and ascaricide

—Use of benomyl in veterinary medicine as an anthelmintic

—Use of benomyl as an oxidizer in sewage treatment

The following methods are effective in controlling worker exposures to benomyl, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers

for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to benomyl, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the skin.

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to benomyl at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history of skin allergies or other diseases of the skin. On the basis of effects seen in animals, men and women who plan to have children should be advised that they may be at increased risk of having a child with birth defects, and men should be advised that they may be at increased risk of experiencing adverse reproductive effects.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to benomyl exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of benomyl on the skin and the male reproductive system. Men and women who plan to have children should again be advised that they may be at increased risk of having a child with birth defects. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for benomyl.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne benomyl is determined by using an OSHA Versatile Sampler (OVS-2) with a 13-mm XAD-2 tube (270/140-mg sections, 20/50 mesh). Samples are collected at a maximum flow rate of 1 liter/min until a maximum air volume of 480 liters is collected. Analysis is conducted by high-performance liquid chromatography. This method is described in the OSHA Computerized Information System [OSHA 1989].

PERSONAL HYGIENE

If benomyl contacts the skin, workers should wash the affected areas with soap and water.

Clothing and shoes contaminated with benomyl should be removed, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of benomyl.

A worker who handles benomyl should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where benomyl or a solution containing benomyl is handled, processed, or stored.

STORAGE

Benomyl should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of benomyl should be protected

from physical damage and should be stored separately from strong acids, strong alkalies, heat, sparks, and open flame. Because containers that formerly contained benomyl may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving benomyl, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Ventilate the area of the spill or leak.
4. For dry spills, use a vacuum or a wet method to reduce dust dispersion and place the material into a clean, dry container; cover and remove the container from the spill area.
5. Absorb liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Benomyl is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of benomyl; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of benomyl emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although benomyl is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of benomyl exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For

additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective gloves and clothing should be worn to prevent skin contact with benomyl. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to benomyl permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to benomyl.

If benomyl is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which benomyl might contact the eyes (e.g., through dust particles or splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with benomyl. Contact lenses should not be worn if the potential exists for benomyl exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BISMUTH TELLURIDE DOPED WITH SELENIUM SULFIDE

INTRODUCTION

This guideline summarizes pertinent information about doped bismuth telluride for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

Bi_2Te_3 doped with Bi_2Se_3, SnTe, and Te

- **Synonyms**

Doped bismuth sesquitelluride, doped bismuth tritelluride, doped dibismuth tritelluride, doped tellurobismuthite

- **Identifiers**

1. CAS No.: 1304-82-1
2. RTECS No.: EB3110000
3. DOT UN: None
4. DOT label: None

- **Appearance and odor**

Bismuth telluride doped with selenium is a nonflammable, gray, crystalline solid that has been enhanced (or doped) with a small amount of a selenium compound; doping confers on the semiconductor the charge characteristics of the doping agent, which alters the conductivity of the semiconductor.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 800.76
2. Boiling point: Data not available
3. Specific gravity (water = 1): 7.7 at 20°C (68°F)
4. Vapor density: Not applicable
5. Melting point: 573°C (1,063.4°F)
6. Vapor pressure: Not applicable
7. Solubility: Insoluble in water; decomposes in nitric acid
8. Evaporation rate: Not applicable

- **Reactivity**

1. Conditions contributing to instability: None reported
2. Incompatibilities: A violent reaction may result from contact of doped bismuth telluride with strong oxidizers (such as bromine, fluorine, or chlorine), and a toxic gas may evolve from contact with moisture.
3. Hazardous decomposition products: Toxic materials (such as tellurium) may be released in a fire involving doped bismuth telluride.
4. Special precautions: None reported

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to doped bismuth telluride; this substance is not flammable.

1. Flash point: Not applicable
2. Autoignition temperature: Not applicable
3. Flammable limits in air: Not applicable
4. Extinguishant: Use an extinguishant suitable for the materials involved in the surrounding fire.

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Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving doped bismuth telluride.

EXPOSURE LIMITS

• **OSHA PEL**

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for bismuth telluride doped with selenium sulfide is 5 mg/m^3 of air as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• **NIOSH REL**

The National Institute for Occupational Safety and Health (NIOSH) has established an 8-hr TWA of 5 mg/m^3 as the recommended exposure limit (REL) for bismuth telluride doped with selenium sulfide [NIOSH 1992].

• **ACGIH TLV®**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned bismuth telluride doped with selenium sulfide a threshold limit value (TLV) of 5 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• **Rationale for limits**

The limits are based on the risk of respiratory effects associated with exposure to doped bismuth telluride.

HEALTH HAZARD INFORMATION

• **Routes of exposure**

Exposure to doped bismuth telluride can occur through inhalation, eye or skin contact, and ingestion.

• **Summary of toxicology**

1. *Effects on Animals*: Selenium-doped bismuth telluride causes reversible, nonfibrotic lesions in the lungs of exposed experimental animals [Clayton and Clayton 1981]. Dogs, rabbits, and rats were exposed to 15 mg/m^3 of a dust (average particle size 1.04 microns) containing a mixture of doped bismuth telluride and stannous telluride for 6 hr/day, 5 days/week for 1 year. The dogs and rabbits developed small granulomatous lesions in the lungs, and the rats developed epithelialization of the alveolar walls [ACGIH 1991a; Clayton and Clayton 1981]. Fibrotic changes did not occur in any species; in dogs examined 4 months after the cessation of exposure, these lesions had regressed, indicating reversibility [ACGIH 1991a; Clayton and Clayton 1981].

2. *Effects on Humans*: No adverse effects of exposure to doped bismuth telluride have been noted in humans except for the development of "tellurium breath" (breath that smells like garlic) [Clayton and Clayton 1981]. Based on effects seen in animals, overexposure to the dust of doped bismuth telluride is likely to cause reversible pulmonary changes in humans [Proctor et al. 1988].

• **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to doped bismuth telluride can cause garlic breath and local irritation of the eyes and skin.

2. *Chronic exposure*: No signs or symptoms of chronic exposure to doped bismuth telluride have been reported in humans.

• **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Irritation may result! ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Irritation may result. ***Immediately and thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: Move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: If a large amount of doped bismuth telluride is ingested take the following steps:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do *not* force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

Use of doped bismuth telluride as a semiconductor may result in worker exposures to this substance.

The following methods are effective in controlling worker exposures to doped bismuth telluride, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to doped bismuth telluride, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to doped bismuth telluride at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employ-

ment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to doped bismuth telluride exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of doped bismuth telluride on the respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for doped bismuth telluride.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and the selected physiologic or laboratory tests conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne selenium-doped bismuth telluride (measured as bismuth) is determined by using a mixed cellulose ester filter (0.8 micron). Samples are collected at a maximum flow rate of 2 liters/min until a maximum air volume of 960 liters is collected. Analysis is conducted by atomic absorption spectroscopy. This method is described in the OSHA Laboratory In-House Methods File [OSHA 1989] and in the OSHA Computerized Information System [OSHA 1990].

PERSONAL HYGIENE

If the dust of doped bismuth telluride collects on the skin, workers should wash the affected areas with soap and water.

Clothing contaminated with doped bismuth telluride should be removed.

A worker who handles doped bismuth telluride should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where doped bismuth telluride is handled, processed, or stored.

STORAGE

Doped bismuth telluride should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of doped bismuth telluride should be protected from physical damage and should be stored separately from strong oxidizers, heat, sparks, and open flame. Because containers that formerly contained doped bismuth telluride may still hold product residues, they should be handled appropriately.

SPILLS

In the event of a spill involving doped bismuth telluride, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate the area of the spill or leak.
5. Use a clean shovel and place the material into a clean, dry container; cover and remove the container from the spill area.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Doped bismuth telluride is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of doped bismuth telluride; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of doped bismuth telluride emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although doped bismuth telluride is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of doped bismuth telluride exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective gloves and clothing should be worn to prevent skin contact with doped bismuth telluride. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to doped bismuth telluride permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to doped bismuth telluride.

If doped bismuth telluride is dissolved in an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which doped bismuth telluride might contact the eyes (e.g., through dust particles). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with doped bismuth telluride.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BISMUTH TELLURIDE, UNDOPED

INTRODUCTION

This guideline summarizes pertinent information about undoped bismuth telluride for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

Bi_2Te_3

- **Synonyms**

Bismuth sesquitelluride, bismuth tritelluride, dibismuth tritelluride, tellurobismuthite

- **Identifiers**

1. CAS No.: 1304-82-1
2. RTECS No.: EB3110000
3. DOT UN: None
4. DOT label: None

- **Appearance and odor**

Undoped bismuth telluride is a gray, crystalline solid that is not flammable.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 800.76
2. Boiling point (760 mm Hg): Data not available
3. Specific gravity (water = 1): 7.7 at 20°C (68°F)
4. Vapor density: Not applicable
5. Melting point: 573°C (1,063.4°F)
6. Vapor pressure at 20°C (68°F): Not applicable
7. Solubility: Insoluble in water; decomposes in nitric acid
8. Evaporation rate: Not applicable

- **Reactivity**

1. Conditions contributing to instability: None reported
2. Incompatibilities: A violent reaction may result from contact of undoped bismuth telluride with strong oxidizers (such as bromine, fluorine, or chlorine), and a toxic gas may evolve from contact with moisture.
3. Hazardous decomposition products: Toxic materials (such as tellurium) may be released in a fire involving undoped bismuth telluride.
4. Special precautions: None reported

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to undoped bismuth telluride; this substance is not flammable.

1. Flash point: Not applicable
2. Autoignition temperature: Not applicable
3. Flammable limits in air: Not applicable
4. Extinguishant: Use an extinguishant that is suitable for the materials involved in the surrounding fire.

Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving undoped bismuth telluride.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

EXPOSURE LIMITS

• **OSHA PEL**

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for undoped bismuth telluride is 15 mg/m^3 of air (total dust) and 5 mg/m^3 (respirable fraction) as an 8-hr time-weighted average (TWA) [29 CFR 1910.1000, Table Z-1-A].

• **NIOSH REL**

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for undoped bismuth telluride of 10 mg/m^3 (total dust) and 5 mg/m^3 (respirable fraction) as an 8-hr TWA [NIOSH 1992].

• **ACGIH TLV®**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned undoped bismuth telluride a threshold limit value (TLV) of 10 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• **Rationale for limits**

The limits are based on the risk of physical irritation associated with exposure to undoped bismuth telluride.

HEALTH HAZARD INFORMATION

• **Routes of exposure**

Exposure to undoped bismuth telluride can occur through inhalation, eye or skin contact, and ingestion.

• **Summary of toxicology**

1. *Effects on Animals*: Dogs, rabbits, and rats exposed to undoped bismuth telluride dust (average particle size 0.4 micron) at 15 mg/m^3 for 6 hr/day, 5 days/week for 11 months showed no adverse responses other than accumulation of this substance in the lungs [Cralley and Cralley 1985].

2. *Effects on Humans*: In humans, exposure to the dust of undoped bismuth telluride causes physical irritation of the eyes, nose, and throat [NJDH 1985]. Long-term exposure causes accumulation of dust in the lungs; this dust is radiographically visible [NJDH 1985].

• **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to undoped bismuth telluride can cause local irritation of the eyes and skin.

2. *Chronic exposure*: No signs or symptoms of chronic exposure to undoped bismuth telluride have been reported.

• **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Irritation may result! ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Irritation may result. ***Immediately and thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: Move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if undoped bismuth telluride is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of undoped bismuth telluride may result in worker exposures:

—Use for thermoelectric cooling

—Use as a semiconductor

The following methods are effective in controlling worker exposures to undoped bismuth telluride, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to undoped bismuth telluride, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to undoped bismuth telluride at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to undoped bismuth telluride exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of undoped bismuth telluride on the respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for undoped bismuth telluride.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne undoped bismuth telluride (measured as bismuth) is determined by using a mixed cellulose ester filter (0.8 micron). Samples are collected at a maximum flow rate of 2 liters/min until a maximum air volume of 960 liters is collected. Analysis is conducted by atomic absorption spectroscopy. This method is described in the OSHA Laboratory In-House Methods File [OSHA 1989] and in the OSHA Computerized Information System [OSHA 1990].

PERSONAL HYGIENE

If the dust of undoped bismuth telluride collects on the skin in excessive amounts, workers should wash the affected areas with soap and water.

Clothing contaminated with the dust of undoped bismuth telluride should be removed.

A worker who handles undoped bismuth telluride should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where undoped bismuth telluride is handled, processed, or stored.

STORAGE

Undoped bismuth telluride should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [40 CFR 1910.1200]. Containers of undoped bismuth telluride should be protected from physical damage and should be stored separately from strong oxidizers, heat, sparks, and open flame. Because containers that formerly contained undoped bismuth telluride may still hold product residues, they should be handled appropriately.

SPILLS

In the event of a spill involving undoped bismuth telluride, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate the area of the spill.
5. Use a clean shovel and place the material into a clean, dry container, cover and remove the container from the spill area for reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Undoped bismuth telluride is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of undoped bismuth telluride; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of undoped bismuth telluride emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although undoped bismuth telluride is not specifically listed as

a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of undoped bismuth telluride exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective gloves and clothing should be worn to prevent skin contact with undoped bismuth telluride. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to undoped bismuth telluride permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to undoped bismuth telluride.

If undoped bismuth telluride is dissolved in an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which undoped bismuth telluride might contact the eyes (e.g., through dust particles). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with undoped bismuth telluride.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BORON TRIBROMIDE

INTRODUCTION

This guideline summarizes pertinent information about boron tribromide for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

BBr_3

- **Synonyms**

Boron bromide; tribromoborane, trona

- **Identifiers**

1. CAS No.: 10294-33-4
2. RTECS No.: ED7400000
3. DOT UN: 2692 59
4. DOT label: Corrosive

- **Appearance and odor**

Boron tribromide is a colorless, fuming, nonflammable, volatile liquid with a sharp, irritating odor. No quantitative data are available on the odor threshold for boron tribromide.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 250.6
2. Boiling point (760 mm Hg): 90°C (194°F)
3. Specific gravity (water = 1): 2.7 at 0°C (32°F)
4. Vapor density (air = 1 at boiling point of boron tribromide): 8.6
5. Melting point: −46°C (−51°F)
6. Vapor pressure at 33.5°C (92.3°F), 100 mm Hg; at 14°C (57.1°F), 40 mm Hg
7. Solubility: Decomposes in water or alcohol; soluble in carbon tetrachloride and sulfur dioxide
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat and moisture
2. Incompatibilities: Fire and explosions may result from contact of boron tribromide with water, steam, potassium, sodium, or alcohol.
3. Hazardous decomposition products: Toxic gases and particulates (such as hydrogen bromide, oxides of boron, and oxides of bromine) may be released in a fire involving boron tribromide.
4. Special precautions: Boron tribromide attacks metals, wood, rubber, and Bakelite® but does not attack Teflon® or stainless steel.

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to boron tribromide; this substance is not combustible.

1. Flash point: Not applicable
2. Autoignition temperature: Not applicable
3. Flammable limits in air: Not applicable
4. Extinguishant: Use an extinguishant that is suitable for the materials involved in the surrounding fire.

Fires involving boron tribromide should be fought upwind and from the maximum distance possible. Isolate the hazard

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Containers of boron tribromide may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving boron tribromide. Firefighters' protective clothing may not provide protection against permeation by boron tribromide.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for boron tribromide is 1 ppm (10 mg/m^3) as a ceiling limit. A worker's exposure to boron tribromide shall at no time exceed this limit [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 1 ppm (10 mg/m^3) as a ceiling limit [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned boron tribromide a threshold limit value (TLV) of 1 ppm (10 mg/m^3) as a ceiling limit that should not be exceeded during any part of the working exposure [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of irritation associated with exposure to boron tribromide.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to boron tribromide can occur through inhalation, ingestion, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: No acute toxicity data specific to boron tribromide is available. However, the toxicity and action of boron tribromide is similar to that of boron trichloride, which causes marked swelling and burns in contact with the eyes, skin, or mucous membranes; hemorrhages of the lungs, kidneys, and intestines in some animals acutely exposed to lethal concentrations; and death in all mice and rats exposed to 20 ppm for 7 hr [Clayton and Clayton 1981]. The LC_{50} for a 1-hr exposure to hydrogen bromide, a hydrolysis product of boron tribromide, is 814 ppm in the mouse and 2,858 ppm in the rat [Sax and Lewis 1989].

2. *Effects on Humans*: Boron tribromide is an irritant that is strongly corrosive because of its rapid hydrolysis to boric acid and hydrogen bromide [ACGIH 1991a; Clayton and Clayton 1981]. Acute exposure to boron tribromide causes marked irritation of the eyes, nose, throat, and skin, and contact of the eyes or skin with boron tribromide leads to burns [NJDH 1985]. Pulmonary edema, which is potentially life threatening, may result from acute respiratory exposure to boron tribromide [NJDH 1985]. A chemist who splashed boron tribromide into his eyes experienced no pain at the time but subsequently developed permanent corneal injury, including corneal opacification, in the most severely exposed eye; the other eye gradually returned to normal [Grant 1986].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to boron tribromide can cause redness, swelling, and tearing of the eyes; runny nose; coughing; and shortness of breath. Contact of this substance with the skin or eyes may lead to burns of the affected tissues.

2. *Chronic exposure*: No signs or symptoms of chronic exposure to boron tribromide have been reported.

• Emergency procedures

WARNING!

Exposed victims may die!
Transport immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Tissue destruction and blindness may result from exposure to concentrated solutions, vapors, mists, or aerosols of boron tribromide! ***Immediately but gently*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Severe burns and skin corrosion may result! ***Immediately*** remove all contaminated clothing! ***Immediately and gently*** wash skin for at least 15 min. Use soap and water if skin is intact; use only water if skin is not intact.

3. *Inhalation exposure*: If vapors, mists, or aerosols of boron tribromide are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if boron tribromide or a solution containing it is ingested:

—Do ***not*** induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water. Immediately after rinsing, have the victim drink one cup (8 oz) of fluid and ***no more***.

—Do ***not*** permit the victim to drink milk or carbonated beverages!

—Do ***not*** permit the victim to drink any fluid if more than 60 min have passed since initial ingestion.

NOTE: These instructions must be followed exactly. Drinking a carbonated beverage or more than one cup of fluid could create enough pressure to perforate already damaged stomach tissue. The tissue-coating action of milk can sometimes impede medical assessment of tissue damage. Ingestion of any fluid more than 60 min after initial exposure could further weaken damaged tissue and result in perforation.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve boron tribromide and may result in worker exposures to this substance:

—Use of boron tribromide as a catalyst in organic synthesis

—Production of diborane and ultra-high-purity boron

—Manufacture of semiconductors

The following methods are effective in controlling worker exposures to boron tribromide, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to boron tribromide, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be

aggravated or may result in increased risk when a worker is exposed to boron tribromide at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to boron tribromide exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of boron tribromide on the respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for boron tribromide.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne boron tribromide is determined by using a midget fritted-glass bubbler containing 10 ml of 0.003M $NaHCO_3$/0.0024 M Na_2CO_3. Samples are collected at a recommended flow rate of 1.0 liter/min until a recommended air volume of 5 liters is collected. Analysis is conducted by ion chromatography. The limit of detection for this procedure is 0.01 mg/m^3. This method is included in the OSHA Laboratory In-House Methods File [OSHA 1991].

PERSONAL HYGIENE

If boron tribromide contacts the skin, workers should immediately flood the affected areas with water and then wash with soap and water.

Clothing and shoes contaminated with boron tribromide should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of boron tribromide, particularly its potential to cause skin burns.

A worker who handles boron tribromide should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where boron tribromide or a solution containing boron tribromide is handled, processed, or stored.

STORAGE

Boron tribromide should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of boron tribromide should be protected from physical damage and should be stored away from water, steam, potassium, sodium, alcohol, heat, sparks, and open flame. Because containers that formerly contained boron tribromide may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving boron tribromide, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate the area of the spill or leak.
5. Use water spray to reduce vapors; do not put water directly on the leak or spill area.
6. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.
7. For large liquid spills, build dikes far ahead of the spill to contain the boron tribromide for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Boron tribromide is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of boron tribromide; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of boron tribromide emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although boron tribromide is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limits. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of boron tribromide exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with boron tribromide. Full-body protection and gloves are recommended to prevent skin contact with this substance. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Chlorinated polyethylene has demonstrated fair to good protection against permeation by boron tribromide.

If boron tribromide is dissolved in an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which boron tribromide might contact the eyes (e.g., through splashes of solution). Eyewash

fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with boron tribromide. Contact lenses should not be worn if the potential exists for boron tribromide exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BROMACIL

INTRODUCTION

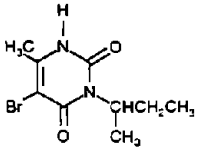
This guideline summarizes pertinent information about bromacil for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_9H_{13}BrN_2O_2$

- **Structure**



- **Synonyms**

Borea; bromazil; 5-bromo-6-methyl-3-(1-methyl propyl)-2,4(1H,3H)-pyrimidinedione; 5-bromo-6-methyl-3-(1-methylpropyl)-uracil; 5-bromo-3-sec-butyl-6-methyl-uracil; Cynogan; Eerex Granular Weed Killer; Eerex Water Soluble Concentrate Weed Killer; Herbicide 976; Hyvar; Hyvarex; isocil; Krovar II; Nalkil; Uragan; Uragon; Urox B.

- **Identifiers**

1. CAS No.: 314-40-9
2. RTECS No.: YQ9100000
3. DOT UN: None
4. DOT label: None

- **Appearance and odor**

Bromacil is an nonflammable, odorless, colorless-to-white, crystalline substance. It is commercially available as a wettable powder, liquid formulation, and mixture with various other agricultural chemicals. Bromacil-containing mixtures and liquid formulations may be combustible.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 261.11
2. Boiling point (760 mm Hg): Not applicable
3. Specific gravity (water = 1): 1.55 at 25°C (77°F)
4. Vapor density: Data not available
5. Melting point: 157.5° to 160°C (313.7° to 320°F): slowly sublimes
6. Vapor pressure at 100°C (212°F): 0.0008 mm Hg
7. Solubility: Slightly soluble in water; moderately soluble in xylene, strong aqueous bases, acetone, acetonitrile, and ethanol; sparingly soluble in hydrocarbons.
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame.
2. Incompatibilities: Decomposes slowly upon contact with strong acids.
3. Hazardous decomposition products: Toxic gases (such as bromine and oxides of nitrogen) may be released in a fire involving bromacil.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to bromacil. It may burn in its solid form,

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but it does not ignite easily. Liquid formulations or mixtures containing bromacil may be combustible.

1. Flash point: Data not available

2. Autoignition temperature: Data not available

3. Flammable limits in air: Data not available

4. Extinguishant: Use an extinguishant that is suitable for the materials involved in the surrounding fire.

Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving bromacil.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for bromacil is 1 ppm (10 mg/m^3) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 1 ppm (10 mg/m^3) as an 8-hr TWA [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned bromacil a threshold limit value (TLV) of 1 ppm (10 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of thyroid-damaging and irritant effects associated with exposure to bromacil.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to bromacil can occur through inhalation or ingestion.

• Summary of toxicology

1. *Effects on animals*: Bromacil is an irritant of the eyes and upper respiratory tract in experimental animals; this substance has also been shown to have endocrine and reproductive effects in rodents. When instilled into the eyes of rabbits, this substance caused reversible conjunctival irritation but no corneal damage [Grant 1986]. When applied to the skin of guinea pigs, bromacil caused mild to moderate irritation but was not a skin sensitizer [Clayton and Clayton 1981]. The dermal LD_{50} in rabbits is greater than 5 g/kg [NIOSH 1991]. The oral LD_{50} in rats is 641 mg/kg and does not induce signs or symptoms. Acute administration of 1,100 mg/kg to dogs induced salivation, vomiting, muscular weakness, excitability, diarrhea, and mydriasis. Chickens and cattle developed weight loss and abnormal gait following an oral dose of 250 mg/kg. Toxic symptoms in poisoned animals include anorexia, depression, tympanites, and increased respiratory rates. One dog survived a 5 g/kg dose [NLM 1992]. Male rats were given bromacil 5 days/week for 2 weeks at oral doses of 650, 1,035, or 1,500 mg/kg; 5 of 6 rats died after 5 doses at the highest level, 1 died after 10 doses at 1,035 mg/kg, and no animal died at the lowest dose. At autopsy, focal cell hypertrophy and hyperplasia of the liver were seen [NRC 1977]. Rats were fed bromacil at 50, 500, 2,500, 5,000, 6,000, or 7,000 ppm for 90 days; those in the 5,000-ppm or higher groups developed hyperthyroidism [NRC 1977]. In another study, rats were fed bromacil at 50, 250, or 1,250 ppm for 2 years; those in the 1,250-ppm group developed hyperplasia of the thyroid, and one female rat also developed a follicular adenoma [NRC 1977]. When pregnant rats were exposed by inhalation to 38 mg/m^3 (3.8 ppm) for 2 hr/day on gestation days 7 through 14, they developed reproductive, embryotoxic, and developmental effects [NIOSH 1991]. Conversely, rabbits that ingested diets containing 50 to 250 ppm bromacil during days 8 through 16 of pregnancy delivered normal pups. A three-generation rat study also demonstrated a lack of induced developmental toxicity [NLM 1992]. Contradictory mutagenicity results have been published for bromacil [NLM 1992]. A 2-yr chronic dietary study in rats did not result in cancer induction but did demonstrate that bromacil caused thyroid hyperplasia [NRC 1977]. All rats exposed to 4,800 mg/m^3 (480 ppm) bromacil for 4 hr survived [ACGIH 1991a].

2. *Effects on humans*: Bromacil is known to cause eye, nose, and throat irritation in workers handling formulations containing this substance. Skin irritation has also been reported [NLM 1992; NJDH 1985]. There are no reports of bromacil-induced systemic toxicity.

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to bromacil dust can cause redness and itching of the eyes, runny nose, scratchy throat, and redness, dryness, and cracking of the skin.

2. *Chronic exposure*: No signs or symptoms of chronic bromacil exposure have been reported.

• Emergency procedures

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to particulates or to concentrated solutions, vapors, mists, or aerosols of bromacil. ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If particulates or vapors, mists, or aerosols of bromacil are inhaled move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if bromacil or any material containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations involve bromacil and may result in worker exposures to this substance:

—Manufacture or formulation of bromacil

—Use of bromacil as a herbicide to control annual and perennial grasses and broadleaf weeds

—Use of bromacil on noncrop lands as a nonselective herbicide and on a few crops (pineapple and citrus) as a selective herbicide

The following methods are effective in controlling worker exposures to bromacil, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to bromacil, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and

laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the skin and respiratory tract. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to bromacil at or below the prescribed exposure limit. The examining physician should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with skin or upper respiratory tract diseases.

- **Periodic medical examinations and biological monitoring.**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to bromacil exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of bromacil on the skin and respiratory tract. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for bromacil.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne bromacil is determined by using a midget impinger containing 15 ml of ethylene glycol. Samples are collected at a maximum flow rate of 1 liter/min until a maximum air volume of 50 liters is collected. Analysis is conducted by high-pressure liquid chromatography using an ultraviolet detector. This method is described in the OSHA Computerized Information System [OSHA 1990] and in the OSHA Laboratory In-House Methods File [OSHA 1989].

PERSONAL HYGIENE

If bromacil contacts the skin, workers should wash the affected areas with soap and water.

Clothing and shoes contaminated with bromacil should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of bromacil, particularly its potential to cause irritation.

A worker who handles bromacil should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where bromacil is handled, processed, or stored.

STORAGE

Bromacil should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of bromacil should be protected from physical damage and should be stored separately from strong acids and heat. Because containers that formerly contained bromacil may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving bromacil, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate the area of the spill or leak.

5. For dry spills, use a clean shovel and place the material into a clean, dry container; cover and remove the container from the spill area.

6. Absorb any spilled liquid containing bromacil with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Bromacil is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of bromacil; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of bromacil emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although bromacil is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of bromacil exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent skin contact with bromacil. One source suggests wearing protective gloves and clothing when handling this substance. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use.

No reports have been published on the resistance of various protective clothing materials to permeation by formulations containing bromacil. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protec-

tive clothing for workers to wear when they are exposed to bromacil.

If bromacil is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which bromacil might contact the eyes (e.g., through dust particles or splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with bromacil. Contact lenses should not be worn if the potential exists for bromacil exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BROMINE PENTAFLUORIDE

INTRODUCTION

This guideline summarizes pertinent information about bromine pentafluoride for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

BrF_5

- **Synonyms**

Bromine fluoride

- **Identifiers**

1. CAS No.: 7789-30-2
2. RTECS No.: EF9350000
3. DOT UN: 1745 44
4. DOT label: Oxidizer

- **Appearance and odor**

Bromine pentafluoride is a reactive, colorless or pale yellow, fuming liquid at temperatures below 40.3°C (104.5°F); it has a pungent odor and is not flammable. The odor threshold is unknown. At temperatures above 40.3°C (104.5°F), it is a colorless, pungent, and corrosive gas. It is shipped in compressed gas cylinders under its own vapor pressure.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 174.92
2. Boiling point (760 mm Hg): 40.5°C (104.9°F)
3. Specific gravity (water = 1): 2.48 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of bromine pentafluoride): 6.05
5. Melting point: -60.5°C (-76.9°F)
6. Vapor pressure at 20°C (68°F): 328 mm Hg
7. Solubility: Reacts violently with water
8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Bromine pentafluoride is stable under normal handling and storage procedures.

2. Incompatibilities: Bromine pentafluoride is a highly reactive compound; it reacts with every known element except the inert gases, nitrogen, and oxygen. Bromine pentafluoride is incompatible with acids, halogens, arsenic, selenium, alkaline halides, sulfur, iodine, glass, metallic halides, metal oxides, and metals (except copper, stainless steel, nickel, and Monel®). Fire or explosion may result from contact of bromine pentafluoride with combustibles or organic matter at room temperature, and contact of this substance with water produces an explosion.

3. Hazardous decomposition products: Toxic gases (such as hydrogen fluoride and hydrogen bromide) may be released in a fire involving bromine pentafluoride.

4. Special precautions: Even under mild reaction conditions, bromine pentafluoride attacks organic compounds vigorously, often causing an explosion.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 0 (no fire hazard) to bromine pentafluoride.

1. Flash point: Not applicable
2. Autoignition temperature: Not applicable

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3. Flammable limits in air: Not applicable

4. Extinguishant: Avoid contact of this material with water. However, water may be used if large amounts of combustible material are involved in the fire and if firefighters can protect themselves by barriers or distance from the violent reaction of bromine pentafluoride and water. Fires involving bromine pentafluoride and small amounts of combustibles may be smothered using a carbon dioxide or dry chemical extinguishant.

Fires involving bromine pentafluoride should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of bromine pentafluoride may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out; do **not** get water inside the containers. Stay away from the ends of containers. Runoff to sewers may create a fire or explosion hazard. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving bromine pentafluoride. Chemical protective clothing that is specifically recommended for bromine pentafluoride may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by bromine pentafluoride.

EXPOSURE LIMITS

- **OSHA PEL**

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for bromine pentafluoride is 0.1 ppm (0.7 mg/m^3) as an 8-hr time-weighted average (TWA) [29 CFR 1910.1000, Table Z-1-A].

- **NIOSH REL**

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 0.1 ppm (0.7 mg/m^3) as an 8-hr TWA [NIOSH 1992].

- **ACGIH TLV®**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned bromine pentafluoride a threshold limit value (TLV) of 0.1 ppm (0.7 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

- **Rationale for limits**

The limits are based on the risk of irritation, corneal necrosis, and systemic effects associated with exposure to bromine pentafluoride.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Exposure to bromine pentafluoride can occur through inhalation, ingestion, and eye or skin contact.

- **Summary of toxicology**

1. *Effects on Animals*: Acute exposure to bromine pentafluoride is corrosive to the eyes, skin, mucous membranes, and upper respiratory tract, chronic exposure is toxic to the liver and kidneys. Experimental animals (species not identified) exposed to a 500-ppm concentration of bromine pentafluoride vapor immediately exhibited the following signs of acute distress: swollen eyelids, tearing, gasping, corneal cloudiness, and excessive salivation; reducing the concentration to 100 ppm produced these signs after an exposure of 3 min [ACGIH 1991a]. Exposure to 50 ppm caused death in these animals after 30 min [ACGIH 1991a]. At autopsy, animals chronically exposed to bromine pentafluoride at concentrations above 3 ppm showed toxic hepatosis and severe nephrosis, as well as severe respiratory involvement [ACGIH 1991a].

2. *Effects on Humans*: Bromine pentafluoride is a severe pulmonary irritant and is also intensely corrosive to the skin, eyes, and mucous membranes of humans in either the liquid or vapor state [Genium 1986]. Exposure to high (not further specified) concentrations are usually fatal; death is caused by respiratory damage and pulmonary edema [Braker and Mossman 1980]. Exposure to a concentration of 5 to 10 ppm is irritating to the eyes, nose, and throat; based on effects seen in animals, chronic exposure may cause liver, kidney, and lung damage [Braker and Mossman 1980; Genium 1986].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to bromine pentafluoride can cause redness and tearing of the eyes, coughing, breathing difficulty, and a burning sensation of the eyes, nose, and throat. Direct contact of this substance with the eyes or skin can cause severe thermal and chemical burns and tissue destruction.

2. *Chronic exposure*: On the basis of effects seen in animals, long-term exposure to low levels of this substance may cause pain in the abdomen; enlargement of the liver;

blood, pus, or protein in the urine; jaundice; and other signs of lung, liver, or kidney damage.

- **Emergency procedures**

> **WARNING!**
>
> **Exposed victims may die!**
> **Transport immediately to emergency medical facility!**

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Tissue destruction and blindness may result from exposure to concentrated solutions, vapors, mists or aerosols of bromine pentafluoride! ***Immediately but gently*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Severe burns, skin corrosion, and absorption of toxic amounts may result! ***Immediately*** remove all contaminated clothing! ***Immediately and gently*** wash skin for at least 15 min. Use soap and water if skin is intact; use only water if skin is not intact.

3. *Inhalation exposure*: If vapors, mists, or aerosols of bromine pentafluoride are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if bromine pentafluoride or a solution containing it is ingested:

—Do ***not*** induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water. Immediately after rinsing, have the victim drink one cup (8 oz) of fluid and ***no more.***

—Do ***not*** permit the victim to drink milk or carbonated beverages!

—Do ***not*** permit the victim to drink any fluid if more than 60 min have passed since initial ingestion.

NOTE: These instructions must be followed exactly. Drinking a carbonated beverage or more than one cup of fluid could create enough pressure to perforate already damaged stomach tissue. The tissue-coating action of milk may impede medical assessment of tissue damage. Ingestion of any fluid more than 60 min after initial exposure could further weaken damaged tissue and result in perforation.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of bromine pentafluoride may result in worker exposures to this substance:

—Use as an oxidizer in liquid rocket propellant combinations and in chemical synthesis

—Use as a fluorinating agent in isotope enrichment and in fuel-element reprocessing

The following methods are effective in controlling worker exposures to bromine pentafluoride, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers

for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to bromine pentafluoride, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the liver, kidneys, and lungs. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to bromine pentafluoride at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with liver, kidney, or lung diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to bromine pentafluoride exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of bromine pentafluoride on the liver, kidneys, and lungs. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for bromine pentafluoride.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population. Because occupational exposure to bromine pentafluoride may cause diseases with prolonged latent periods, the need for medical monitoring may extend well beyond the termination of employment.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne bromine pentafluoride is determined by using a silica gel tube (Supelco ORBO 53 or equivalent). Samples are collected at a recommended flow rate of 0.2 liter/min until a recommended air volume of 48 liters is collected. Analysis is conducted by ion chromatography. This method is included in the *OSHA Chemical Information Manual* [OSHA 1987] and is based on OSHA Method ID-108.

PERSONAL HYGIENE

If bromine pentafluoride contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min and then wash with soap and water. Washing should be continued until the liquid is completely removed from the skin. The burned area should then be immersed in an ice bath, or a cold compress should be applied to the affected area.

Clothing and shoes contaminated with bromine pentafluoride should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of bromine pentafluoride, particularly its potential for being corrosive to the skin and eyes.

A worker who handles bromine pentafluoride should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where bromine pentafluoride is handled, processed, or stored.

STORAGE

Bromine pentafluoride should be isolated from other stored materials; it must be stored in a cool, dry, well-ventilated area in tightly sealed gas cylinders that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Extreme caution should be used when handling this material. Containers of bromine pentafluoride should be protected from physical damage and separated from combustible or organic materials, water, acids, halogens, arsenic, selenium, alkaline halides, sulfur, iodine, glass, metallic halides, metal oxides, metals (except for copper, stainless steel, nickel, and Monel), heat, sparks, and open flame. Bromine pentafluoride reacts with every known element except nitrogen, oxygen, and the inert gases. Because containers that formerly held bromine pentafluoride may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving bromine pentafluoride, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. Remove leaking cylinder(s) to a safe place if feasible; attempt to stop the leak if it is possible to do so without risk.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Bromine pentafluoride is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of bromine pentafluoride; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of bromine pentafluoride emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although bromine pentafluoride is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of bromine pentafluoride exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators

that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with bromine pentafluoride. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to bromine pentafluoride permeation; however, sources recommend the use of acid suits, aprons, boots, neoprene gloves, and other appropriate protective clothing when handling this substance. Since specific test data are not available for bromine pentafluoride, the information provided here should be considered as a guideline only. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to bromine pentafluoride.

Safety glasses, goggles, or face shields should be worn during operations in which bromine pentafluoride might contact the eyes (e.g., through vapors or splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with bromine pentafluoride. Contact lenses should not be worn if the potential exists for bromine pentafluoride exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR n-BUTANE

INTRODUCTION

This guideline summarizes pertinent information about n-butane for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

C_4H_{10}

- **Structure**

$CH_3CH_2CH_2CH_3$

- **Synonyms**

Butane, butyl hydride, diethyl, liquefied petroleum gas, methylethylmethane

- **Identifiers**

1. CAS No.: 106-97-8
2. RTECS No.: EJ4200000
3. DOT UN: 1011 22
4. DOT label: Flammable Gas

- **Appearance and odor**

n-Butane is a colorless gas with no odor, although an odorant is sometimes added to the gas to provide warning of its presence. This gas is commercially available in several grades of purity and in various mixtures (with the isobutane isomer, propane, and/or pentane). n-Butane is usually shipped under pressure as a liquefied gas and is one of the major ingredients in bottled gas.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 58.1
2. Boiling point (760 mm Hg): -0.5°C (31.1°F)
3. Specific gravity (water = 1): 0.5788 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of n-butane): 2.07
5. Melting point: -138.4°C (-217.1°F)
6. Vapor pressure at 20°C (68°F): 1,557 mm Hg
7. Solubility: Soluble in water; very soluble in alcohol, ether, and chloroform
8. Evaporation rate: Not applicable

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame
2. Incompatibilities: Fire and explosions may result from contact of n-butane with oxidizers. A mixture of n-butane and oxygen will explode on contact with nickel carbonyl in the 20° to 40°C (68° to 104°F) temperature range.
3. Hazardous decomposition products: Acrid smoke and fumes may be released when n-butane undergoes thermal oxidative decomposition.
4. Special precautions: Do not use n-butane around sparking motors or other nonexplosionproof equipment. Ground all lines and equipment used with n-butane.

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 4 (extreme fire hazard) to n-butane.

1. Flash point: -60°C (-76°F) (closed cup) (liquefied n-butane).
2. Autoignition temperature: 430°C (806°F)

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

3. Flammable limits in air (% by volume): Lower, approximately 1.9; upper, approximately 8.4

4. Extinguishant: Stop flow of gas. Use water to keep fire-exposed containers cool and to protect persons effecting the shutoff. If a leak or spill has not ignited, water spray may be used to disperse the gas or vapor and to protect persons attempting to stop the leak.

Fires involving n-butane should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of n-butane may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving n-butane.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for n-butane is 800 ppm (1,900 mg/m^3) as an 8-hr time-weighted average (TWA) [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for n-butane of 800 ppm (1,900 mg/m^3) as an 8-hr TWA [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned n-butane a threshold limit value (TLV) of 800 ppm (1,900 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The limits are based on drowsiness and the risk of narcosis associated with exposure to n-butane.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to n-butane can occur through inhalation or eye and skin contact.

• Summary of toxicology

1. *Effects on Animals*: Contact with liquid n-butane can cause frostbite. This gas is also an anesthetic and asphyxiant in animals at very high concentrations. Although n-butane was mildly to moderately irritating to rabbit skin, it did not produce ocular or respiratory tract irritation [NLM 1992]. However, direct tissue contact with liquid n-butane can cause frostbite [NLM 1992]. Anesthetized dogs concomitantly exposed to 5,000 ppm developed hemodynamic changes (decreased myocardial contractility, stroke volume, cardiac output, and left ventricular and aortic pressures) [Clayton and Clayton 1981]. Dogs exposed to 10,000 ppm for 2 hr or 200,000 ppm for 2 min were hypersensitized to epinephrine-induced ventricular fibrillation. Exposure of dogs to 150,000 to 900,000 ppm for 10 min also caused heart sensitization to epinephrine-induced arrhythmias [NLM 1992]. The anesthetic concentration for n-butane is 250,000 ppm in dogs [NLM 1992] and 220,000 ppm for 1 min or 130,000 ppm for 25 min in mice [Clayton and Clayton 1981]. The 30-min LC_{50} for mice is approximately 285,000 ppm, but the 15-min LC_{50} for rats is about 275,000 ppm [NLM 1992]. n-Butane was not mutagenic in the *Salmonella typhimurium* assay [NLM 1992].

2. *Effects on Humans*: A transient blurring of vision resulted when n-butane was accidently sprayed into the eyes from a cigarette lighter [NLM 1992]. However, contact of the eyes or skin with n-butane gas does not normally cause irritation, but contact with the liquefied form may cause frostbite of the eyes or skin [Clayton and Clayton 1981; Genium 1990]. Exposure to 10,000 ppm for 10 min may lead to drowsiness but does not appear to cause systemic effects [Clayton and Clayton 1981]. A 2-year-old girl developed seizures, hypotension, and recurrent ventricular tachycardia following inhalation of an aerosol spray from a can containing a mixture of n-butane, isobutane, and propane [NLM 1992]. Progressive bilateral pulmonary infiltrates consistent with hydrocarbon pneumonitis developed in a "fire breather" following an inhalation of unignited fumes from a butane lighter. Exposure of volunteers to 1,000 ppm for 8 hr or 500 ppm for 8 hr/day, 5 days/week for 2 weeks did not induce toxicity [ACGIH 1991a]. Intentional inhalation abuse of n-butane for 1 year by a 16-year-old girl caused her to suffer from visual hallucinations, increased irritability, and social withdrawal [NLM 1992]. Exposure to n-butane at very high concentrations can affect the central nervous system, causing narcosis and asphyxiation [Clayton and Clayton 1981].

• **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to n-butane can cause central nervous system depression (drowsiness and lightheadedness), narcosis, and asphyxiation. Contact with liquefied n-butane can cause eye and skin burns (frostbite).

2. *Chronic exposure*: Visual hallucinations, irritability, and social withdrawal have been reported with chronic exposure. Cardiac sensitization may also be possible.

• **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of frostbite, toxicity, or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: If tissue is frozen, seek medical attention ***immediately***; if tissue is not frozen, ***immediately and thoroughly*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the lower and upper eyelids. If irritation, pain, swelling, lacrimation, or photophobia persists, get medical attention as soon as possible.

2. *Skin exposure*: If frostbite has occurred, seek medical attention ***immediately***; do ***not*** rub the affected areas or flush them with water. If frostbite has ***not*** occurred, ***immediately and thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: Move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve n-butane and may result in worker exposures to this substance:

—Use of n-butane as a raw material in the production of motor and aviation fuels

—Use of n-butane as a household fuel, solvent, refrigerant, standby and enricher gas, and propellant in aerosols

—Use of pure grades of n-butane in calibrating instruments

—Use of n-butane as a food additive

—Manufacture of ethylene and butadiene

—Use of n-butane as a special motor fuel for in-plant trucking, where the presence of gasoline vapors is undesirable

The following methods are effective in controlling worker exposures to n-butane, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To

place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for n-butane.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne n-butane is determined by using two charcoal tubes in series (100/50-mg sections, 20/40 mesh). Samples are collected at a maximum flow rate of 0.1 liter/min until a maximum air volume of 10 liters is collected. The sample is then treated with carbon disulfide to extract the n-butane. Analysis is conducted by gas chromatography using a flame ionization detector. This method is included in the OSHA In-House Methods File [OSHA 1989].

PERSONAL HYGIENE

If liquefied n-butane contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min and should not rub the affected areas.

Workers should not eat, drink, or use tobacco products in areas where n-butane is handled, processed, or stored.

Workers should wash their hands after handling liquefied n-butane.

STORAGE

n-Butane should be stored in a cool, dry, well-ventilated, low-fire-risk area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of n-butane should be protected from physical damage and should be stored separately from oxidizers (including cylinders of oxygen or chlorine), nickel carbonyl, heat, sparks, and open flame. All equipment used with n-butane should be electrically bonded and grounded. Because containers that formerly contained n-butane may still hold product residues, they should be handled appropriately.

LEAKS

In the event of a leak involving n-butane, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a leak:

1. Notify safety personnel.
2. Remove all sources of heat and ignition.
3. Ventilate potentially explosive atmospheres; supply optimum explosionproof ventilation to disperse the gas.
4. Use self-contained breathing apparatus and protection against contact with the cold liquid to avoid frostbite when attempting to stop the leak.
5. Stop the leak or remove the leaky cylinder or tank to a safe, open area and vent it slowly to empty the container.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

n-Butane is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of n-butane; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of n-butane emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although n-butane is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are

conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of n-butane exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1900.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective gloves and clothing should be worn to prevent skin contact with n-butane. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been shown to provide resistance to liquefied n-butane: neoprene rubber, the combination of nitrile and polyvinyl chloride, and Viton®. Natural rubber, nitrile, and polyvinyl chloride have demonstrated poor resistance to n-butane.

Safety glasses, goggles, or face shields should be worn during operations in which n-butane might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with n-butane. Contact lenses should not be worn if the potential exists for exposure to liquefied n-butane.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BUTYL ACRYLATE

INTRODUCTION

This guideline summarizes pertinent information about butyl acrylate for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_7H_{12}O_2$

- **Structure**

$CH_2 = CHCOOC_4H_9$

- **Synonyms**

2-Propenoic acid, butyl ester; acrylic acid, butyl ester; acrylic acid, n-butyl ester; butyl 2-propenoate

- **Identifiers**

1. CAS No.: 141-32-2
2. RTECS No.: UD3150000
3. DOT UN: 2348 26 (for the inhibited form)
4. DOT label: Flammable Liquid

- **Appearance and odor**

Butyl acrylate is a flammable, clear, colorless liquid with a sharp, fragrant, characteristic odor. The odor threshold is reported to be 0.1 part per billion (ppb) parts of air. Butyl acrylate is highly reactive and can undergo spontaneous polymerization. To prevent premature polymerization, the commercially available product often contains an inhibitor.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 128.17
2. Boiling point (760 mm Hg): 145°C (293°F) (polymerizes)
3. Specific gravity (water = 1): 0.9 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of butyl acrylate): 4.4
5. Melting point: -64°C (-83.2°F)
6. Vapor pressure at 20°C (68°F): 4 mm Hg
7. Solubility: Very slightly soluble in water; soluble in alcohol, ether, and acetone.
8. Evaporation rate (butyl acetate = 1): 0.42

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame (heat may cause an explosive polymerization reaction)
2. Incompatibilities: Hazardous polymerization may result from contact of butyl acrylate with peroxides, sunlight, or other catalysts. Butyl acrylate is incompatible with strong acids, strong alkalies, amines, halogens, hydrogen compounds, and oxidizers.
3. Hazardous decomposition products: Toxic gases (such as carbon dioxide and carbon monoxide) may be released in a fire involving butyl acrylate.
4. Special precautions: None

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 2 (moderate fire hazard) to butyl acrylate.

1. Flash point: 49°C (120°F) (open cup)
2. Autoignition temperature: 293°C (559°F)
3. Flammable limits in air (% by volume): Lower, 1.4; upper, 9.9

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Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

4. Extinguishant: Use dry chemical, foam, or carbon dioxide to fight fires involving butyl acrylate. Water may be used to cool fire-exposed containers. If a leak or spill has not ignited, water spray may be used to disperse vapors and to protect persons attempting to stop the leak.

Fires involving butyl acrylate should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of butyl acrylate may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving butyl acrylate. Firefighters' protective clothing may not provide protection against permeation by butyl acrylate.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for butyl acrylate is 10 ppm (55 mg/m^3) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 10 ppm (55 mg/m^3) as an 8-hr TWA [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned butyl acrylate a threshold limit value (TLV) of 10 ppm (52 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of eye and skin irritation associated with exposure to butyl acrylate and on its toxicological similarity to methyl acrylate.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to butyl acrylate can occur through inhalation, eye or skin contact, and absorption through the skin.

• Summary of toxicology

1. *Effects on Animals*: Butyl acrylate is an irritant of the eyes, skin, and respiratory tract in animals. Instillation of this substance into the eyes of rabbits also caused mild to moderate irritation [NIOSH 1991]. Corneal necrosis occurred when ocular washing was not performed [ACGIH 1991a]. When applied to the skin of rabbits for 24 hr, 10 mg butyl acrylate caused mild irritation. Butyl acrylate is a sensitizer in guinea pigs, and sensitized animals showed cross-sensitization reactions to other monoacrylates [IARC 1986]. The dermal LD_{50} for rabbits has ranged from 1,800 to 3,000 mg/kg [Carpenter et al. 1974; Smyth et al. 1951]. The maximum duration that all rats survived exposure to inhalation of saturated vapors (7,050 ppm) was 30 min [ACGIH 1991a; Smyth et al. 1951]. The 2-hr LC_{50} is 1,345 ppm for mice and 6,035 ppm for rats [Izmerov et al. 1982]. The 4-hr LC_{50} in rats is 2,730 ppm [NIOSH 1991]. These animals exhibited signs of eye and respiratory tract irritation (e.g., corneal necrosis and labored breathing) [ACGIH 1991a; Proctor et al. 1988]. Wide variations are reported in the oral LD_{50} for rats: 900 mg/kg [Izmerov et al. 1982]; 3,730 mg/kg [Smyth et al. 1951]; and 8,050 mg/kg [Carpenter et al. 1974]. The oral LD_{50} in mice has ranged from 5,400 to 7,500 mg/kg [IARC 1986]. Rats were exposed for 6 hr/day to 25, 135, or 250 ppm on days 6 to 15 after mating. Maternal toxicity and embryo lethality occurred at the two highest doses, but exposure to 25 ppm caused no observable effects. However, terata were not induced by any concentration of butyl acrylate [Proctor et al. 1988]. The International Agency for Research on Cancer (IARC) found no evidence of mutagenic potential in the in vivo or in vitro data reviewed [IARC 1986]. In a dermal carcinogenesis study, 1% butyl acrylate in acetone was applied three times weekly to the skin of mice over their lifetimes; no site-of-application tumors occurred in these animals [Proctor et al. 1988]. In a 2-year inhalation study, Sprague-Dawley rats were exposed to butyl acrylate concentrations ranging from 15 to 135 ppm. Exposures were for 6 hr/day, 5 days/week for 24 months followed by a 6-month recovery period. No tumors were induced by butyl acrylate after either the treatment or recovery periods [IARC 1986]. IARC has concluded that there is inadequate evidence of the carcinogenicity of butyl acrylate in animals [IARC 1986].

2. *Effects on Humans*: Butyl acrylate is an irritant of the eyes and skin as well as the mucous membranes of the nose, throat, and respiratory tract in humans [Gosselin et al. 1984]. Allergic contact dermatitis attributed to butyl acrylate has

been reported in dentists, dental technicians, paint stock room clerks, and other occupationally exposed individuals [Kanerva et al. 1988; Proctor et al. 1988]. Fourteen of 33 workers exposed to 50 mg/m^3 (approximately 10 ppm) for an average of 5 years reported experiencing nervous system and behavioral symptoms, but these were not confirmed by electroencephalography [IARC 1986]. IARC classified butyl acrylate as a Group 3 material (not classifiable as to its carcinogenicity to humans) [IARC 1987].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to butyl acrylate vapor can cause redness, tearing, and irritation of the eyes, runny nose, scratchy throat, difficult breathing, and redness and cracking of the skin.

2. *Chronic exposure*: Repeated contact of the skin with this substance may cause skin sensitization in some individuals, with redness, swelling, itching, and oozing of the affected areas. Nervous system and behavioral effects are also possible.

- **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of butyl acrylate. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of butyl acrylate are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if butyl acrylate or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve butyl acrylate and may result in worker exposures to this substance:

—Manufacture of polymers and resins for leather finishes, paint formulations, and textiles

—Organic synthesis of polymers and copolymers for solvent coatings, paper, adhesives, binders, sealants, and emulsifiers

The following methods are effective in controlling worker exposures to butyl acrylate, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to butyl acrylate, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the skin and respiratory tract. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to butyl acrylate at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history of allergies or other findings consistent with skin or respiratory tract diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to butyl acrylate exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of butyl acrylate on the skin and respiratory tract. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for butyl acrylate.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne butyl acrylate is determined by using two XAD-2 tubes in series (80/50-mg sections, 20/50 mesh). Samples are collected at a maximum flow rate of 0.1 liter/min until a maximum air volume of 3 liters is collected. The sample is then treated with carbon disulfide to extract the butyl acrylate. Analysis is conducted by gas chromatography using a flame ionization detector. This method is included in the OSHA Laboratory In-House Methods File [OSHA 1989].

PERSONAL HYGIENE

If butyl acrylate contacts the skin, workers should flush the affected areas immediately with plenty of water for 15 min and then wash with soap and water.

Clothing and shoes contaminated with butyl acrylate should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of butyl acrylate, particularly its potential for causing skin irritation and sensitization.

A worker who handles butyl acrylate should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where butyl acrylate or a solution containing butyl acrylate is handled, processed, or stored.

STORAGE

Butyl acrylate should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. The inhibitor concentration in containers of this substance should be checked at regular intervals and inhibitor should be added as needed. Butyl acrylate should be stored at temperatures below 38°C (100°F). Containers of butyl acrylate should be protected from physical damage and should be stored separately from peroxides, strong acids, strong alkalies, amines, halogens, hydrogen compounds, oxidizers, sunlight, heat, sparks, and open flame. Because containers that formerly contained butyl acrylate may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving butyl acrylate, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. Water spray may be used to reduce vapors, but the spray may not prevent ignition in closed spaces.
6. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.
7. For large liquid spills, build dikes far ahead of the spill to contain the butyl acrylate for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Butyl acrylate is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of butyl acrylate; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers who own or operate facilities in SIC codes 20 to 39, who employ 10 or more workers, and who manufacture 25,000 lb or more or otherwise use 10,000 lb or more of butyl acrylate per calendar year are required by EPA [40 CFR 372.30] to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of butyl acrylate emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although butyl acrylate is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of

respirators to control exposure. Respirators must be worn if the ambient concentration of butyl acrylate exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent skin contact with butyl acrylate; impervious gloves are recommended. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. Teflon® has been tested against permeation by butyl acrylate and has demonstrated good-to-excellent resistance for more than 4 but fewer than 8 hr. Butyl rubber, natural rubber, neoprene, nitrile rubber, polyvinyl chloride, and Viton® have demonstrated poor resistance to permeation by butyl acrylate.

If butyl acrylate is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which butyl acrylate might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with butyl acrylate. Contact lenses should not be worn if the potential exists for butyl acrylate exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR n-BUTYL LACTATE

INTRODUCTION

This guideline summarizes pertinent information about n-butyl lactate for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_7H_{14}O_3$

- **Structure**

$CH_3CH(OH)COOC_4H_9$

- **Synonyms**

Butyl α-hydroxypropionate; butyl lactate; 2-hydroxypropanoic acid, butyl ester; lactic acid, butyl ester

- **Identifiers**

1. CAS No.: 138-22-7
2. RTECS No.: OD4025000
3. DOT UN: 1993 27 (combustible liquid not otherwise specified)
4. DOT label: None

- **Appearance and odor**

n-Butyl lactate is a clear, colorless to white, combustible liquid. It has a mild, transient odor. The odor threshold is reported to be 7 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 146.2
2. Boiling point (760 mm Hg): 188°C (370.4°F)
3. Specific gravity (water = 1): 0.9 to 0.984 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of n-butyl lactate): 5.0
5. Melting point: -43°C (-45.4°F)
6. Vapor pressure at 20°C (68°F): 0.4 mm Hg
7. Solubility: Slightly soluble in water; miscible with alcohol and ether; hydrolyzed by acids and bases
8. Evaporation rate (butyl acetate = 1): 0.44

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame. Strong acids (such as hydrochloric, sulfuric, or nitric) and strong bases (such as sodium hydroxide) can cause butyl lactate to decompose.
2. Incompatibilities: A reaction may result from contact of n-butyl lactate with strong oxidizers.
3. Hazardous decomposition products: Toxic gases (such as carbon dioxide) may be released in a fire involving n-butyl lactate.
4. Special precautions: None reported

- **Flammability**

The National Fire Protection Association has assigned a flammability rating of 2 (moderate fire hazard) to n-butyl lactate.

1. Flash point: 71°C (160°F) (open cup)
2. Autoignition temperature: 382°C (720°F)
3. Flammable limits in air (% by volume): Lower, 1.15; upper, data not available
4. Extinguishant: Use water fog, dry chemical, alcohol foam, or carbon dioxide to fight fires involving n-butyl lactate. Do not use a solid stream of water because this will scatter and spread the fire. Water may be ineffective for fighting fires, but it may be used to cool fire-exposed containers.

Fires involving n-butyl lactate should be fought upwind and from the maximum distance possible. Isolate the hazard area

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and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapor explosion and poison hazards may occur indoors, outdoors, or in sewers. Vapors may travel to a source of ignition and flash back. Containers of n-butyl lactate may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving n-butyl lactate. Firefighters' protective clothing may not provide protection against permeation by n-butyl lactate.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for n-butyl lactate is 5 ppm (25 mg/m^3) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 5 ppm (25 mg/m^3) as an 8-hr TWA [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned n-butyl lactate a threshold limit value (TLV) of 5 ppm (30 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of headaches and irritation of pharyngeal and laryngeal mucosa associated with exposure to n-butyl lactate.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to n-butyl lactate can occur through inhalation, ingestion, or eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: n-Butyl lactate is an eye and respiratory tract irritant and a central nervous system depressant; it also causes a moderate degree of irritation to the skin of rabbits [NIOSH 1991]. The oral LD_{50} in rats is 5 g/kg [NIOSH 1991]. Acutely poisoned animals exhibit somnolence, flaccid paralysis, and dyspnea before death.

2. *Effects on Humans*: n-Butyl lactate is a central nervous system depressant and an irritant of the eyes, mucous membranes, and upper respiratory tract. Prolonged or repeated contact with the skin by n-butyl lactate causes defatting, redness, and cracking of the skin [Genium 1987]. Prolonged exposures to approximately 7 ppm with peak exposures to 11 ppm caused irritation of the pharyngeal and laryngeal mucosa, coughing, and complaints of sleepiness and headache in the evening after work [ACGIH 1991a]. Some workers also experienced nausea and vomiting [ACGIH 1991a]. Exposure to 4 ppm also caused some of these symptoms [ACGIH 1991a]. No symptoms were reported by workers exposed to n-butyl lactate at concentrations below 1.4 ppm [ACGIH 1991a].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to n-butyl lactate may cause coughing, scratchy throat, nausea, headache, dyspnea, vomiting, CNS depression, and redness, pain, and tearing of the eyes.

2. *Chronic exposure*: Prolonged or repeated contact with n-butyl lactate may cause ocular or mucosal irritation, dryness, redness, cracking, and defatting of the skin.

• Emergency procedures

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure*: Tissue irritation may result from exposure to concentrated solutions, vapors, mists, or aerosols of n-butyl lactate. ***Immediately and thoroughly*** flush eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Skin irritation may result. ***Immediately*** remove contaminated clothing and ***thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: If vapors, mists, or aerosols of n-butyl lactate are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if n-butyl lactate or a solution containing it is ingested:

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

—Have the victim drink a glass (8 oz) of fluid such as water.

—Induce vomiting by giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—Do ***not*** force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of n-butyl lactate may result in worker exposures to this substance:

—Use as a solvent for cellulose, varnishes, lacquers, stencil pastes, natural gums, oils, dyes, and many synthetic polymers

—Use in making paint, inks, perfumes, and dry cleaning fluids

—Use in making antiskinning agents and adhesives and as a chemical intermediate

The following methods are effective in controlling worker exposures to n-butyl lactate, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety or health, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

• Preplacement medical evaluation

Before a worker is placed in a job with a potential for exposure to n-butyl lactate, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the skin and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific

job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to n-butyl lactate at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with skin or respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to n-butyl lactate exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of n-butyl lactate on the skin and respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for n-butyl lactate.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne n-butyl lactate is determined by using a charcoal tube (100/50-mg front and backup sections). Samples are collected at a maximum flow rate of 0.2 liter/min until a maximum air volume of 10 liters is collected. The sample is then treated with a 95:5 mixture of methylene chloride and methanol to extract the n-butyl lactate. Analysis is conducted by gas chromatography using a flame ionization detector. This method is described in the OSHA Computerized Information System [OSHA 1989] and in the OSHA Laboratory In-House Methods File [OSHA 1990].

PERSONAL HYGIENE

If n-butyl lactate contacts the skin, workers should immediately wash the affected areas with soap and water.

Clothing and shoes contaminated with n-butyl lactate should be removed, and provisions should be made for safely removing this chemical from these articles.

A worker who handles n-butyl lactate should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where n-butyl lactate or a solution containing n-butyl lactate is handled, processed, or stored.

STORAGE

n-Butyl lactate should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. The storage area must meet the requirements for OSHA Class IIIA [29 CFR 1910.106] combustible liquids. Containers of n-butyl lactate should be protected from physical damage and should be stored separately from strong oxidizers, heat, sparks, and open flame. Only nonsparking tools may be used to handle n-butyl lactate. To prevent static sparks, containers and equipment must be grounded and bonded when transferring this material. Because containers that formerly contained n-butyl lactate may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving n-butyl lactate, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.

2. Notify safety personnel.

3. Remove all sources of heat and ignition.

4. Ventilate potentially explosive atmospheres using ventilation of explosionproof design.

5. Water spray may be used to reduce vapors, but the spray may not prevent ignition in closed spaces.

6. Absorb small liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

7. For large liquid spills, build dikes far ahead of the spill to contain the n-butyl lactate for later reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

n-Butyl lactate is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of n-butyl lactate; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of n-butyl lactate emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although n-butyl lactate is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of n-butyl lactate exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent repeated or prolonged skin contact with n-butyl lactate. Impervious

gloves, aprons, boots, gauntlets, plastic coveralls, and other protective clothing should be worn as necessary when handling this material. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use.

No reports have been published on the resistance of various protective clothing materials to n-butyl lactate permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to n-butyl lactate.

If n-butyl lactate is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which n-butyl lactate might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with n-butyl lactate. Contact lenses should not be worn if the potential exists for n-butyl lactate exposure.

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE

FOR o-sec-BUTYLPHENOL

INTRODUCTION

This guideline summarizes pertinent information about o-sec-butylphenol for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_{10}H_{14}O$

- **Structure**

$C_2H_5(CH_3)CHC_6H_4OH$

- **Synonyms**

2-(1-Methylpropyl)phenol; 2-sec-butylphenol

- **Identifiers**

1 CAS No.: 89-72-5

2. RTECS No.: SJ8920000

3. DOT UN: 2228 53

4. DOT label: St. Andrew's Cross

- **Appearance and odor**

o-sec-Butylphenol is a colorless, slightly volatile, combustible liquid.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 150.2

2. Boiling point (760 mm Hg): 226° to 228°C (438.8° to 442°F)

3. Specific gravity (water = 1): 0.98 at 20°C (68°F)

4. Vapor density: Data not available

5. Melting point: 16°C (60.9°F)

6. Vapor pressure at 20°C (68°F): Data not available; however, o-sec-butylphenol is reported to be slightly volatile.

7. Solubility: Insoluble in water; soluble in alcohol, ether, and alkalies

8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, and open flame

2. Incompatibilities: None known

3. Hazardous decomposition products: Toxic gases may be released in a fire involving o-sec-butylphenol.

4. Special precautions: None known

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to o-sec-butylphenol; other sources report that this substance is combustible but does not ignite readily.

1. Flash point: 107.2°C (225°F)

2. Autoignition temperature: Data not available

3. Flammable limits in air: Data not available

4. Extinguishant: Use dry chemical, carbon dioxide, water spray, or alcohol to fight fires involving o-sec-butylphenol.

Fires involving o-sec-butylphenol should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of o-sec-butylphenol may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not

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possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving o-sec-butylphenol. Chemical protective clothing that is specifically recommended for o-sec-butylphenol may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by o-sec-butylphenol.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for o-sec-butylphenol is 5 ppm (30 mg/m^3) as an 8-hr time-weighted average (TWA) concentration. The OSHA PEL also bears a "Skin" notation, which indicates that the cutaneous route of exposure (including mucous membranes and eyes) contributes to overall exposure [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 5 ppm (30 mg/m^3) as an 8-hr TWA with a "Skin" notation [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned o-sec-butylphenol a threshold limit value (TLV) of 5 ppm (31 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek. The ACGIH also assigns a "Skin" notation to o-sec-butylphenol [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of eye and respiratory irritation and skin burns associated with exposure to o-sec-butylphenol.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to o-sec-butylphenol can occur through inhalation, ingestion, and eye or skin contact.

• Summary of toxicology

1. *Effects on Animals*: o-sec-Butylphenol is an irritant of the eyes, skin, and upper respiratory tract. Application of 0.05 mg of o-sec-butylphenol to the eyes of rabbits caused severe injury [NIOSH 1991; ACGIH 1991a]. When applied to the skin of rabbits for 24 hr, 500 mg caused severe burns [ACGIH 1991a; NIOSH 1991]. The dermal LD_{50} in guinea pigs is 600 mg/kg [NIOSH 1991]. Rats survived a 7-hr exposure to an atmosphere saturated with o-sec-butylphenol vapor [ACGIH 1991a]. The oral LD_{50} is 2,700 mg/kg in rats and 600 mg/kg in guinea pigs [NIOSH 1991]. This material was nonmutagenic when tested in five strains of *Salmonella typhimurium* [NLM 1991].

2. *Effects on Humans*: o-sec-Butylphenol is an eye, skin, and respiratory tract irritant and a potential corrosive. Acute occupational exposures to unspecified concentrations of this substance cause mild respiratory tract irritation, and prolonged skin contact results in dermal ulcerations and burns [ACGIH 1991a; NLM 1991]. Ingestion of a solution exceeding 5% o-sec-butylphenol may cause oral burns, which can become necrotic several days later [NLM 1991]. Using analogous data from other phenolic compounds, it may also cause nausea, vomiting, intense sweating, diarrhea, methomoglobinemia, tachycardia, hypotension, arrhythmias, seizures, CNS depression, hepatic injury, and death from respiratory arrest [NLM 1991].

• Signs and symptoms of exposure

1. *Acute exposure*: Acute exposure to o-sec-butylphenol can cause eye irritation, redness, and pain; irritation of the nasal and respiratory tract mucosa; scratchy throat; and redness, swelling, and chemical burns of the skin.

2. *Chronic exposure*: Other than irritation, no signs or symptoms of chronic exposure to o-sec-butylphenol have been reported.

• Emergency procedures

WARNING!

Transport victims immediately to emergency medical facility!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. ***Immediately*** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

1. *Eye exposure*: Tissue destruction and blindness may result from exposure to concentrated solutions, vapors, mists or aerosols of o-sec-butylphenol! ***Immediately but gently***

flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids.

2. *Skin exposure*: Severe burns, skin corrosion, and absorption of toxic amounts may result! ***Immediately*** remove all contaminated clothing! ***Immediately, continuously, and gently*** wash skin for at least 15 min. Use soap and water if skin is intact; use only water if skin is not intact.

3. *Inhalation exposure*: If vapors, mists, or aerosols of o-sec-butylphenol are inhaled, move the victim to fresh air ***immediately***.

If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure*: Take the following steps if o-sec-butylphenol or a solution containing it is ingested:

—Do ***not*** induce vomiting.

—Have the victim rinse the contaminated mouth cavity several times with a fluid such as water. Immediately after rinsing, have the victim drink one cup (8 oz) of fluid and ***no more***.

—Do ***not*** permit the victim to drink milk or carbonated beverages!

—Do ***not*** permit the victim to drink any fluid if more than 60 min have passed since initial ingestion.

NOTE: These instructions must be followed exactly. Drinking a carbonated beverage or more than one cup of fluid could create enough pressure to perforate already damaged stomach tissue. The tissue-coating action of milk may impede medical assessment of tissue damage. Ingestion of any fluid more than 60 min after initial exposure could further weaken damaged tissue and result in perforation.

5. *Rescue*: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The preparation of plasticizers, resins, surface-active agents, and other products may involve o-sec-butylphenol and may result in worker exposures to this substance.

The following methods are effective in controlling worker exposures to o-sec-butylphenol, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

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Before a worker is placed in a job with a potential for exposure to o-sec-butylphenol, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the respiratory system. Medical monitoring for respiratory disease should be conducted using

the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to o-sec-butylphenol at or below the prescribed exposure limit. The licensed health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with respiratory system diseases.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to o-sec-butylphenol exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of o-sec-butylphenol on the respiratory tract and skin. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for o-sec-butylphenol.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of job placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne o-sec-butylphenol is determined by using a XAD-7 tube (100/50-mg sections; 15/50 mesh). Samples are collected at a recommended flow rate of 0.1 liter/min until a recommended air volume of 10 liters is collected. Analysis is conducted by high-performance liquid chromatography using ultraviolet light. This method is described in the OSHA Computerized Information System [OSHA 1989] and in the OSHA Laboratory In-House Methods File [OSHA 1990].

PERSONAL HYGIENE

Because o-sec-butylphenol can be absorbed through the skin in toxic amounts, workers should immediately and thoroughly wash with soap and water any areas of the skin that have contacted this substance.

Clothing and shoes contaminated with o-sec-butylphenol should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of o-sec-butylphenol, particularly its potential for being an irritant and for being absorbed through the skin in toxic amounts.

A worker who handles o-sec-butylphenol should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, or using toilet facilities.

Workers should not eat, drink, or use tobacco products in areas where o-sec-butylphenol or a solution containing it is handled, processed, or stored.

STORAGE

o-sec-Butylphenol should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Containers of o-sec-butylphenol should be protected from physical damage and should be stored separately from heat, sparks, and open flame. Because containers that formerly contained o-sec-butylphenol may still hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving o-sec-butylphenol, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate the area of the spill or leak.

5. Absorb liquid spills with sand or other noncombustible absorbent material and place the material in a covered container for later disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

o-sec-Butylphenol is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of o-sec-butylphenol; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of o-sec-butylphenol emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although o-sec-butylphenol is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of o-sec-butylphenol exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent prolonged or repeated skin contact with o-sec-butylphenol. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to o-sec-butylphenol permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to o-sec-butylphenol.

If o-sec-butylphenol is dissolved in an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which o-sec-butylphenol might contact the eyes (e.g., through splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with o-sec-butylphenol. Contact lenses should not be worn if the potential exists for o-sec-butylphenol exposure.

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