OCCUPATIONAL SAFETY AND HEALTH GUIDELINES FOR CHEMICAL HAZARDS

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
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NOTE TO THE READER

This document supplements the 1981 publication entitled 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 30 chemicals described here are among those listed but not described in the 1981 publication. Readers may wish to insert each guideline at the appropriate place in that 3-volume set.

These 30 occupational safety and health guidelines are being published to disseminate technical information about chemical hazards to workers, employers, and occupational safety and health professionals. Each guideline includes data on chemical names and synonyms, chemical and physical properties, exposure limits, signs and symptoms of exposure, as well as recommendations for medical monitoring, respiratory and personal protective equipment, and control procedures. These recommendations reflect good industrial hygiene and medical monitoring practices, and their implementation should help employers achieve a sound occupational health program.

The recommendations and information contained in these guidelines may be superseded as new information becomes available; readers are advised to regard these recommendations as general guidelines and should not rely on them for achieving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

NOTICE

The guidelines in Supplement I are not packaged in the exact order listed in the contents. Please add them to your notebook binders in alphabetical order, as indicated in the table of contents.

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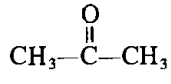
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ACETONE

INTRODUCTION

This guideline summarizes pertinent information about acetone for workers, employers, and occupational safety and health professionals who may need such information to conduct effective programs. Recommendations may be superseded by new developments in these fields; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** C_3H_6O
- **Structure:**



- **Synonyms:** Dimethyl ketone, ketone propane, propanone, 2-propanone
- **Identifiers:** CAS 67-64-1; RTECS AL3150000; DOT 1090, label required: "Flammable Liquid"
- **Appearance and odor:** Colorless liquid with a fragrant, mintlike odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 58.09
2. Boiling point (at 760 mmHg): 56.2 °C (133 °F)
3. Specific gravity (water = 1): 0.79
4. Vapor density (air = 1 at boiling point of acetone): 2.0
5. Melting point: -94.8 °C (-138 °F)
6. Vapor pressure at 20 °C (68 °F): 180.0 mmHg; at 25 °C (77 °F), 226.3 mmHg
7. Miscible in water
8. Evaporation rate (butyl acetate = 1): 6
9. Saturation concentration in air (approximate) at 20 °C (68 °F): 23.7% (237,000 ppm); at 25 °C (77 °F), 29.8% (298,000 ppm)
10. Ionization potential: 9.69 eV

- **Reactivity**

1. Incompatibilities: Contact with acids and oxidizing materials may cause fires and explosions.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., ketene) may be released in a fire involving acetone.
3. Caution: Acetone will dissolve most plastics, resins, and rubber.

- **Flammability**

1. Flash point: -18.0 °C (0 °F) (closed cup)
2. Autoignition temperature: 465 °C (869 °F)
3. Flammable limits in air, % by volume: Lower, 2.2; Upper, 13
4. Extinguishant: Carbon dioxide, dry chemical, or alcohol foam
5. Class IB Flammable Liquid (29 CFR 1910.106), Flammability Rating 3 (NFPA)

- **Warning properties**

1. Odor threshold: 20 ppm
2. Eye irritation levels: Acetone has been reported to cause a burning sensation of the eyes at a vapor concentration of 500 ppm. Other reports have concluded that irritation in acclimated workers occurs between 1,000 and 1,500 ppm.
3. Evaluation of warning properties for respirator selection: Because of its odor, acetone can be detected below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus, it is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for acetone is 1,000 parts of acetone per million parts of air (ppm) [2,400 milligrams of acetone per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The NIOSH REL is 250 ppm (590 mg/m³) as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 750 ppm (1,780 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek; the (ACGIH) short-term exposure limit (STEL) is 1,000 ppm (2,375 mg/m³) (Table 1).

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Table 1.—Occupational exposure limits for acetone

	Exposure limits ppm	mg/m³
OSHA PEL TWA	1,000	2,400
NIOSH REL TWA	250	590
ACGIH TLV® TWA	750	1,780
STEL	1,000	2,375

HEALTH HAZARD INFORMATION

• Routes of exposure

Acetone may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• Summary of toxicology

1. *Effects on animals:* Acute inhalation of acetone produced depression of respiration and narcosis in rats. Subchronic dermal application or subcutaneous injection of acetone produced cataracts in guinea pigs.

2. *Effects on humans:* Acute inhalation of acetone has produced narcosis, and repeated exposures have caused inflammation of the respiratory tract, stomach, and small intestine. Studies of persons clinically exposed indicate that acetone is metabolized slowly and may accumulate in the body throughout a 40-hour workweek.

• Signs and symptoms of exposure

1. *Short-term (acute):* Exposure to acetone can cause eye irritation, dryness of the mouth and throat, nausea, vomiting, headache, sleepiness, dizziness, light-headedness, weakness, incoordination, loss of energy, fainting, and unconsciousness.

2. *Long-term (chronic):* Exposure to acetone can cause dizziness and sleepiness. Dryness, irritation, and inflammation of skin can also occur.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to acetone, the physician 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, eyes, and nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to acetone at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis.

• Periodic medical screening and/or biologic monitoring

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to acetone. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the skin, eyes, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and ATS: standardized questionnaires and tests of lung function.

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

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

• Sentinel health events

Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **TWA exposure evaluation**

Measurements to determine worker exposure to acetone should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

• **Method**

Sampling and analysis may be performed by collecting acetone vapors with charcoal tubes followed by desorption with carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure acetone may also be used if available. A detailed sampling and analytical method for acetone may be found in the *NIOSH Manual of Analytical Methods* (method number 1300).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with acetone.

Workers should be provided with and required to use splash-proof safety goggles where acetone may come in contact with the eyes.

SANITATION

Clothing which is contaminated with acetone should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of acetone from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of acetone's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with acetone should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle acetone should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to acetone may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for acetone

Operations	Controls
During application of lacquer, paints, and varnishes	Natural ventilation, local exhaust ventilation, workroom ventilation, personal protective equipment
During use of solvents and cementing agents	Personal protective equipment
During dip application of protective coatings; during cleaning operations	Local exhaust ventilation, personal protective equipment
During fabric coating and dyeing processes	Local exhaust ventilation, general dilution ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to acetone, an eye-wash fountain should be provided within the immediate work area for emergency use.

If acetone gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to acetone, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If acetone gets on the skin, wash it immediately with soap and water. If acetone penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. If irritation persists after washing, get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

In cases in which environmental levels exceed the NIOSH REL, workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If acetone is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing acetone, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from acetone vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing acetone may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. Acetone should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing acetone may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for acetone

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 1,000 ppm	Any chemical cartridge respirator with organic vapor cartridge(s)
	Any powered air-purifying respirator with organic vapor cartridge(s)
	Any supplied-air respirator
	Any self-contained breathing apparatus
Less than or equal to 6,250 ppm	Any supplied-air respirator operated in a continuous flow mode (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 12,500 ppm	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any supplied-air respirator with a full facepiece
	Any self-contained breathing apparatus with a full facepiece
Less than or equal to 20,000 ppm	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 20,000 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 250 ppm (590 mg/m^3) (TWA).

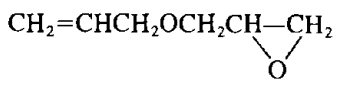
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ALLYL GLYCIDYL ETHER

INTRODUCTION

This guideline summarizes pertinent information about allyl glycidyl ether (AGE) for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_6H_{10}O_2$
- **Structure:**



- **Synonyms:** AGE; allyl 2,3-epoxypropyl ether; 1-(allyloxy)-2,3-epoxypropane; ((2-propenyloxy)methyl)-oxirane
- **Identifiers:** CAS 106-92-3; RTECS RR0875000; DOT 2219, label required: "Flammable Liquid"
- **Appearance and odor:** Colorless liquid with a sweet odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 114.16
2. Boiling point (at 760 mmHg): 154°C (309°F)
3. Specific gravity (water = 1): 0.97
4. Vapor density (air = 1 at boiling point of AGE): 3.32
5. Melting point: -100°C (-148°F)
6. Vapor pressure at 25°C (77°F): 4.7 mmHg
7. Solubility in water, g/100 g water at 20°C (68°F): 14.1
8. Saturation concentration in air (approximate) at 25°C (77°F): 0.62% (6,200 ppm)

- **Reactivity**

1. Incompatibilities: Contact with strong oxidizers may cause fires and explosions. AGE should not be exposed to light or air because explosive peroxides may be formed.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving AGE.
3. Caution: AGE will cause some forms of plastics, coatings, and rubber to deteriorate.

- **Flammability**

1. Flash point: 57.2°C (135°F) (open cup)
2. Extinguishant: Dry chemical, carbon dioxide, or alcohol foam
3. Class II Combustible Liquid (29 CFR 1910.106)

- **Warning properties**

1. Odor threshold: 10 ppm
2. Evaluation of warning properties for respirator selection: Because of the lack of odor or irritant effects at concentrations below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL), AGE is treated as a chemical with poor warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for AGE is 10 parts of AGE per million parts of air (ppm) [45 milligrams of AGE per cubic meter of air (mg/m³)] as a ceiling concentration which shall at no time be exceeded. The NIOSH REL is 9.6 ppm (45 mg/m³) as a ceiling concentration determined in any 15-minute sampling period. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 5 ppm (22 mg/m³) (Skin) as a time-weighted average (TWA) concentration for a normal 8-hour workday and a 40-hour workweek; the ACGIH short-term exposure limit (STEL) is 10 ppm (44 mg/m³) (Skin). The notation "Skin" refers to the potential contribution to overall exposure by the cutaneous route including mucous membranes and eyes (Table 1).

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Table 1.—Occupational exposure limits for allyl glycidyl ether

	Exposure limits	
	ppm	mg/m³
OSHA PEL ceiling	10	45
NIOSH REL ceiling (15 min)	9.6	45
ACGIH TLV® TWA (Skin)*	5	22
STEL (Skin)	10	44

* (Skin): Potential contribution to overall exposure by the cutaneous route including mucous membranes and eyes.

HEALTH HAZARD INFORMATION

• Routes of exposure

AGE may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• Summary of toxicology

Effects on animals: In mice and rats, acute inhalation or oral administration of AGE caused tearing, nasal discharge, dyspnea (breathing difficulty), narcosis, and death (due to pulmonary edema and central nervous system depression); acute intramuscular injection in rats produced testicular degeneration and toxic effects on the hematopoietic (blood-cell-forming) systems, including decreased leukocyte counts and atrophy of lymphoid tissue. Subchronic inhalation of AGE by rats caused central nervous system depression, reduction in weight gain, corneal opacity, pneumonia, emphysema, and enlarged adrenal glands. AGE was mutagenic in bacterial test systems.

• Signs and symptoms of exposure

1. *Short-term (acute):* Exposure to AGE can cause moderate irritation of the skin and severe irritation of the eyes and respiratory tract.

2. *Long-term (chronic):* Exposure to AGE can cause dermatitis with itching, swelling, and blisters. Skin sensitization to AGE and cross sensitization with other epoxy agents can also occur.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to AGE, the physician 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, nervous, hematopoietic, and reproductive systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to AGE at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such workers. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis.

• Periodic medical screening and/or biologic monitoring

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to AGE. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, and respiratory, nervous, hematopoietic, and reproductive systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

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

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

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

• **Sentinel health events**

Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **Ceiling concentration evaluation**

Measurements to determine worker exposure should be taken during periods of maximum expected airborne concentrations of AGE. Each measurement to determine the NIOSH REL (ceiling exposure) in the worker's breathing zone (air that most nearly represents that inhaled by the worker) should consist of a 15-minute sample or a series of consecutive samples that total 15 minutes. A minimum of three measurements should be taken during one workshift, and the highest of all measurements taken is an estimate of the worker's exposure. If the periods of maximum exposure are not clearly defined, a statistical procedure which can be used as a peak exposure detection strategy is given in the *Occupational Exposure Sampling Strategy Manual*.

• **Method**

Sampling and analysis may be performed by collecting AGE vapors with adsorption tubes of Tenax-GC resin followed by desorption with diethyl ether and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure AGE may also be used if available. A detailed sampling and analytical method for AGE may be found in the *NIOSH Manual of Analytical Methods* (method number S346).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with AGE.

Workers should be provided with and required to use splash-proof safety goggles where AGE may come in contact with the eyes.

SANITATION

Clothing which becomes contaminated with AGE should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of AGE from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of AGE's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with AGE should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle AGE should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to AGE may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for allyl glycidyl ether

Operations	Controls
During use as a reactive diluent in formulation of epoxy resins	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During use as a copolymer for vulcanization of rubber, surface coatings, and epoxy resins	Local exhaust ventilation, general dilution ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to AGE, an eye-wash fountain should be provided within the immediate work area for emergency use.

If AGE gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to AGE, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If AGE gets on the skin, wash it immediately with soap and water. If AGE penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty.

Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If AGE is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing AGE, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from AGE vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing AGE may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. AGE should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing AGE may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for allyl glycidyl ether

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 96 ppm	Any supplied-air respirator
	Any self-contained breathing apparatus
	Any chemical cartridge respirator with organic vapor cartridge(s)
Less than or equal to 240 ppm	Any supplied-air respirator operated in a continuous flow mode (substance reported to cause eye irritation or damage—may require eye protection)
	Any powered air-purifying respirator with organic vapor cartridge(s) (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 270 ppm	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
	Any powered air-purifying respirator with a tight-fitting facepiece and organic vapor cartridge(s) (substance reported to cause eye irritation or damage—may require eye protection)
	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s)
Planned or emergency entry into environments containing unknown concentrations or levels above 270 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

*Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 9.6 ppm (45 mg/m^3) (ceiling).

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ANTIMONY AND ITS COMPOUNDS (as Sb)

INTRODUCTION

"Antimony" is defined as elemental antimony and all antimony compounds with the exception of the gas stibine. This guideline summarizes pertinent information about antimony and its compounds for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** Sb
- **Synonyms:** Antimony regulus, stibium
- **Identifiers:** CAS 7440-36-0; RTECS CC402500; DOT 2871, label required: "St. Andrew's Cross (X)"
- **Appearance:** Silvery, white solid

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data for elemental antimony**

1. Molecular weight: 121.75
2. Boiling point (at 760 mmHg): 1,635 °C (2,975 °F)
3. Specific gravity (water = 1): 6.68
4. Melting point: 630.5 °C (1,116.9 °F)
5. Insoluble in water

- **Reactivity**

Incompatibilities: Oxidizing materials and acids, especially halogenated acids, can react with antimony and alloys containing antimony to produce stibine gas (antimony hydride), which is more toxic than the antimony metal alone.

- **Flammability**

1. Extinguishant: Dry graphite, sodium chloride, or potassium chloride
2. Antimony is combustible in powder form or by chemical reaction with nitrates or halogenated compounds.

- **Warning properties**

Evaluation of warning properties for respirator selection: Based on lack of information on the odor threshold and eye irritation levels, antimony should be considered to have poor warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for antimony and its compounds (as Sb) is 0.5 milligrams per cubic meter of air (mg/m^3) as a time-weighted average (TWA) concentration over an 8-hour workshift. The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) for antimony and its compounds (as Sb) is 0.5 mg/m^3 as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 0.5 mg/m^3 as a TWA for a normal 8-hour workday and a 40-hour workweek for antimony and its compounds (as Sb) including antimony trioxide during handling and use. The ACGIH has given antimony trioxide production an A2 designation (an A2 substance is a suspected human carcinogen) without having sufficient evidence to assign a TLV (Table 1).

Table 1.—Occupational exposure limits for antimony and its compounds

	Antimony and compounds (as Sb), mg/m^3	Antimony trioxide production, mg/m^3
OSHA PEL TWA	0.5	—
NIOSH REL TWA	0.5	—
ACGIH TLV® TWA	0.5	(A2)*

* (A2): Suspected human carcinogen.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Antimony may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

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

• **Summary of toxicology**

1. *Effects on animals:* Intraperitoneal injection of antimony or its compounds into rats produced an increase in blood eosinophil count, acute congestion of the heart, liver, and kidneys, and death (due to heart failure). Subchronic inhalation of antimony trisulfide by rats and rabbits caused degeneration of the heart muscle and changes in electrocardiograms; subcutaneous injections in rats caused fatty degeneration of the liver and swelling of kidney tubules. Chronic inhalation of antimony trioxide by guinea pigs, rats, or rabbits produced extensive lung inflammation, decreased white blood cell and eosinophil counts, enlargement of splenic follicles, and fatty degeneration of the liver.

2. *Effects on humans:* Exposure of workers to antimony trichloride, antimony trisulfide, or antimony trioxide has caused fibrosis of the lungs (pneumoconiosis), electrocardiogram changes, heart muscle changes, and death due to heart disease. Increased rates of spontaneous late abortions, premature births, and gynecologic problems have been reported for female metallurgic workers exposed to antimony trioxide, antimony pentasulfide, or metallic dust.

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to antimony and its compounds can cause gastrointestinal pain, cough, loss of appetite, itching, skin eruptions, and irritation of the skin, eyes, nose, and throat.

2. *Long-term (chronic):* Exposure to antimony and its compounds can cause headache, sleeplessness, dizziness, metallic taste, ulcers, weight loss, nausea, vomiting, diarrhea, impairment of sense of smell, and pain or tightness in the chest.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control occupational injury and disease. The program should include the education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety and health, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include the systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to antimony, the physician 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 cardiovascular, reproductive, and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to antimony at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history and physical or other findings suggestive of cardiovascular or chronic skin disease. The physician should obtain baseline values for electrocardiographic studies appropriate for the age and medical history of the worker.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to antimony. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, and cardiovascular, reproductive, and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and ATS: standardized questionnaires and tests of lung function.

• **Medical practices recommended at the time of job transfer or termination**

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

• **Sentinel health events**

Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **TWA exposure evaluation**

Measurements to determine worker exposure to antimony should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

• **Method**

Sampling and analysis of antimony may be performed by collecting with a cellulose membrane filter, digesting with nitric, sulfuric, and perchloric acids, and analyzing by atomic absorption spectrophotometry. Detailed sampling and analytical methods for antimony may be found in the *NIOSH Manual of Analytical Methods* (method numbers 189 and 261).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with antimony.

Workers should be provided with and required to use dust- and splash-proof safety goggles where antimony may come in contact with the eyes.

SANITATION

Clothing which is contaminated with antimony should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of antimony from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of antimony's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with antimony should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle antimony should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to antimony may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for antimony

Operations	Controls
During crushing and transferring antimony ore	Process enclosure, dilution ventilation, and dust control with water
During production of lead/antimony alloys	Local exhaust ventilation
During machining, grinding, buffing, and polishing of metal products containing antimony	Local exhaust ventilation, personal protective clothing
During the manufacture of paints, pigments, enamels, glazes, ceramics, and glass	Local exhaust ventilation

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to antimony, an eye-wash fountain should be provided within the immediate work area for emergency use.

If antimony gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to antimony, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If antimony gets on the skin, wash it immediately with soap and water. If antimony penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If antimony is spilled or leaked, the following steps should be taken:

1. Ventilate area of spill or leak.
2. For small quantities of liquids containing antimony, absorb on paper towels and place in an appropriate container.
3. Large quantities of liquids containing antimony may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container.
4. If in solid form, antimony may be collected and placed in an appropriate container.
5. Antimony may be collected by vacuuming with an appropriate system.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal of antimony and its compounds are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 3).

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Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for antimony and its compounds

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 5.0 mg/m^3	Any dust and mist respirator except single-use and quarter-mask respirators, if not present as fume
	Any supplied-air respirator
	Any self-contained breathing apparatus
Less than or equal to 12.5 mg/m^3	Any powered air-purifying respirator with dust and mist filter, if not present as fume
	Any supplied-air respirator operated in a continuous flow mode
Less than or equal to 25 mg/m^3	Any air-purifying full facepiece respirator with a high-efficiency particulate filter
	Any powered air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate filter
	Any supplied-air respirator with a tight-fitting facepiece and operated in a continuous flow mode
	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
Less than or equal to 80 mg/m^3	Any supplied-air respirator with a full half-mask and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 80 mg/m^3	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator with a high-efficiency particulate filter
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 0.5 mg/m^3 (TWA).

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BENZENE

POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about benzene for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** C_6H_6
- **Structure:**

- **Synonyms:** Benzol, benzole, benzolene, bicarburet of hydrogen, carbon oil, coal naphtha
- **Identifiers:** CAS 71-43-2; RTECS CY1400000; DOT 1114, label required: "Flammable Liquid"
- **Appearance and odor:** Colorless liquid with an aromatic odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 78.12
2. Boiling point (at 760 mmHg): 80.1°C (176°F)
3. Specific gravity (water = 1): 0.88
4. Vapor density (air = 1 at boiling point of benzene): 2.7
5. Melting point: 5.5°C (42°F)
6. Vapor pressure at 20°C (68°F): 75 mmHg
7. Solubility in water, g/100 g water at 20°C (68°F): 0.06
8. Evaporation rate (butyl acetate = 1): 5.1
9. Saturation concentration in air (approximate) at 25°C (77°F): 12.5% (125,000 ppm)
10. Ionization potential: 9.25 eV

- **Reactivity**

Incompatibilities: Benzene reacts with strong oxidizers including chlorine, oxygen, and bromine with iron.

2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving benzene.
3. Caution: Benzene will attack some forms of plastics, coatings, and rubber.

- **Flammability**

1. Flash point: -11.1°C (12°F) (closed cup)
2. Autoignition temperature: 498°C (928°F)
3. Flammable limits in air, % by volume: Lower, 1.4; upper, 7.1
4. Extinguishant: Alcohol foam, carbon dioxide, and dry chemical extinguishants are effective. Water may be an ineffective extinguishant but may be used to cool fire-exposed containers.
5. Class IB Flammable Liquid (29 CFR 1910.106), Flammability Rating 3 (NFPA)
6. Unusual fire and explosion hazards: Benzene liquid is flammable, and its vapors can easily form explosive mixtures. Flashbacks may occur along a vapor trail.

- **Warning properties**

1. Odor threshold: 12 ppm
2. Eye irritation levels: 3,000 ppm for 0.5-1 hour
3. Other information: 3,000 ppm may irritate nose and respiratory tract.
4. Evaluation of warning properties for respirator selection: Warning properties are not considered in recommending respirators for use with carcinogens.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for benzene is 1 part of benzene per million parts of air (PPM) as a time-weighted average (TWA) concentration over an 8-hour workshift; the short-term exposure limit is 5 ppm in any 15-minute sampling period. The National Institute for Occupational Safety and Health (NIOSH) recommends that benzene be controlled and handled as a potential human carcinogen in the workplace and that exposure be reduced to the lowest feasible limit. The NIOSH recommended exposure limit (REL) is 0.1 ppm [0.32 milligrams of benzene per cubic meter of air (mg/m^3)] as an 8-hour TWA and 1 ppm (3.2 mg/m^3) as a ceiling in any 15-minute sampling period. The NIOSH REL is the lowest con-

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

centration detectable by current NIOSH-validated sampling and analytical methods. The American Conference of Governmental Industrial Hygienists (ACGIH) has designated benzene as an A2 substance (suspected human carcinogen) having an assigned threshold limit value (TLV®) of 10 ppm (30 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek.

Table 1.—Occupational exposure limits for benzene

	Exposure limits ppm	mg/m³
OSHA PEL TWA	1	—
Short-term exposure limit (15 min)	5	—
NIOSH REL (Ca)* TWA	0.1	0.32
Ceiling (15 min)	1	3.2
ACGIH TLV® TWA (A2)†	10	30

* (Ca): NIOSH recommends treating as a potential human carcinogen.
†(A2): Suspected human carcinogen.

HEALTH HAZARD INFORMATION

• Routes of exposure

Benzene may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• Summary of toxicology

1. *Effects on animals:* Acute inhalation of benzene by rats, mice, or rabbits caused narcosis, spontaneous heart contractions (ventricular fibrillation), and death due to respiratory paralysis. Subchronic inhalation of benzene by rats produced decreased white blood cell counts, decreased bone marrow cell activity, increased red blood cell activity, and cataracts. In rats, chronic inhalation or oral administration of benzene produced cancers of the liver, mouth, and Zymbal gland. Inhalation of benzene by pregnant rats caused retardation of fetal development and increased fetal mortality.

2. *Effects on humans:* Acute inhalation exposure of benzene has caused nerve inflammation (polyneuritis), central nervous system depression, and cardiac sensitization. Chronic exposure to benzene has produced anorexia and irreversible injury to the blood-forming organs; effects include aplastic anemia and leukemia.

• Signs and symptoms of exposure

1. *Short-term (acute):* Exposure to benzene can cause dizziness, euphoria, giddiness, headache, nausea, staggering gait, weakness, drowsiness, respiratory irritation, pulmonary edema and pneumonia, gastrointestinal irritation, convulsions, and paralysis. Benzene can also cause irritation to the skin, eyes, and mucous membranes.

2. *Long-term (chronic):* Exposure to benzene can cause fatigue, nervousness, irritability, blurred vision, and labored breathing. Repeated skin contact can cause redness, blistering, and dry, scaly dermatitis.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to benzene, the physician 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, liver, and respiratory, nervous, and hematopoietic (blood-cell-forming) systems. The physician should obtain baseline values for the complete blood count and a stained differential count of all blood cell types. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to benzene at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindi-

cations to job placement, include a history of chronic skin disease, concurrent dermatitis, or mild non-hemolytic anemia (e.g., mild iron-deficiency anemia).

• **Periodic medical screening and/or biologic monitoring**
Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker report symptoms that may be attributed to exposure to benzene. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the integrity and physiologic function of the skin, liver, and respiratory, nervous, and hematopoietic (blood-cell-forming) systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

• **Medical practices recommended at the time of job transfer or termination.**
The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic and laboratory tests which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population. Because occupational exposure to benzene may cause diseases of prolonged induction-latency, the need for medical surveillance may extend well beyond termination of employment.

• **Sentinel health events**
1. Acute SHE's include: Acute myeloid leukemia and contact and/or allergic dermatitis.
2. Delayed-onset SHE's include: Decrease in the number (neutropenia) or absence (agranulocytosis) of certain white blood cells in the peripheral circulation and/or in the bone marrow (aplastic anemia) and cancer of the red blood cells (erythroleukemia).

MONITORING AND MEASUREMENT PROCEDURES

• **TWA exposure evaluation**
Measurements to determine worker exposure to benzene should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

• **Ceiling concentration evaluation**
Measurements to determine worker exposure should be taken during periods of maximum expected airborne concentrations of benzene. Each measurement to determine the NIOSH REL (ceiling exposure) in the worker's breathing zone (air that most nearly represents that inhaled by the worker) should consist of a 15-minute sample. A minimum of three measurements should be taken during one workshift, and the highest of all measurements taken is an estimate of the worker's exposure. If the periods of maximum exposure are not clearly defined, a statistical procedure which can be used as a peak exposure detection strategy is given in the *Occupational Exposure Sampling Strategy Manual*.

• **Method**
Sampling and analysis may be performed by collecting benzene vapors with charcoal tubes followed by desorption with carbon disulfide and analysis by gas chromatography. Direct-reading devices calibrated to measure benzene may also be used if available. A detailed sampling and analytical method for benzene may be found in the *NIOSH Manual of Analytical Methods* (method number 1500).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, and other appropriate protective clothing necessary to prevent skin contact with benzene.

SANITATION

Clothing which is contaminated with benzene should be removed immediately and placed in sealed containers for storage until it can be discarded or until provision is made for the removal of benzene from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of benzene's hazardous properties. Reusable clothing and equipment should be checked for residual contamination before reuse or storage.

A change room with showers, washing facilities, and lockers that permit separation of street and work clothes should be provided.

Workers should be required to shower following a workshift and prior to putting on street clothes. Clean work clothes should be provided daily.

Skin that becomes contaminated with benzene should be promptly washed with soap and water.

Workers who handle benzene should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or use of smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to benzene may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for benzene

Operations	Controls
During the manufacture and processing of benzene; during use as a raw material in the production of aromatic compounds and derivatives	Process enclosure, local exhaust ventilation, personal protective equipment
During the use of chemicals in which benzene may be an impurity (e.g., naphthas, toluene, xylene)	Process enclosure, local exhaust ventilation, personal protective equipment
During the manufacture and use of motor fuel blends in which benzene is used as an ingredient; during use as an extracting solvent	Process enclosure (when possible), local exhaust ventilation, personal protective equipment, material substitution
During the preparation and use of paint and varnish removers, rubber cements, and lacquers	Process enclosure (when possible), local exhaust ventilation, personal protective equipment, material substitution

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**
Where there is any possibility of a worker's eyes being exposed to benzene, an eye-wash fountain should be provided within the immediate work area for emergency use.

If benzene gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**
Where there is any possibility of a worker's body being exposed to benzene, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If benzene gets on the skin, wash it immediately with soap and water. If benzene penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**
If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If benzene is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing benzene, absorb on paper towels and place in an appropriate container.
4. Large quantities of liquids containing benzene may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container.
5. Liquids containing benzene may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

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Table 3.—Respiratory protection for benzene

Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BERYLLIUM AND ITS COMPOUNDS POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about beryllium and its compounds for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** Be
- **Synonyms:** Synonyms vary depending upon specific compound
- **Identifiers:** CAS 7440-41-7; RTECS DS1750000; DOT 1567, label required: "Poison, Flammable Solid"
- **Appearance:** Silvery gray metal

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 9.01
2. Boiling point (at 760 mmHg): 2,970°C (5,378°F)
3. Specific gravity (water = 1): 1.85
4. Melting point: 1,283°C (2,341°F)
5. Insoluble in water

- **Reactivity**

1.Incompatibilities: Acids, alkalies, chlorinated hydrocarbons, and oxidizable agents

2. Hazardous decomposition products: Beryllium reacts with strong acids to evolve hydrogen.

- **Flammability**

1. Extinguishant: Sand, soda ash, or commercial metal fire extinguishant powder may be used. Do not use water or carbon dioxide.
2. Flammability Rating 1 (NFPA)
3. Caution: Powdered beryllium is flammable in air. Hazard increases as fineness of powder increases.

- **Warning properties**

Evaluation of warning properties for respirator selection: Warning properties are not considered in recommending respirators for use with carcinogens.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for beryllium and its compounds is 2 micrograms of beryllium per cubic meter of air ($\mu g/m^3$) as a time-weighted average (TWA) concentration over an 8-hour workshift; the acceptable ceiling concentration is 5 $\mu g/m^3$; and the maximum peak concentration above the acceptable ceiling concentration (maximum duration of 30 minutes) is 25 $\mu g/m^3$. The National Institute for Occupational Safety and Health (NIOSH) recommends that beryllium be controlled and handled as a potential human carcinogen in the workplace and that exposure be minimized to the lowest feasible level. The NIOSH recommended exposure limit (REL) is that occupational exposure to beryllium be controlled so that no worker will be exposed in excess of 0.5 $\mu g/m^3$. The NIOSH REL is the lowest concentration reliably detectable by current NIOSH-validated sampling and analytical methods. The American Conference of Governmental Industrial Hygienists (ACGIH) has designated beryllium as an A2 substance (suspected human carcinogen) having an assigned threshold limit value (TLV®) of 2 $\mu g/m^3$ as a TWA for a normal 8-hour workday and a 40-hour workweek (Table 1).

Table 1.—Occupational exposure limits for beryllium

	Exposure limits $\mu g/m^3$
OSHA PEL TWA	2
Acceptable ceiling	5
Maximum peak above ceiling (30 min)	25
NIOSH REL (Ca)*	
No exposure in excess of	0.5
ACGIH TLV® TWA (A2)†	2

* (Ca): NIOSH recommends treating as a potential human carcinogen.
† (A2): Suspected human carcinogen.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Beryllium may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

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• **Summary of toxicology**

1. *Effects on animals:* Chronic inhalation or intratracheal injection of beryllium metal or its compounds produced lung cancer in rats. Single intrabronchial implantations of beryllium oxide or chronic inhalation of beryllium sulfate produced lung cancer in monkeys. In rabbits, intraosseous administration of beryllium metal or its compounds produced bone cancer.

2. *Effects on humans:* Acute or chronic inhalation of beryllium has caused rhinitis (inflammation of the mucous membranes of the nose), tracheobronchitis (inflammation of the trachea and bronchi), pneumonitis (inflammation of the lungs), and death due to pulmonary edema or heart failure. Chronic inhalation of beryllium has been associated with kidney stones; enlargement of the liver, spleen, and heart; multiple granulomas of the lung, spleen, liver, and lymph nodes; and an increased incidence of lung cancer.

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to beryllium can cause pain below the sternum, weight loss, nonproductive cough, shortness of breath, and irritation of the eyes, respiratory system, and skin.

2. *Long-term (chronic):* Exposure to beryllium can cause cough, pain in the joints, general weakness, weight loss, clubbing of fingers, shortness of breath, cyanosis, and allergic contact dermatitis. Accidental implantation of beryllium metal or crystals into the skin can cause tissue necrosis and ulceration.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to beryllium, the physician 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, liver, kidneys, spleen, and cardiovascular and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to beryllium at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis and significant breathing impairment due to preexisting chronic lung disease. Skin patch testing with soluble beryllium compounds is *not* recommended because of the risk of sensitization.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to beryllium. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the skin, liver, kidneys, spleen, and cardiovascular and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires, tests of lung function, and chest X-rays. In the event of the occurrence of a chronic respiratory disease, diagnostic tests such as the lymphocyte transformation test may be useful in determining the role of beryllium sensitization.

• **Medical practices recommended at the time of job transfer or termination**

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

• **Sentinel health events**

1. Acute SHE's include: Contact and/or allergic dermatitis.
2. Delayed-onset SHE's include: Chronic beryllium disease of the lungs.

MONITORING AND MEASUREMENT PROCEDURES

• **Method**

Sampling and analysis may be performed by collecting beryllium with cellulose membrane filters followed by digestion with acid and analysis by flameless atomic absorption with a graphite furnace. A detailed sampling and analytical method for beryllium may be found in the *NIOSH Manual of Analytical Methods* (method number 7102).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, and other appropriate protective clothing necessary to prevent skin contact with beryllium.

SANITATION

Clothing which is contaminated with beryllium should be removed immediately and placed in sealed containers for storage until it can be discarded or until provision is made for the removal of beryllium from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of beryllium's hazardous properties. Reusable clothing and equipment should be checked for residual contamination before reuse or storage.

A change room with showers, washing facilities, and lockers that permit separation of street and work clothes should be provided.

Workers should be required to shower following a workshift and prior to putting on street clothes. Clean work clothes should be provided daily.

Skin that becomes contaminated with beryllium should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle beryllium should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to beryllium may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for beryllium

Operations	Controls
During use in the manufacture of electrical components and ceramics	Process enclosure, local exhaust ventilation, personal protective equipment
During use in the production of beryllium metal from ore	Process enclosure, local exhaust ventilation, personal protective equipment
During use in the production of alloy	Process enclosure, local exhaust ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to beryllium, an eye-wash fountain should be provided within the immediate work area for emergency use.

If beryllium gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to beryllium, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If beryllium gets on the skin, wash it immediately with soap and water. If beryllium penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If beryllium is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.

3. For small quantities of liquids containing beryllium or beryllium compounds, absorb on paper towels and place in an appropriate container.
4. Large quantities of liquids containing beryllium or beryllium compounds may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container.
5. Beryllium dust may be collected by vacuuming with an appropriate high-efficiency filtration system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

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Table 3.—Respiratory protection for beryllium

Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator with a high-efficiency particulate filter
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.

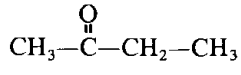
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR 2-BUTANONE

INTRODUCTION

This guideline summarizes pertinent information about 2-butanone for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** C_4H_8O
- **Structure:**



- **Synonyms:** Ethyl methyl ketone, MEK, methyl ethyl ketone
- **Identifiers:** CAS 78-93-3; RTECS EL6475000; DOT 1193, label required: "Flammable Liquid"
- **Appearance and odor:** Clear and colorless liquid with an odor like acetone

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 72.12
2. Boiling point (at 760 mmHg): 79.6 °C (175 °F)
3. Specific gravity (water = 1): 0.806
4. Vapor density (air = 1 at boiling point of 2-butanone): 2.5
5. Melting point: -86.5 °C (-123.7 °F)
6. Vapor pressure at 20 °C (68 °F): 70 mmHg; at 25 °C (77 °F), 100 mmHg
7. Solubility in water, g/100 g water at 20 °C (68 °F): 25.6
8. Evaporation rate (butyl acetate = 1): 5.7
9. Saturation concentration (approximate) at 20 °C (68 °F): 10.2% (102,000 ppm); at 25 °C (77 °F), 13.2% (132,000 ppm)
10. Ionization potential: 9.48 eV

- **Reactivity**

1. Incompatibilities: Strong oxidizing agents
2. Hazardous decomposition products: Toxic vapors and gases (e.g., formaldehyde and carbon monoxide) may be released in a fire involving 2-butanone.

- **Flammability**

1. Flash point: -9 °C (16 °F) (closed cup)
2. Autoignition temperature: 515.5 °C (959 °F)
3. Flammable limits in air, % by volume: Lower, 2; upper, 10
4. Extinguishant: Carbon dioxide, dry chemicals, or alcohol foam
5. Class IB Flammable Liquid (29 CFR 1910.106), Flammability Rating 3 (NFPA)

- **Warning properties**

1. Odor threshold: 5 ppm
2. Eye irritation levels: 200-350 ppm
3. Evaluation of warning properties for respirator selection: Because of its odor, 2-butanone can be detected below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus, it is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for 2-butanone is 200 parts of 2-butanone per million parts of air (ppm) [590 milligrams of 2-butanone per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The NIOSH REL is 200 ppm (590 mg/m³) as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 200 ppm (590 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek; the ACGIH short-term exposure limit (STEL) is 300 ppm (885 mg/m³) (Table 1).

Table 1.—Occupational exposure limits for 2-butanone

	Exposure limits	
	ppm	mg/m³
OSHA PEL TWA	200	590
NIOSH REL TWA	200	590
ACGIH TLV® TWA	200	590
STEL	300	885

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

HEALTH HAZARD INFORMATION

• **Routes of exposure**

2-Butanone may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• **Summary of toxicology**

Effects on animals: Acute inhalation of 2-butanone by guinea pigs caused narcosis, corneal opacities, emphysema, congestion of the brain, lungs, liver, and kidneys, and death. Inhalation of 2-butanone by pregnant rats caused an increased incidence of reduced lengths and weights in offspring.

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to 2-butanone can cause headache, dizziness, drowsiness, vomiting, and numbness of the extremities. Irritation of the eyes, nose, and throat can also occur.
2. *Long-term (chronic):* Exposure to 2-butanone can cause dryness and irritation of the skin.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to 2-butanone, the physician 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, liver, kidneys, and nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to 2-butanone at or below the NIOSH REL (especially if exposure occurs in combination with 2-hexanone). The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include concurrent dermatitis, a history of chronic skin disease, or a history and physical findings consistent with peripheral neuropathy.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to 2-butanone. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, liver, kidneys, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

• **Medical practices recommended at the time of job transfer or termination**

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

• **Sentinel health events**

Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **TWA exposure evaluation**

Measurements to determine worker exposure to 2-butanone should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to deter-

mine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

- **Method**

Sampling and analysis may be performed by collecting 2-butanone vapors with charcoal tubes followed by desorption with carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure 2-butanone may also be used if available. A detailed sampling and analytical method for 2-butanone may be found in the *NIOSH Manual of Analytical Methods* (method number 2500).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with 2-butanone.

Workers should be provided with and required to use splash-proof goggles where 2-butanone may come in contact with the eyes.

SANITATION

Clothing which is contaminated with 2-butanone should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of 2-butanone from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of 2-butanone's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with 2-butanone should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle 2-butanone should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to 2-butanone may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for 2-butanone

Operations	Controls
During spray application of vinyl and acrylic coatings; during mixing of dye solutions; during use in laboratories	Local exhaust ventilation, personal protective equipment
During surface spreading and coating of nitrocellulose and vinyl resins; during mixing, batching, and packaging of surface coating preparations; during forced drying of furniture finishes; during dewaxing; during use as a chemical intermediate	Local exhaust ventilation
During use in the application of adhesives for artificial leather	Dilution ventilation, personal protective equipment
During preparatory formulations of lacquers; during sponge or brush application of solvent for cleaning operations; during mixing of waterproofing compounds	Personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to 2-butanone, an eye-wash fountain should be provided within the immediate work area for emergency use.

If 2-butanone gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to 2-butanone, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If 2-butanone gets on the skin, wash it immediately with soap and water. If 2-butanone penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If 2-butanone is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing 2-butanone, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from 2-butanone vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing 2-butanone may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. 2-Butanone should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing 2-butanone may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for 2-butanone

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 1,000 ppm	Any powered air-purifying respirator with organic vapor cartridge(s) (substance causes eye ir ritation or damage—eye protection needed)
	Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s)
Less than or equal to 3,000 ppm	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any supplied-air respirator operated in a continuous flow mode (substance causes eye irritation or damage—eye protection needed)
	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
Planned or emergency entry into environments containing unknown concentrations or levels above 3,000 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 200 ppm (590 mg/m^3) (TWA).

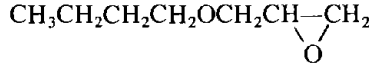
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR n-BUTYL GLYCIDYL ETHER

INTRODUCTION

This guideline summarizes pertinent information about n-butyl glycidyl ether (BGE) for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_7H_{14}O_2$
- **Structure:**



- **Synonyms:** BGE; butyl glycidyl ether; 2,3-epoxypropyl butyl ether; 1-butoxy-2,3-epoxypropane
- **Identifiers:** CAS 2426-08-6; RTECS TX4200000; DOT not assigned
- **Appearance and odor:** Colorless to pale yellow liquid with a slightly unpleasant odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 130.21
2. Boiling point (at 760 mmHg): 164°C (327°F)
3. Specific gravity (water = 1): 0.91
4. Vapor density (air = 1 at boiling point of BGE): 4.5
5. Vapor pressure at 20°C (68°F): 3 mmHg
6. Solubility in water, g/100 g water at 20°C (68°F): 2
7. Evaporation rate (butyl acetate = 1): 0.36
8. Saturation concentration in air (approximate) at 25°C (77°F): 0.42% (4,200 ppm)

- **Reactivity**

1. Incompatibilities: Contact between BGE and strong oxidizing agents may cause fires and explosions. Contact between BGE and strong caustics may cause polymerization with the liberation of heat, which may cause the container to burst. BGE should not be exposed to light or air because explosive peroxides may be formed.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving BGE.
3. Caution: BGE will cause some forms of plastics, coatings, and rubber to deteriorate.

- **Flammability**

1. Flash point: 54°C (130°F) (closed cup)
2. Extinguishant: Dry chemical, carbon dioxide, or alcohol foam
3. Class II Combustible Liquid (29 CFR 1910.106)

- **Warning properties**

Evaluation of warning properties for respirator selection: Based on lack of information on odor threshold and eye irritation levels, BGE should be considered to have poor warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for BGE is 50 parts of BGE per million parts of air (ppm) [270 milligrams of BGE per cubic meter of air (mg/m^3)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) is 5.6 ppm (30 mg/m^3) as a ceiling concentration determined in any 15-minute sampling period. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 25 ppm (135 mg/m^3) as a TWA for a normal 8-hour workday and a 40-hour workweek (Table 1).

Table 1.—Occupational exposure limits for n-butyl glycidyl ether

	Exposure limits	
	ppm	mg/m^3
OSHA PEL TWA	50	270
NIOSH REL Ceiling (15 min)	5.6	30
ACGIH TLV® TWA	25	135

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

HEALTH HAZARD INFORMATION

• **Routes of exposure**
BGE may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• **Summary of toxicology**
Effects on animals: In rats and mice, acute inhalation or oral administration of BGE caused central nervous system depression, pulmonary edema, and death; intramuscular injection in rats produced increased white blood cell counts. Subchronic inhalation of BGE by rats produced testicular atrophy; dermal exposure of male mice that were subsequently bred to unexposed females produced an increased incidence of fetal deaths. BGE was mutagenic in bacterial test systems, and DNA damage was induced *in vitro* in human white blood cells.

• **Signs and symptoms of exposure**
1. *Short-term (acute):* Exposure to BGE can cause mild irritation of the skin, eyes, nose, and respiratory tract.
2. *Long-term (chronic):* Exposure to BGE can cause inflammation and sensitization of the skin.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**
Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**
Prior to placing a worker in a job with a potential for exposure to BGE, the physician 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 reproductive, nervous respiratory, and hematopoietic (blood-cell-forming) systems Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to BGE at or below the NIOSH REL.

The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis.

• **Periodic medical screening and/or biologic monitoring**
Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to BGE. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, and reproductive, nervous, respiratory, and hematopoietic systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

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

• **Sentinel health events**
Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **Ceiling concentration evaluation**
Measurements to determine worker exposure should be taken during periods of maximum expected airborne concentrations of BGE. Each measurement to determine the NIOSH REL (ceiling exposure) in the worker's breathing zone (air that most nearly represents that inhaled by the worker) should consist of a 15-minute sample or a series of consecutive samples that total 15 minutes. A minimum of three measurements should be taken during one workshift, and the highest of all measurements taken is an estimate of the worker's exposure. If the peri-

ods of maximum exposure are not clearly defined, a statistical procedure which can be used as a peak exposure detection strategy is given in the *Occupational Exposure Sampling Strategy Manual.*

• **Method**
Sampling and analysis may be performed by collecting BGE vapors with charcoal tubes followed by desorption with carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure BGE may also be used if available. A detailed sampling and analytical method for BGE may be found in *NIOSH Manual of Analytical Methods* (method number S81).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with BGE.

Workers should be provided with and required to use splash-proof safety goggles where BGE may come in contact with the eyes.

SANITATION

Clothing which is contaminated with BGE should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of BGE from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of BGE's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with BGE should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle BGE should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to BGE may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for BGE

Operations	Controls
During use as a reactive diluent of epoxy resins	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During use as a chemical intermediate for preparation of ethers, surfactants, polymers, and resins	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During use as a stabilizing agent for organic chemicals	Local exhaust ventilation, general dilution ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**
Where there is any possibility of a worker's eyes being exposed to BGE, an eye-wash fountain should be provided within the immediate work area for emergency use.

If BGE gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**
Where there is any possibility of a worker's body being exposed to BGE, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If BGE gets on the skin, wash it immediately with soap and water. If BGE penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**
If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If BGE is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing BGE, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from BGE vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing BGE may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. BGE should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing BGE may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for n-butyl glycidyl ether

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 56 ppm	Any supplied-air respirator (substance reported to cause eye irritation or damage—may require eye protection)
	Any self-contained breathing apparatus (substance reported to cause eye irritation or damage—may require eye protection)
	Any chemical cartridge respirator with organic vapor cartridge(s) (substance reported to cause eye irritation or damage may require eye protection)
Less than or equal to 140 ppm	Any supplied-air respirator operated in a continuous flow mode (substance reported to cause eye irritation or damage—may require eye protection)
	Any powered air-purifying respirator with organic vapor cartridge(s) (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 280 ppm	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
	Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s)
	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any powered air-purifying respirator with a tight-fitting facepiece and organic vapor cartridge(s) (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 3,500 ppm	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 3,500 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 5.6 ppm (30 mg/m^3) (ceiling).

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR n-BUTYL MERCAPTAN

INTRODUCTION

This guideline summarizes pertinent information about n-butyl mercaptan for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_4H_{10}S$
- **Structure:** CH_3-$(CH_2)_2$-CH_2-SH
- **Synonyms:** n-Butanethiol; 1-butanethiol; butyl sulfhydrate; thiobutyl alcohol
- **Identifiers:** CAS 109-79-5; RTECS EK6300000; DOT 2347, label required: "Flammable Liquid"
- **Appearance and odor:** Clear, colorless liquid with a strong, obnoxious odor like garlic or skunk

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical Data**

1. Molecular weight: 90.19
2. Boiling point (at 760 mmHg): 97.8°C (208°F)
3. Specific gravity (water = 1): 0.8368
4. Vapor density (air = 1 at boiling point of n-butyl mercaptan): 3.1
5. Melting point: -116°C (-177°F)
6. Vapor pressure at 20°C (68°F): 35 mmHg
7. Solubility in water, g/100 g water at 20°C (68°F): 0.06
8. Evaporation rate (butyl acetate = 1): 2.86
9. Saturation concentration in air (approximate) at 20°C (68°F): 4.6% (46,000 ppm)
10. Ionization potential: 9.14 eV

- **Reactivity**

1. Incompatibilities: Strong oxidizing agents; n-butyl mercaptan should not be stored in copper or copper-containing materials.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., sulfur dioxide and carbon monoxide) may be released in a fire involving n-butyl mercaptan.
3. Caution: n-Butyl mercaptan will attack some forms of plastics, coating, and rubber.

- **Flammability**

1. Flash point: 2°C (35°F)
2. Extinguishant: Carbon dioxide, dry chemicals, or foam
3. Class IB Flammable Liquid (29 CFR 1910.106), Flammability Rating 3 (NFPA)

- **Warning properties**

1. Odor threshold: 1.0 to 48 ppb
2. Evaluation of warning properties for respirator selection: Because of its odor, n-butyl mercaptan can be detected below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus, it is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for n-butyl mercaptan is 10 parts of n-butyl mercaptan per million parts of air (ppm) [35 milligrams of n-butyl mercaptan per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The NIOSH REL is 0.5 ppm (1.8 mg/m³) as a ceiling concentration determined in any 15-minute sampling period. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 0.5 ppm (1.5 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek (Table 1).

Table 1.—Occupational exposure limits for n-butyl mercaptan

	Exposure limit	
	ppm	mg/m³
OSHA PEL TWA	10	35
NIOSH REL ceiling (15 min)	0.5	1.8
ACGIH TLV® TWA	0.5	1.5

HEALTH HAZARD INFORMATION

- **Routes of exposure**

n-Butyl mercaptan may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

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• **Summary of toxicology**

1. *Effects on animals:* In mice and rats, inhalation of n-butyl mercaptan caused increased breathing rates, hyperactivity, uncoordinated movement, staggering gait, muscular weakness, partial skeletal muscle paralysis, deficient oxygenation of the blood (cyanosis), sedation, and death.
2. *Effects on humans:* In an industrial accident, seven workers were exposed to n-butyl mercaptan for approximately 1 hour at a concentration estimated between 50 and 500 ppm; all workers experienced some of the symptoms listed below, although the specific combination of symptoms varied for each individual.

• **Signs and symptoms of exposure**

Short-term (acute): Exposure to n-butyl mercaptan can cause irritation of the mucous membranes, weakness, malaise, increased respiration, neck pain, drowsiness, nausea, vomiting, sweating, dizziness, confusion, and coma.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to n-butyl mercaptan, the physician 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 risk. These should concentrate on the function and integrity of the nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to n-butyl mercaptan at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include chronic diseases of the respiratory system.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to n-butyl mercaptan. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

• **Medical practices 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 which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population.

MONITORING AND MEASUREMENT PROCEDURES

• **Ceiling concentration evaluation**

Measurements to determine worker exposure should be taken during periods of maximum expected airborne concentrations of n-butyl mercaptan. Each measurement to determine the NIOSH REL (ceiling exposure) in the worker's breathing zone (air that most nearly represents that inhaled by the worker) should consist of a 15-minute sample or a series of consecutive samples that total 15 minutes. A minimum of three measurements should be taken during one workshift, and the highest of all measurements taken is an estimate of the worker's exposure. If the periods of maximum exposure are not clearly defined, a statistical procedure which can be used as a peak exposure detection strategy is given in the *Occupational Exposure Sampling Strategy Manual*.

• **Method**

Sampling and analysis may be performed by collecting n-butyl mercaptan vapors with Chromosorb 104 tubes, followed by desorption with acetone and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure n-butyl mercaptan may be used if available. A detailed sampling and analytical method for n-butyl mercaptan may be found in the *NIOSH Manual of Analytical Methods* (method number S350).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with n-butyl mercaptan.

Workers should be provided with and required to use splash-proof safety goggles where n-butyl mercaptan may come in contact with the eyes.

SANITATION

Clothing which is contaminated with n-butyl mercaptan should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of n-butyl mercaptan from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of n-butyl mercaptan's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with n-butyl mercaptan should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle n-butyl mercaptan should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to n-butyl mercaptan may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for n-butyl mercaptan

Operations	Controls
During the manufacture and processing of n-butyl mercaptan; during use as an odorant for natural gas	Process enclosure, local exhaust ventilation, personal protective equipment
During use as a chemical intermediate in the manufacture of agricultural chemicals, herbicides, and defoliants	Process enclosure, local exhaust ventilation, personal protective equipment
During use in the polymer industry in the manufacture of polymerization catalysts, stabilizers, modifiers, and chain transfer agents	Process enclosure, local exhaust ventilation, personal protective equipment
During use as a solvent; during the cleaning and maintenance of storage vessels and equipment	Local exhaust ventilation, general dilution ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to n-butyl mercaptan, an eye-wash fountain should be provided within the immediate work area for emergency use.

If n-butyl mercaptan gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to n-butyl mercaptan, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If n-butyl mercaptan gets on the skin, wash it immediately with soap and water. If n-butyl mercaptan penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the location of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If n-butyl mercaptan is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing n-butyl mercaptan, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from n-butyl mercaptan vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing n-butyl mercaptan may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. n-Butyl mercaptan should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing n-butyl mercaptan may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for n-butyl mercaptan

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 5 ppm	Any supplied-air respirator
	Any self-contained breathing apparatus
	Any chemical cartridge respirator with organic vapor cartridge(s)
Less than or equal to 12.5 ppm	Any supplied-air respirator operated in a continuous flow mode
	Any powered air-purifying respirator with organic vapor cartridge(s)
Less than or equal to 25 ppm	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
	Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s)
	Any powered air-purifying respirator with a tight-fitting facepiece and organic vapor cartridge(s)
	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
Less than or equal to 500 ppm	Any supplied-air respirator with a half-mask and operated in a pressure-demand or other positive pressure mode (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 1,000 ppm	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 1,000 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any suppplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 0.5 ppm (1.8 mg/m^3) (ceiling).

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR CRESOL, ALL ISOMERS

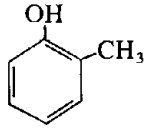
INTRODUCTION

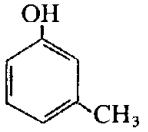
This guideline summarizes pertinent information about the three isomers of cresol (ortho-, meta-, and para-cresol) for workers, employers, and occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; therefore, readers are advised to regard these recommendations as general guidelines. Throughout this guideline, the term "cresol" refers to any of the three isomers.

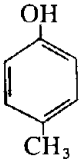
SUBSTANCE IDENTIFICATION

Data in the following section are presented for the three isomers of cresol: (1) ortho; (2) meta; (3) para. If unspecified, data apply to all three isomers.

- **Formula:** C_7H_8O
- **Structure:**

(1) 

(2) 

(3) 

- **Synonyms:** (1) o-Cresol; 2-cresol; o-cresylic acid; 1-hydroxy-2-methylbenzene; o-hydroxy toluene; (2) m-Cresol; 3-cresol; m-cresylic acid; 1-hydroxy-3-methylbenzene; m-hydroxy toluene; 3-hydroxy toluene; (3) p-Cresol; 4-cresol; p-cresylic acid; 1-hydroxy-4-methylbenzene; p-hydroxy toluene; 4-hydroxy toluene

- **Identifiers:** (1) CAS 95-48-7; RTECS G06300000; DOT 2076; (2) CAS 108-39-4; RTECS G06125000; DOT 2076; (3) CAS 106-44-5; RTECS G06475000; DOT 2076; DOT label required for all isomers: "Poison"

- **Appearance and odor:** Colorless crystals or liquid with an odor like phenol or creosote

CHEMICAL AND PHYSICAL PROPERTIES

Data in the following section are presented for the three isomers of cresol: (1) ortho; (2) meta; (3) para. If unspecified, data apply to all three isomers.

- **Physical data**

1. Molecular weight: 108.13
2. Boiling point (at 760 mmHg): (1) 191°C (376°F); (2) 202.7°C (397°F); (3) 201.9°C (395°F)
3. Specific gravity (water = 1): (1) 1.048; (2) 1.034; (3) 1.035
4. Vapor density (air = 1 at boiling point of cresol): 3.72
5. Melting point: (1) 30.9°C (87.8°F); (2) 12.0°C (49°F); (3) 34.8°C (95°F)
6. Vapor pressure at 25°C (77°F): (1) 0.25 mmHg; (2) 0.15 mmHg; (3) 0.11 mmHg
7. Solubility in water, g/100 g water at 25°C (77°F): (1) 2.5; (2) 2.2; (3) 1.9
8. Evaporation rate (butyl acetate = 1): (1) 0.025; (2) 0.015; (3) 0.011
9. Saturation concentration in air (approximate) at 25°C (77°F): (1) 0.03% (300 ppm); (2) 0.02% (200 ppm); (3) 0.014% (140 ppm)
10. Ionization potential: (1) 8.93 eV; (2) 8.98 eV; (3) 8.97 eV

- **Reactivity**

1. Incompatibilities: Strong oxidizing agents, alkalies, and heat.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide and formaldehyde) may be released in a fire involving cresol.
3. Caution: Liquid cresol will attack some forms of plastics, coatings, and rubber.

- **Flammability**

1. Flash point: (1) 81.1°C (178°F) (closed cup); (2) 86.1°C (187°F) (closed cup); (3) 86.1°C (187°F) (closed cup)
2. Autoignition temperature: (1) 559°C (1040°F); (2) 626°C (1158°F); (3) 559°C (1040°F)
3. Flammable limits in air, % by volume: (1) Lower, 1.4 at 149°C (300°F); upper, not available; (2) lower, 1.1 at 150°C (302°F); upper, not available; (3) lower, 1.1 at 150°C (302°F); upper, not available
4. Extinguishant: Dry chemical, foam, or carbon dioxide
5. Class IIIA Combustible Liquid (29 CFR 1910.106), Flammability Rating 2 (NFPA)

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• **Warning properties**

1. Odor threshold: Less than 1 ppm
2. Evaluation of warning properties for respirator selection: Because of its odor, cresol can be detected below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus, cresol is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for cresol is 5 parts of cresol per million parts of air (ppm) [22 milligrams of cresol per cubic meter of air (mg/m^3)] as a time-weighted average (TWA) concentration over an 8-hour workshift (Skin). The notation "Skin" refers to the potential contribution to overall exposure by the cutaneous route including mucous membranes and eyes. The NIOSH REL is 2.3 ppm (10 mg/m^3) as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 5 ppm (22 mg/m^3) (Skin) as a TWA for a normal 8-hour workday and a 40-hour workweek (Table 1).

Table 1.—Occupational exposure limits for cresol (all isomers)

	Exposure limits	
	ppm	mg/m^3
OSHA PEL TWA (Skin)*	5	22
NIOSH REL TWA	2.3	10
ACGIH TLV® TWA (Skin)	5	22

* (Skin): Potential contribution to overall exposure by the cutaneous route including mucous membranes and eyes.

HEALTH HAZARD INFORMATION

• **Routes of exposure**

Cresol may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• **Summary of toxicology**

1. *Effects on animals:* In rats and rabbits, acute dermal absorption of cresol caused tremors, convulsions, fluid in the lungs, liver injury, and kidney inflammation; oral administration caused gastrointestinal tract inflammation, pneumonia, injury to the liver and kidneys, convulsions, and coma. Chronic inhalation of cresol by rats and mice produced inflammation and fluid accumulation in the airways, damage to the bone marrow, and degeneration of cells in the brain.
2. *Effects on humans:* Acute exposure to cresol has caused alterations in brain function and death due to respiratory failure. Repeated exposure by any route has produced nervous disorders, fluid in the lungs, and death due to severe damage to the liver, kidneys, pancreas, or spleen.

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to cresol can cause muscular weakness, nausea, vomiting, abdominal pain, headache, dizziness, dimness of vision, ringing in the ears, weak pulse, rapid and labored breathing, fainting, and mental confusion and depression. Skin irritation and burns can also occur. Eye contact with cresol can cause extensive damage and blindness.
2. *Long-term (chronic):* Exposure to cresol can cause difficulty in swallowing, vomiting, salivation, loss of appetite, and diarrhea. Skin eruptions, rash, and dermatitis can also occur.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to cresol, the physician 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, liver, kidneys, and respiratory and central nervous systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to cresol at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include historical and physical or laboratory findings consistent with chronic diseases of the skin or liver. In addition to the medical interview and physical examination, the means to identify these conditions may include serologic screening tests of liver function and markers for hepatitis A or B infection.

• **Periodic medical screening and/or biologic monitoring**
Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker report symptoms that may be attributed to exposure to cresol. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the integrity or physiologic function of the eyes, skin, liver, kidneys, and respiratory and central nervous systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. Liver function tests should be used and interpreted according to standardized epidemiologic procedures and evaluation criteria.

The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and ATS: standardized questionnaires and tests of lung function.

• **Medical practices recommended at time of job transfer or termination**
The medical, environmental, and occupational history interviews, the physical examination, the selected physiologic and laboratory tests which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population. Because occupational exposure to cresol may cause diseases of prolonged induction-latency, the need for medical surveillance may extend well beyond termination of employment.

• **Sentinel health events**
Acute and delayed-onset SHE's include toxic hepatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **TWA exposure evaluation**
Measurements to determine worker exposure to cresol should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

• **Method**
Sampling and analysis may be performed by collecting cresol with silica gel tubes followed by desorption with acetone and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure cresol may also be used if available. A detailed sampling and analytical method for cresol may be found in the *NIOSH Manual of Analytical Methods* (method number 2001).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with cresol.

Workers should be provided with and required to use dust- and splash-proof safety goggles where cresol may come in contact with the eyes.

SANITATION

Clothing which is contaminated with cresol should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of cresol from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of cresol's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with cresol should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle cresol should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to cresol may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for cresol

Operations	Controls
During use in the manufacture of antiseptics and disinfectants, phosphate esters, antioxidants, resins, herbicides, perfumes, explosives, and photographic developers	Process enclosure, general dilution ventilation, personal protective equipment
During use as a solvent and as an engine and metal cleaner; during use in the textile industry	Process enclosure, general dilution ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to cresol, an eyewash fountain should be provided within the immediate work area for emergency use.

If cresol gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to cresol, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If cresol gets on the skin, wash it immediately with soap and water. If cresol penetrates the clothing, remove the clothing immediately and wash the skin with soap and water.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If cresol is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing cresol, absorb on paper towels and place in an appropriate container. Place tow in a safe place such as a fume hood for evaporation. Allow suf cient time for evaporation of the vapors so that the hood du work is free from cresol vapors. Burn the paper in a suitat location away from combustible materials.
4. Large quantities of liquids containing cresol may be absorb in vermiculite, dry sand, earth, or a similar material and plac in an appropriate container. Cresol should not be allowed enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing cresol may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for cresol (all isomers)

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 23 ppm	Any chemical cartridge respirator with organic vapor cartridge(s) in combination with a dust and mist filter
	Any supplied-air respirator
	Any self-contained breathing apparatus
Less than or equal to 57.5 ppm	Any supplied-air respirator operated in a continuous flow mode
	Any powered air-purifying respirator with organic vapor cartridge(s) in combination with a dust and mist filter
Less than or equal to 115 ppm	Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s) in combination with a high-efficiency particulate filter
	Any supplied-air respirator with a full facepiece
	Any self-contained breathing apparatus with a full facepiece
	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister having a high-efficiency particulate filter
	Any powered air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate filter (substance reported to cause eye irritation or damage—may require eye protection)
	Any supplied-air respirator with a tight-fitting facepiece operated in a continuous flow mode (substance reported to cause eye damage—may require eye protection)
Less than or equal to 250 ppm	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 250 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister having a high-efficiency particulate filter
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 2.3 ppm (10 mg/m³) (TWA).

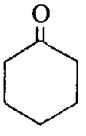
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR CYCLOHEXANONE

INTRODUCTION

This guideline summarizes pertinent information about cyclohexanone for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_6H_{10}O$
- **Structure:**



- **Synonyms:** Anone, hexanon, ketohexamethylene, nadone, pimelic ketone, pimelin ketone
- **Identifiers:** CAS 108-94-1; RTECS GW1050000; DOT 1915, label required: "Flammable Liquid"
- **Appearance and odor:** Colorless to slightly yellow liquid with an odor like peppermint

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 98.16
2. Boiling point (at 760 mmHg): 155.6°C (312°F)
3. Specific gravity (water = 1): 0.95
4. Vapor density (air = 1 at boiling point of cyclohexanone): 3.4
5. Melting point: -47°C (-52.6°F)
6. Vapor pressure at 20°C (68°F): 2 mmHg; at 25°C (77°F), 4.5 mmHg
7. Slightly soluble in water
8. Evaporation rate (butyl acetate = 1): 0.23
9. Saturation concentration in air (approximate) at 20°C (68°F): 0.26% (2,600 ppm); at 25°C (77°F), 0.60% (6,000 ppm)
10. Ionization potential: 9.14 eV

- **Reactivity**

1. Incompatibilities: Cyclohexanone may react with oxidizing agents and nitric acid causing fires and explosions.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving cyclohexanone.
3. Caution: Cyclohexanone will dissolve most plastics, resins, and rubber.

- **Flammability**

1. Flash point: 43.9°C (111°F) (closed cup)
2. Autoignition temperature: 420°C (788°F)
3. Flammable limits in air, % by volume: Lower, 1.1; Upper, 9.4
4. Extinguishant: Alcohol foam, dry chemical, or carbon dioxide
5. Class II Combustible Liquid (29 CFR 1910.106), Flammability Rating 2 (NFPA)

- **Warning properties**

1. Odor threshold: 0.88 ppm
2. Eye irritation level: 75 ppm
3. Evaluation of warning properties for respirator selection: Because of its odor, cyclohexanone can be detected at concentrations below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus, it is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for cyclohexanone is 50 parts of cyclohexanone per million parts of air (ppm) [200 milligrams of cyclohexanone per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The NIOSH REL is 25 ppm (100 mg/m³) as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 25 ppm (100 mg/m³) (Skin) as a TWA for a normal 8-hour workday and a 40-hour workweek (Table 1).

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

Table 1.—Occupational exposure limits for cyclohexanone

	Exposure limits	
	ppm	mg/m³
OSHA PEL TWA	50	200
NIOSH REL TWA	25	100
ACGIH TLV® TWA (Skin)	25	100

HEALTH HAZARD INFORMATION

• Routes of exposure

Cyclohexanone may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• Summary of toxicology

Effects on animals: Subchronic inhalation of cyclohexanone by rabbits and monkeys caused central nervous system depression and liver and kidney degeneration. Cutaneous or subcutaneous application of cyclohexanone for several days caused cataracts in guinea pigs.

• Signs and symptoms of exposure

1. *Short-term (acute):* Exposure to cyclohexanone can cause dizziness and unconsciousness. Irritation of the eyes, nose, and throat can also occur.
2. *Long-term (chronic):* Dermal exposure to cyclohexanone can cause dryness, irritation, and inflammation of the skin.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to cyclohexanone, the physician 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, liver, kidneys, and respiratory system. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to cyclohexanone at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindication to job placement, include concurrent dermatitis or a history of chronic skin disease.

• Periodic medical screening and/or biologic monitoring

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to cyclohexanone. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, liver, kidneys, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

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

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

• Sentinel health events

Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• TWA exposure evaluation

Measurements to determine worker exposure to cyclohexanone should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under cer-

tain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

• **Method**

Sampling and analysis may be performed by collecting cyclohexanone vapors with charcoal tubes followed by desorption with carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure cyclohexanone may also be used if available. A detailed sampling and analytical method for cyclohexanone may be found in the *NIOSH Manual of Analytical Methods* (method number 1300).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with cyclohexanone.

Workers should be provided with and required to use splash-proof safety goggles where cyclohexanone may come in contact with the eyes.

SANITATION

Clothing which is contaminated with cyclohexanone should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of cyclohexanone from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of cyclohexanone's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with cyclohexanone should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle cyclohexanone should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to cyclohexanone may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for cyclohexanone

Operations	Controls
During surface coating or spray painting of fabrics and plastics	Local exhaust ventilation, personal protective equipment
During cleaning of leathers and textiles; during degreasing of leathers and metals	Local exhaust ventilation, personal protective equipment
During use as a solvent in crude rubber, insecticides, and epoxy resins; during use as a sludge solvent in lubricating oils	Local exhaust ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to cyclohexanone, an eye-wash fountain should be provided within the immediate work area for emergency use.

If cyclohexanone gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

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Where there is any possibility of a worker's body being exposed to cyclohexanone, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If cyclohexanone gets on the skin, wash it immediately with soap and water. If cyclohexanone penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

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4. Large quantities of liquids containing cyclohexanone may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. Cyclohexanone should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Cyclohexanone may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill and flashback prevention devices should be provided.

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Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for cyclohexanone

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 625 ppm	Any supplied-air respirator operated in a continuous flow mode (substance causes eye irritation or damage—eye protection needed)
	Any powered air-purifying respirator with organic vapor cartridge(s) (substance causes eye irritation or damage—eye protection needed)
Less than or equal to 1,000 ppm	Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s)
Less than or equal to 1,250 ppm	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
Less than or equal to 5,000 ppm	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 5,000 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 25 ppm (100 mg/m³) (TWA).

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR DIACETONE ALCOHOL

INTRODUCTION

This guideline summarizes pertinent information about diacetone alcohol for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_6H_{12}O_2$
- **Structure:** $(CH_3)_2C(OH)CH_2COCH_3$
- **Synonyms:** Diketone alcohol; 4-hydroxy-2-keto-4-methylpentane; 4-hydroxy-4-methyl-2-pentanone; 2-methyl-2-pentanol-4-one
- **Identifiers:** CAS 123-42-2; RTECS SA9100000; DOT 1148, label required: "Flammable Liquid"
- **Appearance and odor:** Colorless to yellow liquid with a mild odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 116.62
2. Boiling point (at 760 mmHg): 169.2 °C (335 °F)
3. Specific gravity (water = 1): 0.94
4. Vapor density (air = 1 at boiling point of diacetone alcohol): 4.0
5. Melting point: -43 °C (-45 °F)
6. Vapor pressure: At 20 °C (68 °F), 0.8 mmHg; at 25 °C (77 °F), 1.2 mmHg
7. Miscible in water
8. Evaporation rate (butyl acetate = 1): 0.14
9. Saturation concentration in air (approximate) at 20 °C (68 °F): 0.10% (1,000 ppm); at 25 °C (77 °F), 0.16% (1,600 ppm)

- **Reactivity**

1. Incompatibilities: Contact with strong oxidizers may cause fires and explosions. Contact with strong alkalies may cause formation of flammable acetone vapors.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving diacetone alcohol.
3. Caution: Diacetone alcohol will dissolve some forms of plastics, resins, and rubber.

- **Flammability**

1. Flash point: 57.8 °C (136 °F) (closed cup)
2. Autoignition temperature: 643 °C (1,190 °F)
3. Flammable limits in air, % by volume: Lower, 1.8; upper, 6.9
4. Extinguishant: Carbon dioxide, dry chemical, or alcohol foam
5. Class II Combustible Liquid (29 CFR 1910.106), Flammability Rating 2 (NFPA)

- **Warning properties**

1. Odor threshold: 0.28 ppm
2. Eye irritation level: 100 ppm
3. Other information: Nasal irritation may occur at 100 ppm.
4. Evaluation of warning properties for respirator selection: Because of its odor, diacetone alcohol can be detected below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus, it is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for diacetone alcohol is 50 parts of diacetone alcohol per million parts of air (ppm) [240 milligrams of diacetone alcohol per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The NIOSH REL is 50 ppm (240 mg/m³) as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 50 ppm (240 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek (Table 1).

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Table 1.—Occupational exposure limits for diacetone alcohol

	Exposure limits ppm	mg/m³
OSHA PEL TWA	50	240
NIOSH REL TWA	50	240
ACGIH TLV® TWA	50	240

HEALTH HAZARD INFORMATION

• **Routes of exposure**

Diacetone alcohol may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• **Summary of toxicology**

Effects on animals: In rats and rabbits, acute oral administration or inhalation of diacetone alcohol caused narcosis, kidney damage, and liver damage (vacuolization and granulation of parenchymal cells).

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to diacetone alcohol can cause chest discomfort, narcosis, and irritation of the eyes, nose, and throat.

2. *Long-term (chronic):* Exposure to diacetone alcohol can cause dryness, irritation, and inflammation of the skin.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to diacetone alcohol, the physician 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, liver, kidneys, and nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to diacetone alcohol at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include concurrent dermatitis or a history of chronic skin disease.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to diacetone alcohol. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, liver, kidneys, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

• **Medical practices 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 which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population.

• **Sentinel health events**

Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **TWA exposure evaluation**

Measurements to determine worker exposure to diacetone alcohol should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of

consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

- **Method**

Sampling and analysis may be performed by collecting diacetone alcohol vapors with charcoal tubes followed by desorption with 2-proponal in carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure diacetone alcohol may also be used if available. A detailed sampling and analytical method for diacetone alcohol may be found in the *NIOSH Manual of Analytical Methods* (Method number 1402).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with diacetone alcohol.

Workers should be provided with and required to use splash-proof goggles where diacetone alcohol may come in contact with the eyes.

SANITATION

Clothing which is contaminated with diacetone alcohol should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of diacetone alcohol from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of diacetone alcohol's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with diacetone alcohol should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle diacetone alcohol should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to diacetone alcohol may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for diacetone alcohol

Operations	Controls
During application of nitrocellulose lacquer	Process enclosure, local exhaust ventilation, personal protective equipment
During application of paper and textile coatings, wood stains, and preservatives; during use and manufacture of artificial silk and leather, quick-drying inks, photographic film, antifreeze preparations, and hydraulic fluids	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During use as a solvent for cellulose esters, epoxy resins, hydrocarbons, oils, fats, resin gums, dyes, tars, cements, and waxes; during use as a pigment solvent in the dyeing industry	Local exhaust ventilation, general dilution ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to diacetone alcohol, an eye-wash fountain should be provided within the immediate work area for emergency use.

If diacetone alcohol gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to diacetone alcohol, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If diacetone alcohol gets on the skin, wash it immediately with soap and water. If diacetone alcohol penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

- **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If diacetone alcohol is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing diacetone alcohol, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from diacetone alcohol vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing diacetone alcohol may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. Diacetone alcohol should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing diacetone alcohol may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for diacetone alcohol

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 1,000 ppm	Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s)
	Any powered air-purifying respirator with organic vapor cartridge(s) (substance causes eye irritation or damage—eye protection needed)
Less than or equal to 1,250 ppm	Any supplied-air respirator operated in a continuous flow mode (substance causes eye irritation or damage—eye protection needed)
Less than or equal to 2,100 ppm	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
Planned or emergency entry into environments containing unknown concentrations or levels above 2,100 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 50 ppm (240 mg/m^3) (TWA).

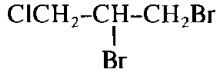
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR DIBROMOCHLOROPROPANE POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about dibromochloropropane (DBCP) for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_3H_5Br_2Cl$
- **Structure:**



- **Synonyms:** 1-Chloro-2,3-dibromopropane; DBCP; 1,2-dibromo-3-chloropropane
- **Identifiers:** CAS 96-12-8; RTECS TX8750000; DOT 2872, label required: "St. Andrew's Cross (X)"
- **Appearance and odor:** Dense yellow or amber liquid or granular solid with a pungent odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 236.35
2. Boiling point (at 760 mmHg): 195°C (383°F)
3. Specific gravity (water = 1): 2.093
4. Melting point: 6°C (43°F)
5. Vapor pressure at 20°C (68°F): 0.8 mmHg
6. Solubility in water, g/100 g water at 20°C (68°F): 0.1
7. Saturation concentration in air (approximate) at 20°C (68°F): 0.1% (1000 ppm)

- **Reactivity**

1. Incompatibilities: DBCP reacts with chemically active metals such as aluminum, magnesium, and tin alloys.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., hydrogen bromide, hydrogen chloride, and carbon monoxide) may be released in a fire involving DBCP.
3. Caution: DBCP will attack some rubber materials and coatings.

- **Flammability**

1. Flash point: 77°C (170°F) (open cup)
2. Extinguishant: Carbon dioxide or dry chemical
3. Class IIIA Combustible Liquid (29 CFR 1910.106)

- **Warning properties**

1. Odor threshold: 0.01-0.03 ppm
2. Evaluation of warning properties for respirator selection: Because of the lack of odor at concentrations below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL), DBCP is treated as a chemical with poor warning properties.

EXPOSURE LIMITS

The Occupational Safety and Health Administration (OSHA) considers DBCP to be a cancer hazard. The current OSHA permissible exposure limit (PEL) for DBCP is 1 part of DBCP per billion parts of air (ppb) as a time-weighted average (TWA) concentration over an 8-hour workshift; the employer shall assure that no employee is exposed to eye or skin contact with DBCP. The NIOSH REL is 10 ppb as a TWA [0.1 milligrams of DBCP per cubic meter of air (mg/m^3)] for up to a 10-hour workshift, 40-hour workweek; however, the NIOSH REL has been superseded by the OSHA standard promulgated in 1978. The American Conference of Governmental Industrial Hygienists (ACGIH) does not have an assigned threshold limit value (TLV®) for DBCP.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

DBCP may cause adverse health effects following exposure via inhalation or dermal or eye contact.

- **Summary of toxicology**

1. *Effects on animals:* In rats, acute inhalation or oral administration of DBCP caused central nervous system depression with sluggishness and loss of muscular coordination (ataxia), weight loss, and decreased spermatogenesis; acute dermal exposure caused dermal and subcutaneous tissue destruction (necrosis).

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Subchronic inhalation of DBCP by rats, guinea pigs, rabbits, or monkeys produced necrosis of the liver, kidney, spleen, testes, or seminiferous tubules; reduction in sperm count; abnormal sperm; or inhibition of the estrous cycle. Cancers of the nasal cavity, tongue, pharynx, lungs, stomach, adrenal glands, or mammary glands have been reported for rats or mice chronically exposed to DBCP by inhalation or oral administration.

2. *Effects on humans:* Low-level repeated or prolonged exposure of male workers has been associated with low sperm count, chromosome abnormality, sterility, decreased testicular size, and increased level of follicle stimulating hormone. These effects have not been associated with exposure in previous years, indicating that they may be reversible following removal from exposure.

• Signs and symptoms of exposure

1. *Short-term (acute):* Exposure to DBCP can cause drowsiness, nausea, vomiting, and irritation of the eyes, nose, throat and skin.

2. *Long-term (chronic):* Exposure to DBCP ean cause congestion or fluid in the lungs and inflammation of the eyes or skin.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to DBCP, the physician 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, liver, kidneys, urinary tract, and reproductive and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to DBCP at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis and a history of reproductive dysfunction. In addition to the medical interview and physical examination, the means to identify these conditions may include an evaluation of fertility.

• Periodic medical screening and/or biologic monitoring

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to DBCP. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function and integrity of the eyes, skin, liver, kidneys, urinary tract, and respiratory and reproductive systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and ATS: standardized questionnaires and tests of lung function.

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

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic and laboratory tests which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population. Because occupational exposure to DBCP may cause adverse reproductive effects and diseases of prolonged induction-latency, the need for medical surveillance may extend well beyond termination of employment.

• Sentinel health events

1. Acute SHE's include: Contact and/or allergic dermatitis.
2. Delayed-onset or reproductive SHE's include: Infertility in exposed males.

MONITORING AND MEASUREMENT PROCEDURES

• TWA exposure evaluation

Measurements to determine worker exposure to DBCP should be taken so that the TWA exposure is based on a single entire

workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

• **Method**

There are no NIOSH validated sampling and analytical methods for DBCP.

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with DBCP.

Workers should be provided with and required to use dust- and splash-proof safety goggles where DBCP or other dust may come in contact with the eyes.

SANITATION

Clothing which is contaminated with DBCP should be removed immediately and placed in sealed containers for storage until it can be discarded or until provision is made for the removal of DBCP from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of DBCP's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with DBCP should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle DBCP should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to DBCP may occur and control methods which may be effective in each case are listed in Table 1.

Table 1.—Operations and methods of control for dibromochloropropane

Operations	Controls
During the manufacture of DBCP	Completely enclosed processes, local exhaust ventilation, personal protective equipment
During the formulation of DBCP into pesticides and fumigants	Local exhaust ventilation, protective clothing and equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to DBCP, an eye-wash fountain should be provided within the immediate work area for emergency use.

If DBCP gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to DBCP, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If DBCP gets on the skin, wash it immediately with soap and water. If DBCP penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If DBCP is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing DBCP, absorb on paper towels and place in an appropriate container. Place towels

in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from DBCP vapors. Burn the paper in a suitable location away from combustible materials.

4. Large quantities of liquids containing DBCP may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. DBCP should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.

5. DBCP liquid or solid may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 2).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 2.—Respiratory protection for dibromochloropropane

Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister having a high-efficiency particulate filter
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.

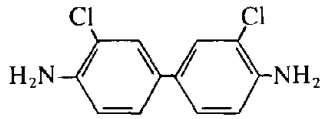
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR 3,3'-DICHLOROBENZIDINE POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about 3,3'-dichlorobenzidine for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_{12}H_{10}Cl_2N_2$
- **Structure:**



- **Synonyms:** DCB; 4,4'-diamino-3,3'-dichlorobiphenyl; dichlorobenzidine; o,o'-dichlorobenzidine; 3,3'-dichlorobiphenyl-4,4'diamine
- **Identifiers:** CAS 91-94-1; RTECS DDO525000; DOT not assigned.
- **Appearance:** Gray to purple crystalline solid

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 253.43
2. Melting point: 133°C (271.4°F)
3. Slightly soluble in water

- **Flammability**

Extinguishant: Dry chemical, alcohol foam, or carbon dioxide

- **Warning properties**

Evaluation of warning properties for respirator selection: Warning properties are not considered in recommending respirators for use with carcinogens.

EXPOSURE LIMITS

The Occupational Safety and Health Administration (OSHA) does not have a specific permissible exposure limit (PEL) for 3,3'-dichlorobenzidine; however, the OSHA standard requires implementation of stringent controls wherever 3,3'-dichlorobenzidine or solid or liquid mixtures containing at least 0.1% by weight or volume of 3,3'-dichlorobenzidine are manufactured, processed, repackaged, released, handled, or stored, (see "General Control Procedures"). Details of this standard can be found in the Code of Federal Regulations, 29 CFR 1910.1007, 3,3'-Dichlorobenzidine (and its salts). The National Institute for Occupational Safety and Health (NIOSH) concurs with the OSHA standard. The American Conference of Governmental Industrial Hygienists (ACGIH) has designated 3,3'-dichlorobenzidine as an A2 substance (suspected human carcinogen) without having sufficient evidence to assign a threshold limit value (TLV®) (Skin). The notation "Skin" refers to the potential contribution to overall exposure by the cutaneous route, including the mucous membranes and eyes.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

3,3'-Dichlorobenzidine may cause adverse health effects following exposure via inhalation, ingestion, or dermal contact.

- **Summary of toxicology**

1. *Effects on animals:* Acute inhalation of 3,3'-dichlorobenzidine by rats caused irritation and moderate pulmonary congestion. Chronic oral administration of 3,3'-dichlorobenzidine to rats produced gastrointestinal congestion and hemorrhage, leukemia, and cancers of the intestines and mammary and sebaceous glands. Chronic oral administration of 3,3'-dichlorobenzidine produced bladder cancer in hamsters, liver cancer in mice, and liver and bladder cancers in dogs. 3,3'-Dichlorobenzidine exposure to pregnant mice caused an increased incidence of tumors in their offspring.
2. *Effects on humans:* No reports have been identified that associate 3,3'-dichlorobenzidine with the occurrence of cancer in man; however, because 3,3'-dichlorobenzidine and benzidine (a human bladder carcinogen) are usually prepared and handled in the same workplace, 3,3'-dichlorobenzidine may contribute to the incidence of bladder cancer in exposed workers.

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

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to 3,3'-dichlorobenzidine can cause allergic skin reaction, dermatitis, headache, and dizziness. It can also cause severe eye irritation and is caustic to the skin.

2. *Long-term (chronic):* Exposure to 3,3'-dichlorobenzidine can cause blood in the urine and painful, difficult, or frequent urination.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to 3,3'-dichlorobenzidine, the physician 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, liver, urinary tract, and hematopoietic (blood-cell-forming) and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to 3,3'-dichlorobenzidine at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include chronic diseases of the liver or urinary tract.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to 3,3'-dichlorobenzidine. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the skin, liver, urinary tract, and hematopoietic and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The physician should consider use of a test which characterizes internal exposure (e.g., benzidine in urine). However, this test should be used and interpreted according to standardized epidemiologic procedures and evaluation criteria. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and ATS: standardized questionnaires and tests of lung function.

• **Medical practices recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic and laboratory tests which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population. Because occupational exposure to 3,3'-dichlorobenzidine may cause diseases of prolonged induction-latency, the need for medical surveillance may extend well beyond termination of employment.

• **Sentinel health events**

Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **Method**

Sampling and analysis may be performed by collecting 3,3'-dichlorobenzidine dust with glass-fiber filters and silica gel tubes followed by desorption with triethylamine in methanol and analysis by high-pressure liquid chromatography and ultraviolet detection. Direct-reading devices calibrated to measure 3,3'-dichlorobenzidine may also be used if available. A detailed sampling and analytical method for 3,3'-dichlorobenzidine may be found in the *NIOSH Manual of Analytical Methods* (method number 5509).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the

manufacturer, and then evaluating the clothing under actual use conditions.

In operations involving "laboratory-type hoods" or in locations where 3,3'-dichlorobenzidine is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, OSHA requires that workers: (1) be provided with and required to use clean, full-body CPC (smocks, coveralls, or long-sleeved shirts and long pants), shoe covers, and gloves prior to entering a regulated area; (2) be provided with and required to use approved respirators (a respirator affording higher levels of protection may be substituted); and (3) remove the protective clothing and equipment prior to exiting a regulated area, and at the last exit of the day, place used clothing and equipment in impervious containers for decontamination or disposal.

SANITATION

For closed system operations or in locations where 3,3'-dichlorobenzidine is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, OSHA requires that workers: (1) wash their hands, forearms, faces, and necks prior to exiting the regulated area and before engaging in other activities, and (2) shower in designated facilities after the last exit of the day.

In isolated systems, such as a "glove box," OSHA requires that workers wash their hands and arms with soap and water upon completion of the assigned task and before engaging in other activities not associated with the isolated system.

If it is necessary for workers to wear protective clothing, OSHA requires that a clean change room be provided and equipped with showers and washing facilities. NIOSH recommends that lockers that permit separation of street and work clothes be provided for the worker.

Clothing which is contaminated with 3,3'-dichlorobenzidine should be removed immediately and placed in sealed containers for storage until it can be discarded or until provision is made for the removal of 3,3'-dichlorobenzidine from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of 3,3'-dichlorobenzidine's hazardous properties. Reusable clothing and equipment should be checked for residual contamination before reuse or storage.

Decontamination and disposal procedures should be established and implemented to remove 3,3'-dichlorobenzidine from materials and equipment. Contaminated material should be removed from regulated areas without further contamination of the facility.

OSHA requires that workers wash their faces, necks, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

In regulated areas, OSHA prohibits the storage or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing.

OSHA prohibits the location of drinking fountains in regulated areas.

GENERAL CONTROL PROCEDURES

The following control procedures are derived from OSHA requirements as stated in 29 CFR 1910.1007:

Areas where 3,3'-dichlorobenzidine is manufactured, processed, used, repackaged, released, handled, or stored shall be designated as regulated areas, and entry into and exit from these areas shall be restricted and controlled. Only authorized workers are permitted access to regulated areas.

Workers authorized to enter regulated areas shall receive a training and indoctrination program including but not limited to the nature of the carcinogenic hazards of 3,3'-dichlorobenzidine, local and systemic toxicity, the specific nature of the operation which could result in exposure, and the purpose for and the significance of decontamination and emergency practices and procedures.

Entrances to regulated areas shall be posted with signs indicating that a cancer-suspect agent is present and that only authorized workers wearing appropriate protective clothing and equipment shall be admitted.

Appropriate signs and instructions shall be posted at the entrance to and exit from regulated areas to inform workers of the procedures that must be followed when entering or leaving a regulated area.

Open vessel system operations involving 3,3'-dichlorobenzidine which are not in an isolated system, laboratory-type hood, or other system affording equivalent protection against the entry of 3,3'-dichlorobenzidine into regulated areas, nonregulated areas, or the external environment are prohibited.

In operations involving "laboratory-type hoods" or in locations where 3,3'-dichlorobenzidine is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, each operation shall be provided with continuous local exhaust ventilation so that air movement is always from ordinary work areas to the operation. Exhaust air shall not be discharged to regulated areas, nonregulated areas, or the external environment unless decontaminated. Clean makeup air shall be introduced in sufficient volume to maintain the correct operation of the local exhaust system.

Containers of 3,3'-dichlorobenzidine shall be identified as to contents and shall contain a hazard warning.

Regulated areas (with the exception of outdoor operations) shall be operated under negative pressure with respect to nonregulated areas. Local exhaust ventilation may be used to satisfy this requirement. Clean makeup air in equal volume shall replace air that is removed.

The introduction or removal of any equipment, materials, or other items to or from a regulated area shall be done in a man-

ner that does not cause contamination of nonregulated areas or the external environment.

Decontamination procedures shall be established and implemented to remove 3,3'-dichlorobenzidine from materials, equipment, and decontamination facility.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to 3,3'-dichlorobenzidine may occur and control methods which may be effective in each case are listed in Table 1.

Table 1.—Operations and methods of control for 3-3'-dichlorobenzidine

Operations	Controls
During use as an intermediate in the manufacture of dyes, pigments, and isocyanate-containing polymers	Process enclosure, restricted access, local exhaust ventilation where appropriate, personal protective equipment, good housekeeping and personal hygiene practices, substitution with less toxic substances

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures. If a worker had contact with 3,3'-dichlorobenzidine, OSHA requires that the worker shower as soon as possible, unless contraindicated by physical injuries.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to 3,3'-dichlorobenzidine, an eye-wash fountain should be provided within the immediate work area for emergency use.

If 3,3'-dichlorobenzidine gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to 3,3'-dichlorobenzidine, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If 3,3'-dichlorobenzidine gets on the skin, wash it immediately with soap and water. If 3,3'-dichlorobenzidine penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

- **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

OSHA requires that hazardous conditions created by spills or leaks be eliminated and that potentially affected areas be decontaminated prior to the resumption of normal operations.

OSHA requires that affected areas of spills or leaks be evacuated as soon as an emergency has been determined.

OSHA requires that only authorized workers provided with and wearing clean, impervious garments (including gloves, boots, and continuous-air-supplied hoods) enter areas of spills or leaks.

OSHA requires that workers authorized to enter areas of spills or leaks be decontaminated before removing the protective garments and hoods and showering.

If 3,3'-dichlorobenzidine is spilled or leaked, the following steps should be taken:

1. Ventilate area of spill or leak.
2. If in solid form, 3,3'-dichlorobenzidine may be collected and placed in an appropriate container.
3. 3,3'-Dichlorobenzidine solid or liquid may be collected by vacuuming with an appropriate high-efficiency filtration system or by using wet methods; it may then be placed in an appropriate container. Dry sweeping and dry mopping of 3,3'-dichlorobenzidine are prohibited by OSHA.
4. For small quantities of liquids containing 3,3'-dichlorobenzidine, absorb on paper towels and place in an appropriate container.
5. Large quantities of liquids containing 3,3'-dichlorobenzidine may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 2).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respira-

tor, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

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Table 2.—Respiratory protection for 3-3′-dichlorobenzidine

Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator with a high-efficiency particulate filter
	Any appropriate escape-type self-contained breathing apparatus

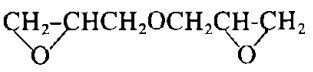
* Only NIOSH/MSHA-approved equipment should be used.

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR DIGLYCIDYL ETHER POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about diglycidyl ether (DGE) for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_6H_{10}O_3$
- **Structure:** 

- **Synonyms:** Bis(2,3-epoxypropyl) ether; DGE; di(2,3--epoxypropyl) ether; di(2,3-epoxy)propyl ether
- **Identifiers:** CAS 2238-07-05; RTECS KN2350000; DOT not assigned
- **Appearance and odor:** Colorless liquid with a strong, irritating odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 130.16
2. Boiling point (at 760 mmHg): 260°C (500°F)
3. Specific gravity (water = 1): 1.26
4. Vapor density (air = 1 at boiling point of DGE): 4.49
5. Vapor pressure at 25°C (77°F): 0.09 mmHg
6. Saturation concentration in air (approximate) at 25°C (77°F): 0.0121% (121 ppm)

- **Reactivity**

1. Incompatibilities: Contact with strong oxidizing agents may cause fires and explosions. Ethers as a class tend to form peroxides upon contact with air and exposure to light.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving DGE.
3. Caution: DGE will cause some forms of plastics, coatings, and rubber to deteriorate.

- **Flammability**

1. Flash point: 64°C (147°F)
2. Extinguishant: Dry chemical, carbon dioxide, alcohol foam
3. Class IIIA Combustible Liquid (29 CFR 1910.106)

- **Warning properties**

1. Odor threshold: Approximately 5 ppm
2. Eye irritation levels: 10 ppm
3. Evaluation of warning properties for respirator selection: Warning properties are not considered in recommending respirators for use with carcinogens.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for DGE is 0.5 parts of DGE per million parts of air (ppm) [2.8 milligrams of DGE per cubic meter of air (mg/m³)] as a ceiling concentration which shall at no time be exceeded. The National Institute for Occupational Safety and Health (NIOSH) recommends that DGE be controlled and handled as a potential human carcinogen in the workplace and that exposure be reduced to the lowest feasible limit. The NIOSH recommended exposure limit (REL) is 0.2 ppm (1 mg/m³) as a ceiling concentration determined in any 15-minute sampling period. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 0.1 ppm (0.5 mg/m³) as a time-weighted average (TWA) concentration for a normal 8-hour workday and a 40-hour workweek (Table 1).

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

Table 1.—Occupational exposure limits for diglycidyl ether

	Exposure limits	
	ppm	mg/m³
OSHA PEL Ceiling	0.5	2.8
NIOSH REL (Ca)*		
Ceiling (15 min)	0.2	1
ACGIH TLV® TWA	0.1	0.5

* (Ca): NIOSH recommends treating as a potential human carcinogen.

HEALTH HAZARD INFORMATION

• Routes of exposure

DGE may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• Summary of toxicology

Effects on animals: In mice and rats, acute inhalation or oral administration of DGE caused central nervous system depression, incoordination, breathing difficulty (dyspnea), respiratory failure, and death. In rats and rabbits, acute or subchronic inhalation or dermal administration of DGE produced weight loss, corneal opacities, testicular degeneration, and abnormalities of the blood-forming tissues including lymphoid atrophy of the thymus and depression of white blood cell and bone marrow cell counts. In skin-painting studies, DGE produced tumors in mice. DGE was mutagenic in bacterial test systems.

• Signs and Symptoms of exposure

1. *Short-term (acute):* Exposure to DGE can cause skin burns and severe irritation of the skin, eyes, and respiratory tract.
2. *Long-term (chronic):* Exposure to DGE can cause dermatitis and skin sensitization.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive value of biologic monitoring and medical screening tests should b evaluated on an industry-wide basis prior to application i any given worker group. Intrinsic to a surveillance prograı is the dissemination of summary data to those who need t know, including employers, occupational health professior als, potentially exposed workers, and regulatory and publi health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to DGE, the physician 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, reproductive, respiratory, nervous, and hematopoietic (blood cell forming) systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to DGE at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis.

• Periodic medical screening and/or biologic monitoring

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to DGE. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, reproductive, nervous, respiratory and hematopoietic systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

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

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic and laboratory tests which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population. Because occupational exposure to DGE may cause adverse reproductive effects or diseases of prolonged

induction-latency, the need for medical surveillance may extend well beyond termination of employment.

• **Sentinel health events**
Acute SHE's include: Contact and/or allergic dermatitis

MONITORING AND MEASUREMENT PROCEDURES

• **Ceiling concentration evaluation**
Measurements to determine worker exposure should be taken during periods of maximum expected airborne concentrations of DGE. Each measurement to determine the NIOSH REL (ceiling exposure) in the worker's breathing zone (air that most nearly represents that inhaled by the worker) should consist of a 15-minute sample or a series of consecutive samples that total 15 minutes. A minimum of three measurements should be taken during one workshift, and the highest of all measurements taken is an estimate of the worker's exposure. If the periods of maximum exposure are not clearly defined, a statistical procedure which can be used as a peak exposure detection strategy is given in the *Occupational Exposure Sampling Strategy Manual.*

• **Method**
Sampling and analysis may be performed by collecting DGE vapors with charcoal adsorption tubes followed by desorption with methylene chloride and analysis by gas chromatography. Refer to the *Criteria for Recommended Standard.... Occupational Exposure to Glycidyl Ethers* for limitations and correct use of this method. Direct-reading devices calibrated to measure DGE may also be used if available.

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, and other appropriate protective clothing necessary to prevent skin contact with DGE.

SANITATION

Clothing which is contaminated with DGE should be removed immediately and placed in sealed containers for storage until it can be discarded or until provision is made for the removal of DGE from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of DGE's hazardous properties. Reusable clothing and equipment should be checked for residual contamination before reuse or storage.

A change room with showers, washing facilities, and lockers that permit separation of street and work clothes should be provided.

Workers should be required to shower following a workshift and prior to putting on street clothes. Clean work clothes should be provided daily.

Skin that becomes contaminated with DGE should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle DGE should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

DGE is not generally used outside of research laboratories. There are no common industrial uses for DGE.

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**
Where there is any possibility of a worker's eyes being exposed to DGE, an eye-wash fountain should be provided within the immediate work area for emergency use.

If DGE gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**
Where there is any possibility of a worker's body being exposed to DGE, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If DGE gets on the skin, wash it immediately with soap and water. If DGE penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**
If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If DGE is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.

3. For small quantities of liquids containing DGE, absorb on paper towels and place in an appropriate container.
4. Large quantities of liquids containing DGE may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container.
5. Liquids containing DGE may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 2).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

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• Scientific Assembly on Environmental and Occupational Health: "Surveillance for Respiratory Hazards in the Occupational Setting," *American Review of Respiratory Diseases*, 126:952-956, 1982.

Table 2.—Respiratory protection for diglycidyl ether

Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type or self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.

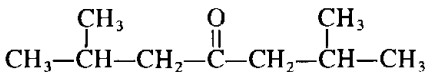
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR DIISOBUTYL KETONE

INTRODUCTION

This guideline summarizes pertinent information about diisobutyl ketone for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_9H_{18}O$
- **Structure:**



- **Synonyms:** DBK; diisopropyl acetone; 2,6-dimethyl-4-heptanone; isovalerone; valerone
- **Identifiers:** CAS 108-83-8; RTECS MJ5775000; DOT 1157, label required: "Flammable Liquid"
- **Appearance and odor:** Colorless liquid with a mild ketone odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 142.27
2. Boiling point (at 760 mmHg): 169.4°C (336.9°F)
3. Specific gravity (water = 1): 0.81
4. Vapor density (air = 1 at boiling point of diisobutyl ketone): 4.9
5. Melting point: -46°C (-51°F)
6. Vapor pressure: At 20°C (68°F), 1.7 mm Hg; at 25°C (77°F), 2.4 mmHg
7. Solubility in water, g/100 g water at 20°C (68°F): 0.05
8. Evaporation rate (butyl acetate = 1): 0.17
9. Saturation concentration in air (approximate): At 20°C (68°F), 0.22% (2,200 ppm); at 25°C (77°F), 0.32% (3,200 ppm)

- **Reactivity**

1. Incompatabilities: Contact with strong oxidizers may cause fires and explosions.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving diisobutyl ketone.
3. Caution: Diisobutyl ketone will dissolve some forms of plastics, resins, and rubber.

- **Flammability**

1. Flash point: 60°C (140°F) (closed cup)
2. Autoignition temperature: 396°C (745°F)
3. Flammable limits in air, % by volume at 100°C: Lower, 0.8; upper, 7.1
4. Extinguishant: Carbon dioxide, dry chemical, or alcohol foam
5. Class IIIA Combustible Liquid (29 CFR 1910.106), Flammability Rating 2 (NFPA)

- **Warning properties**

1. Odor threshold: 0.11 ppm
2. Eye irritation level: 25 ppm
3. Evaluation of warning properties for respirator selection: Because of its odor, diisobutyl ketone can be detected below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus, diisobutyl ketone is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for diisobutyl ketone is 50 parts of diisobutyl ketone per million parts of air (ppm) [290 milligrams of diisobutyl ketone per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The NIOSH REL is 25 ppm (140 mg/m³) as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 25 ppm (150 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek (Table 1).

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

Table 1.—Occupational exposure limits for diisobutyl ketone

	Exposure limits	
	ppm	mg/m³
OSHA PEL TWA	50	290
NIOSH REL TWA	25	140
ACGIH TLV® TWA	25	150

HEALTH HAZARD INFORMATION

• **Routes of exposure**

Diisobutyl ketone may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• **Summary of toxicology**

Effects on animals: Acute inhalation or oral administration of diisobutyl ketone by rats or guinea pigs caused drowsiness, impaired muscular coordination (ataxia), damage to the lungs, liver, or kidneys, and death.

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to diisobutyl ketone can cause headache, dizziness, drowsiness, tearing, and irritation of the eyes, nose, and throat.

2. *Long-term (chronic):* Exposure to diisobutyl ketone can cause dryness, irritation, and inflammation of the skin.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to diisobutyl ketone, the physician 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, liver, kidneys, and nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to diisobutyl ketone at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to diisobutyl ketone. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, liver, kidneys, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

• **Medical practices 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 which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population.

• **Sentinel health events**

Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **TWA exposure evaluation**

Measurements to determine worker exposure to diisobutyl ketone should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to deter-

mine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

- **Method**

Sampling and analysis may be performed by collecting diisobutyl ketone vapors with charcoal tubes followed by desorption with carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure diisobutyl ketone may also be used if available. A detailed sampling and analytical method for diisobutyl ketone may be found in the *NIOSH Manual of Analytical Methods* (method number 1300).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with diisobutyl ketone.

Workers should be provided with and required to use splash-proof safety goggles where diisobutyl ketone may come in contact with the eyes.

SANITATION

Clothing which is contaminated with diisobutyl ketone should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of diisobutyl ketone from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of diisobutyl ketone's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with diisobutyl ketone should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle diisobutyl ketone should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to diisobutyl ketone may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for diisobutyl ketone

Operations	Controls
During use as a paint thinner; during use as a solvent in the production of synthetic coatings, soap, or nitrocellulose	General dilution ventilation, local exhaust ventilation, personal protective equipment
During use as an intermediate in organic synthesis, an extractant in the pharmaceutical industry, a separating agent in the chemical industry, or a dispersant in the manufacture of resins	General dilution ventilation, local exhaust ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to diisobutyl ketone, an eye-wash fountain should be provided within the immediate work area for emergency use.

If diisobutyl ketone gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to diisobutyl ketone, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If diisobutyl ketone gets on the skin, wash it immediately with soap and water. If diisobutyl ketone penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

- **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If diisobutyl ketone is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing diisobutyl ketone, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from diisobutyl ketone vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing diisobutyl ketone may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. Diisobutyl ketone should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing diisobutyl ketone may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for diisobutyl ketone

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 625 ppm	Any supplied-air respirator operated in a continuous flow mode (substance causes eye irritation or damage—eye protection needed)
	Any powered air-purifying respirator with organic vapor cartridge(s) (substance causes eye irritation or damage—eye protection needed)
Less than or equal to 1,000 ppm	Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s)
Less than or equal to 1,250 ppm	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
Less than or equal to 2,000 ppm	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 2,000 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 25 ppm (140 mg/m^3) (TWA).

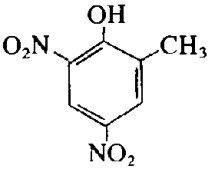
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR DINITRO-ORTHO-CRESOL

INTRODUCTION

This guideline summarizes pertinent information about dinitro-ortho-cresol (DNOC) for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_7H_6N_2O_5$
- **Structure:**



- **Synonyms:** DNOC; 2,4-dinitro-o-cresol; 4,6-dinitro-o-cresol; 3,5-dinitro-2-hydroxytoluene; 4,6-dinitro-2-methyl phenol; antinonin; capsine; chemsect DNOC
- **Identifiers:** CAS 534-52-1; RTECS GO9625000; DOT 2446, label required: "St. Andrew's Cross (X)"
- **Appearance and odor:** Yellow, odorless solid

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical Data**

1. Molecular weight: 198.13
2. Boiling point (at 760 mmHg): 312°C (595°F)
3. Vapor density (air = 1 at boiling point of DNOC): 6.8
4. Melting point: 85.8°C (186°F)
5. Vapor pressure at 20°C (68°F): 5.2 x 10^{-5} mmHg
6. Solubility in water, g/100 g water at 20°C (68°F): 0.01

- **Reactivity**

1. Incompatibilities: Heat and strong oxidizing agents
2. Hazardous decomposition products: Toxic vapors and gases (e.g., oxides of nitrogen and carbon monoxide) may be released in a fire involving DNOC.
3. Caution: DNOC is a combustible solid; DNOC dust may form explosive mixtures with air.

- **Flammability**

1. Minimum explosive dust concentration: 30 g/m³
2. Minimum dust cloud ignition temperature: 340°C (644°F)
3. Extinguishant: Foam, dry chemical, or carbon dioxide

- **Warning properties**

Evaluation of warning properties for respirator selection: Based on lack of information on odor threshold and eye irritation levels, DNOC should be considered to have poor warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for DNOC is 0.2 milligram of DNOC per cubic meter of air (mg/m³) as a time-weighted average (TWA) concentration over an 8-hour workshift (Skin). The notation "Skin" refers to the potential contribution to overall exposure by the cutaneous route including the mucous membranes and eyes. The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) is 0.2 mg/m³ as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 0.2 mg/m³ (Skin) as a TWA for a normal 8-hour workday and a 40-hour workweek (Table 1).

Table 1.—Occupational exposure limits for DNOC

	Exposure limits mg/m³
OSHA PEL TWA (Skin)*	0.2
NIOSH REL TWA	0.2
ACGIH TLV® TWA (Skin)	0.2

* (Skin): Potential contribution to overall exposure by the cutaneous route including mucous membranes and eyes.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

DNOC may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

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

• **Summary of toxicology**

1. *Effects on animals:* Acute inhalation of DNOC by cats produced increased white blood cell counts, decreased red blood cell counts, and decreased blood enzyme activities. Oral administration of DNOC to sheep caused toxic effects to the liver and kidneys. In mutagenicity tests, DNOC caused chromosome damage in the reproductive cells of male mice and DNA damage in bacteria.

2. *Effects on humans:* DNOC has caused increased metabolism, liver and kidney damage, brain hemmorhage with partial loss of circulation, and destruction of nerve sheaths. Chronic ingestion of therapeutic doses of DNOC has produced glaucoma and bilateral cataracts. The toxicity of DNOC is cumulative, and excretion is slow.

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to DNOC can cause euphoria, headache, fatigue, nausea, flushed skin, jaundice, muscular incoordination, cough, fever, profuse sweating, excessive thirst, rapid respiration and heart rate, collapse, and coma. Irritation of the skin and eyes can also occur.

2. *Long-term (chronic):* Exposure to DNOC can cause restlessness, anxiety, weight loss, and jaundice.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to DNOC, the physician 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, liver, kidneys, and nervous and endocrine systems (with particular attention to the thyroid gland).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to DNOC at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include historical and physical or laboratory findings consistent with cataracts or chronic diseases of the skin or liver.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to DNOC. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the integrity or physiologic function of the eyes, skin, liver, kidneys, and nervous and endocrine systems (with particular attention to the thyroid gland) as compared to the baseline status of the individual worker or to expected values for a suitable reference population.

• **Medical practices recommended at the time of job transfer or termination**

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

• **Sentinel health events**

1. Acute SHE's include: Contact and/or allergic dermatitis.
2. Delayed-onset SHE's include: Cataracts.

MONITORING AND MEASUREMENT PROCEDURES

• **TWA exposure evaluation**

Measurements to determine worker exposure to DNOC should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the aver-

age exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

• **Method**

Sampling and analysis may be performed by collecting DNOC with cellulose ester membrane filters followed by extraction with ethylene glycol and analysis by high pressure liquid chromatography. Detector tubes or other direct-reading devices calibrated to measure DNOC may also be used if available. A detailed sampling and analytical method for DNOC may be found in the *NIOSH Manual of Analytical Methods* (method number S166).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with DNOC.

Workers should be provided with and required to use dust- and splash-proof safety goggles where DNOC may come in contact with the eyes.

SANITATION

Clothing which is contaminated with DNOC should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of DNOC from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of DNOC's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with DNOC should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle DNOC should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to DNOC may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for DNOC

Operations	Controls
During the manufacture and processing of DNOC	Process enclosure, local exhaust ventilation, general dilution ventilation, personal protective equipment
During cleaning and maintenance of storage vessels	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During use as a herbicide, insecticide, or fungicide	Personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to DNOC, an eye-wash fountain should be provided within the immediate work area for emergency use.

If DNOC gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to DNOC, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If DNOC gets on the skin, wash it immediately with soap and water. If DNOC penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If DNOC is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.

3. For small quantities of liquids containing DNOC, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from DNOC vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing DNOC may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. DNOC should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. If in solid form, DNOC may be collected and placed in an appropriate container.
6. DNOC may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for dinitro-ortho-cresol

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 2 mg/m³	Any dust and mist respirator with a full facepiece
Less than or equal to 5 mg/m³	Any powered air-purifying respirator with a dust and mist filter (substance causes eye irritation or damage—eye protection needed)
	Any supplied-air respirator operated in a continuous flow mode (substance causes eye irritation or damage—eye protection needed)
	Any air-purifying full facepiece respirator with a high-efficiency particulate filter
	Any supplied-air respirator with a full facepiece
	Any self-contained breathing apparatus with a full facepiece
Planned or emergency entry into environments containing unknown concentrations or levels above 5 mg/m³	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator with a high-efficiency particulate filter
	Any appropriate escape-type self-contained breathing apparatus

*Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 0.2 mg/m³ (TWA).

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ETHYL MERCAPTAN

INTRODUCTION

This guideline summarizes pertinent information about ethyl mercaptan for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** C_2H_5SH
- **Structure:** $CH_3—CH_2—SH$
- **Synonyms:** Ethanethiol, ethyl sulfhydrate, ethyl thiolalcohol, thioethanol, thioethyl alcohol
- **Identifiers:** CAS 75-08-1; RTECS DI9625000; DOT 2363, label required: "Flammable Liquid"
- **Appearance and odor:** Colorless liquid with a penetrating odor like garlic or decayed cabbage

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 62.13
2. Boiling point (at 760 mmHg): 35°C (95°F)
3. Specific gravity (water = 1): 0.839
4. Vapor density (air = 1 at boiling point of ethyl mercaptan): 2.1
5. Melting point: -148°C (-234°F)
6. Vapor pressure at 20°C (68°F): 442 mmHg
7. Solubility in water, g/100 g water at 20°C (68°F): 1.5
8. Evaporation rate (butyl acetate = 1): 24.9
9. Saturation concentration in air (approximate) at 20°C (68°F): 58.2% (582,000 ppm)
10. Ionization potential: 9.28 eV

- **Reactivity**

1. Incompatibilities: Strong oxidizing agents
2. Hazardous decomposition products: Toxic vapors and gases (e.g., sulfur dioxide and carbon monoxide) may be released in a fire involving ethyl mercaptan.
3. Caution: Ethyl mercaptan will attack some forms of plastics, coatings, and rubber.

- **Flammability**

1. Flash point: <−18°C (<0°F) (closed cup)
2. Autoignition temperature: 300°C (572°F)
3. Flammable limits in air, % by volume: Lower, 2.8; upper, 18
4. Extinguishant: Carbon dioxide or dry chemicals for small fires, alcohol foam for large fires
5. Class IA Flammable Liquid (29 CFR 1910.106), Flammability Rating 4 (NFPA)

- **Warning properties**

1. Odor threshold: 0.26 to 0.97 ppb
2. Evaluation of warning properties for respirator selection: Because of its odor, ethyl mercaptan can be detected below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus, it is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for ethyl mercaptan is 10 parts of ethyl mercaptan per million parts of air (ppm) [25 milligrams of ethyl mercaptan per cubic meter of air (mg/m^3)] as a ceiling concentration which shall at no time be exceeded. The NIOSH REL is 0.5 ppm (1.3 mg/m^3) as a ceiling concentration determined in any 15-minute sampling period. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 0.5 ppm (1 mg/m^3) as a time-weighted average (TWA) concentration for a normal 8-hour workday and a 40-hour workweek (Table 1).

Table 1.—Occupational exposure limits for ethyl mercaptan

	Exposure limits	
	ppm	mg/m^3
OSHA PEL ceiling	10	25
NIOSH REL ceiling (15 min)	0.5	1.3
ACGIH TLV® TWA	0.5	1

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

HEALTH HAZARD INFORMATION

• **Routes of exposure**

Ethyl mercaptan may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• **Summary of toxicology**

1. *Effects on animals:* Acute inhalation of ethyl mercaptan by rats and mice caused irritation of mucous membranes, incoordination, staggering gait, weakness, partial skeletal muscle paralysis, deficient oxygenation of the blood (cyanosis), respiratory depression, coma, and death. Sublethal doses produced swelling, fatty degeneration, and tissue destruction (necrosis) of the liver and cloudy swelling in the kidneys. Undiluted ethyl mercaptan instilled in the eyes of rabbits caused slight-to-moderate irritation. Chronic inhalation of ethyl mercaptan by rats and rabbits caused cardiovascular disorders, decreased gas exchange, increased nervous excitability, and effects on the blood-forming system including decreased red blood cell counts.

2. *Effects on humans:* Persons clinically exposed to low concentrations of ethyl mercaptan over a 5- to 10-day period reported an altered taste reaction to bitter and sweet substances and a rise in olfactory threshold.

• **Signs and symptoms of exposure**

Short-term (acute): Exposure to ethyl mercaptan can cause headache, nausea, weakness, fatigue, incoordination, and irritation of the mucous membranes.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to ethyl mercaptan, the physician 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, eyes, and nervous and respiratory systems.

Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to ethyl mercaptan at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include chronic diseases of the skin and respiratory system.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to ethyl mercaptan. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the skin, eyes, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

• **Medical practices 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 which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population.

MONITORING AND MEASUREMENT PROCEDURES

• **Ceiling concentration evaluation**

Measurements to determine worker exposure should be taken during periods of maximum expected airborne concentrations of ethyl mercaptan. Each measurement to determine the

NIOSH REL (ceiling exposure) in the worker's breathing zone should consist of a 15-minute sample or a series of consecutive samples that total 15 minutes. A minimum of three measurements should be taken during one workshift, and the highest of all measurements taken is an estimate of the worker's exposure. If the periods of maximum exposure are not clearly defined, a statistical procedure which can be used as a peak exposure detection strategy is given in the *Occupational Exposure Sampling Strategy Manual*.

- **Method**

Currently there is no NIOSH-validated method for sampling and analysis of ethyl mercaptan. Detector tubes or other direct-reading devices calibrated to measure ethyl mercaptan may be used if available.

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with ethyl mercaptan.

Workers should be provided with and required to use splash-proof safety goggles where ethyl mercaptan may come in contact with the eyes.

SANITATION

Clothing which is contaminated with ethyl mercaptan should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of ethyl mercaptan from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of ethyl mercaptan's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with ethyl mercaptan should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle ethyl mercaptan should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to ethyl mercaptan may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for ethyl mercaptan

Operations	Controls
During use as a fuel gas odorant	Process enclosure, general dilution ventilation, personal protective equipment
During use as a chemical intermediate or raw material in the production of insecticides, anti-oxidants, plastics, and pharmaceuticals	Process enclosure, general dilution ventilation, personal protective equipment
During use as a stabilizer (0.5 to 5% quantities for stabilizing synthetic resins, rubber, polyvinyl compounds, and adhesives)	Process enclosure, general dilution ventilation, personal protective equipment
During synthesis and processing of ethyl mercaptan	Process enclosure, general dilution ventilation, personal protective equipment
During use as a solvent for elastomeric polymers and oil soluble dyes in industrial stains and quicksetting rubber cements	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During cleaning and maintenance of storage vessels and equipment	Local exhaust ventilation, general dilution ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to ethyl mercaptan, an eye-wash fountain should be provided within the immediate work area for emergency use.

If ethyl mercaptan gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to ethyl mercaptan, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If ethyl mercaptan gets on the skin, wash it immediately with soap and water. If ethyl mercaptan penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If ethyl mercaptan is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing ethyl mercaptan, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from ethyl mercaptan vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing ethyl mercaptan may be absorbed in vermiculite, dry sand, earth, or a similar material, treated with hypochlorite, and placed in an appropriate container. Ethyl mercaptan should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing ethyl mercaptan may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for ethyl mercaptan

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 5 ppm	Any supplied-air respirator
	Any self-contained breathing apparatus
	Any chemical cartridge respirator with organic vapor cartridge(s)
Less than or equal to 12.5 ppm	Any supplied-air respirator operated in a continuous flow mode
	Any powered air-purifying respirator with organic vapor cartridge(s)
Less than or equal to 25 ppm	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any powered air-purifying respirator with a tight-fitting facepiece and organic vapor cartridge(s)
	Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s)
	Any supplied-air respirator with a tight-fitting facepiece and operated in a continuous flow mode
Less than or equal to 500 ppm	Any supplied-air respirator with a half-mask and operated in a pressure-demand or other positive pressure mode
Less than or equal to 1,000 ppm	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 1,000 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
†The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 0.5 ppm (1.3 mg/m^3) (ceiling).

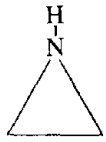
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ETHYLENEIMINE POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about ethyleneimine for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** C_2H_5N
- **Structure:**



- **Synonyms:** Aminoethylene, azirane, dihydroazirene, dihydro-1h-azirine, dimethyleneimine, dimethylenimine
- **Identifiers:** CAS 151-56-4; RTECS KX5075000; DOT 1185, label required: "Flammable Liquid, Poison"
- **Appearance and odor:** Colorless volatile liquid with an intense odor like ammonia

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 43.08
2. Boiling point (at 760 mmHg): 56°C (132°F)
3. Specific gravity (water = 1): 0.8321
4. Vapor density (air = 1 at boiling point of ethyleneimine): 1.5
5. Melting point: -59°C (-74°F)
6. Vapor pressure at 20°C (68°F): 160 mmHg
7. Soluble in water

- **Reactivity**

1. Incompatibilities: Contact with silver, aluminum, or acid may cause explosive polymerization.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide and oxides of nitrogen) may be released in a fire involving ethyleneimine.

- **Flammability**

1. Flash point: -11.1°C (12°F) (closed cup)
2. Autoignition temperature: 320°C (608°F)
3. Flammable limits in air, % by volume: Lower, 3.6; Upper, 46
4. Extinguishant: Dry chemical, alcohol foam, or carbon dioxide
5. Class IB Flammable Liquid (29 CFR 1910.106), Flammability Rating 3 (NFPA)

- **Warning properties**

1. Odor threshold: 2 ppm
2. Eye irritation levels: 100 ppm
3. Evaluation of warning properties for respirator selection: Warning properties are not considered in recommending respirators for use with carcinogens.

EXPOSURE LIMITS

The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for ethyleneimine is 0.5 ppm [1.0 milligram of ethyleneimine per cubic meter of air (mg/m³)] (Skin) as a time-weighted average (TWA) concentration over an 8-hour workshift. The notation "Skin" refers to the potential contribution to overall exposure by the cutaneous route including the mucous membranes and eyes. The OSHA standard requires implementation of stringent controls wherever ethyleneimine or solid or liquid mixtures containing at least 0.1% by weight or volume of ethyleneimine are manufactured, processed, repackaged, released, handled, or stored (see "General Control Procedures"). Details of this standard can be found in the Code of Federal Regulations, 29 CFR 1910.1012, Ethyleneimine. The National Institute for Occupational Safety and Health (NIOSH) concurs with the OSHA standard. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 0.5 ppm (1.0 mg/m³) (Skin) as a TWA for a normal 8-hour workday and a 40-hour workweek.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Ethyleneimine may cause adverse health effects following exposure via inhalation, ingestion, or dermal contact.

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• **Summary of toxicology**

1. *Effects on animals:* In rabbits and cats, acute instillation of ethyleneimine in the eyes caused damage, blindness, and death; oral administration of ethyleneimine to rats caused decreased white blood cell counts and tissue degeneration of the liver, kidneys, and heart. Subchronic subcutaneous injection of ethyleneimine in rats produced injection-site skin cancer. Chronic oral administration of ethyleneimine to mice produced cancers of the liver and lungs.

2. *Effects on humans:* Acute inhalation or dermal exposure of laboratory workers has caused central nervous system (CNS) effects, excess fluid in the lungs, damage to the liver and kidneys, and in some cases, death.

• **Signs and symptoms of exposure**

Short-term exposure (acute): Exposure to ethyleneimine can cause delayed onset headache, dizziness, nausea, and vomiting. Skin sensitization and severe irritation and inflammation of the eyes, nose, and throat can also occur.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to ethyleneimine, the physician 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, liver, kidneys, and nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to ethyleneimine at or below the NIOSH REL.

The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic diseases of the liver or skin or concurrent dermatitis. The physician should obtain baseline values for tests of liver function.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to ethyleneimine. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, liver, kidneys, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and ATS: Standardized questionnaires and tests of lung function.

• **Medical practices recommended at the time of job transfer or termination**

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

• **Sentinel health events**

Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **Method**

Sampling and analysis may be performed by collecting ethyleneimine vapors with bubblers containing Folin's reagent followed by extraction with chloroform and analysis by high-pressure liquid chromatography. Direct-reading devices calibrated to measure ethyleneimine may also be used if available. A detailed sampling and analytical method for ethyleneimine may be found in the *NIOSH Manual of Analytical Methods* (method number 300).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

In operations involving "laboratory-type hoods" or in locations where ethyleneimine is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, OSHA requires that workers: (1) be provided with and required to use clean, full-body CPC (smocks, coveralls, or long-sleeved shirts and long pants), shoe covers, and gloves prior to entering a regulated area; (2) be provided with and required to use approved respirators (a respirator affording higher levels of protection may be substituted); and (3) remove the protective clothing and equipment prior to exiting a regulated area, and at the last exit of the day, place used clothing and equipment in impervious containers for decontamination or disposal.

SANITATION

For closed system operations or in locations where ethyleneimine is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, OSHA requires that workers: (1) wash their hands, forearms, faces, and necks prior to exiting the regulated area and before engaging in other activities, and (2) shower after the last exit of the day in designated facilities.

In isolated systems, such as a "glove box," OSHA requires that workers wash their hands and arms with soap and water upon completion of the assigned task and before engaging in other activities not associated with the isolated system.

If it is necessary for workers to wear protective clothing, OSHA requires that a clean change room be provided and equipped with showers and washing facilities. NIOSH recommends that lockers that permit separation of street and work clothes be provided for the worker.

Clothing which is contaminated with ethyleneimine should be removed immediately and placed in sealed containers for storage until it can be discarded or until provision is made for the removal of ethyleneimine from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of ethyleneimine's hazardous properties. Reusable clothing and equipment should be checked for residual contamination before reuse or storage.

Decontamination and disposal procedures should be established and implemented to remove ethyleneimine from materials and equipment. Contaminated material should be removed from regulated areas without further contamination of the facility.

OSHA requires that workers wash their faces, necks, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

In regulated areas, OSHA prohibits the storage or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing.

OSHA prohibits the location of drinking fountains in regulated areas.

GENERAL CONTROL PROCEDURES

The following control procedures are derived from OSHA requirements as stated in 29 CFR 1910.1012:

Areas where ethyleneimine is manufactured, processed, used, repackaged, released, handled, or stored shall be designated as regulated areas, and entry into and exit from these areas shall be restricted and controlled. Only authorized workers are permitted access to regulated areas.

Workers authorized to enter regulated areas shall receive a training and indoctrination program including but not limited to the nature of the carcinogenic hazards of ethyleneimine, local and systemic toxicity, the specific nature of the operations which could result in exposure, and the purpose for and the significance of decontamination and emergency practices and procedures.

Entrances to regulated areas shall be posted with signs indicating that a cancer-suspect agent is present and that only authorized workers wearing appropriate protective clothing and equipment shall be admitted.

Appropriate signs and instructions shall be posted at the entrance to and exit from regulated areas to inform workers of the procedures that must be followed when entering or leaving a regulated area.

Open vessel system operations involving ethyleneimine which are not in an isolated system, laboratory-type hood, or other system affording equivalent protection against the entry of ethyleneimine into regulated areas, nonregulated areas, or the external environment are prohibited.

In operations involving "laboratory-type hoods" or in locations where ethyleneimine is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, each operation shall be provided with continuous local exhaust ventilation so that air movement is always from ordinary work areas to the operation. Exhaust air shall not be discharged to regulated areas, nonregulated areas, or the external environment unless decontaminated. Clean makeup air shall be introduced in sufficient volume to maintain the correct operation of the local exhaust system.

Containers of ethyleneimine shall be identified as to contents and shall contain a hazard warning.

Regulated areas (with the exception of outdoor operations) shall be operated under negative pressure with respect to nonregulated areas. Local exhaust ventilation may be used to satisfy this requirement. Clean makeup air in equal volume shall replace air that is removed.

The introduction or removal of any equipment, materials, or other items to or from a regulated area shall be done in a manner that does not cause contamination of nonregulated areas or the external environment.

Decontamination procedures shall be established and implemented to remove ethyleneimine from materials, equipment, and the decontamination facility.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to ethyleneimine may occur and control methods which may be effective in each case are listed in Table 1.

Table 1.—Operations and methods of control for ethyleneimine

Operations	Controls
During use in the manufacture of paper, textiles, adhesives, binders, petroleum refining products, rocket and jet fuels, lubricants, chemo-sterilant chemicals, chemotherapeutic agents, coating resins, varnishes, lacquers, agricultural chemicals, cosmetics, ion-exchange resins, photographic chemicals, colloid flocculants, and surfactants	Process enclosure, restricted access, local exhaust ventilation where appropriate, personal protective equipment, good housekeeping and personal hygiene practices, substitution with less toxic substances

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures. If a worker has contact with ethyleneimine, OSHA requires that the worker shower as soon as possible, unless contraindicated by physical injuries.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to ethyleneimine, an eye-wash fountain should be provided within the immediate work area for emergency use.

If ethyleneimine gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to ethyleneimine, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If ethyleneimine gets on the skin, wash it immediately with soap and water. If ethyleneimine penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

- **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

OSHA requires that hazardous conditions created by spills or leaks be eliminated and that potentially affected areas be decontaminated prior to the resumption of normal operations.

OSHA requires that affected areas of spills or leaks be evacuated as soon as an emergency has been determined.

OSHA requires that only authorized workers provided with and wearing clean, impervious garments (including gloves, boots, and continuous air-supplied hoods) enter areas of spills or leaks.

OSHA requires that workers authorized to enter areas of spills or leaks be decontaminated before removing the protective garments and hoods and showering.

If ethyleneimine is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing ethyleneimine, absorb on paper towels and place in an appropriate container.
4. Large quantities of liquids containing ethyleneimine may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container.
5. Liquids containing ethyleneimine may be collected by vacuuming with an appropriate system. If a vacuum system is used to remove ethyleneimine, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls

are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 2).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

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Table 2.—Respiratory protection for ethyleneimine

Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR FORMALDEHYDE

POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about formaldehyde for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** CH_2O
- **Structure:** $CH_2=O$
- **Synonyms:** Formalin, methanal, methyl aldehyde, methylene glycol, methylene oxide, morbicid, paraform, superlysoform
- **Identifiers:** CAS 50-00-0; RTECS LP8925000; DOT 1198 and 2209, label required: "Combustible Liquid"
- **Appearance and odor:** Colorless gas with a pungent and irritating odor at ambient temperatures; also, commercially available at 30% to 55% formaldehyde in aqueous solution (formalin)

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 30.03
2. Boiling point (at 760 mmHg): -19.5°C (-3.06°F); 98°C (208°F) for 37% formaldehyde (15% methanol)
3. Specific gravity at 20°C (water = 1): 0.815; 1.075-1.081 for 37% formaldehyde (15% methanol)
4. Vapor density (air = 1 at boiling point of formaldehyde): 1.07
5. Melting point: -92°C (-133.5°F); -15°C (5°F) for 37% formaldehyde (15% methanol)
6. Vapor pressure at -88°C (-126.3°F): 10 mmHg
7. Soluble in water
8. Ionization potential: 10.88 eV

- **Reactivity**

1. Incompatibilities: Formaldehyde reacts violently with strong oxidants and alkaline materials.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving formaldehyde.
3. Caution: Formaldehyde should not be stored in confined spaces or near open flames, and containers should be protected from physical damage. Formaldehyde may react with hydrogen chloride to form bis-chloromethyl ether, a carcinogen.

- **Flammability**

1. Flash point: 50°C (122°F) for 37% formaldehyde (15% methanol) (closed cup); 85°C (185°F) for 37% formaldehyde (methanol free) (closed cup)
2. Autoignition temperature: 430°C (806°F) for 37% formaldehyde (methanol free)
3. Flammable limits in air, % by volume: Lower, 7; upper, 73
4. Extinguishant: Dry chemical, alcohol foam, carbon dioxide, or water spray (mist)
5. Class II Combustible Liquid (29 CFR 1910.106), Flammability Rating 2 (NFPA) for 37% formaldehyde (15% methanol); Class IIIA Combustible Liquid (29 CFR 1910.106), Flammability Rating 4 (NFPA) for 37% formaldehyde (methanol free)

- **Warning properties**

1. Odor threshold: 0.8 ppm
2. Eye irritation levels: In acclimated workers, mild to unpleasant irritation occurs at 2-10 ppm, and intolerable irritation (tissue damage possible) occurs at levels above 25 ppm.
3. Evaluation of warning properties for respirator selection: Warning properties are not considered in recommending respirators for use with carcinogens.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for formaldehyde is 1 part of formaldehyde per million parts of air (ppm) as a time-weighted average (TWA) concentration over an 8-hour workshift; the OSHA short-term exposure limit (STEL) is 2 ppm for any 15-minute sampling period (see 29 CFR 1910.1048). The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) is 0.016 ppm [0.02 milligram of formaldehyde per cubic meter of air (mg/m^3)] as an 8-hour TWA and 0.1 ppm (0.15 mg/m^3) as a ceiling concentration determined in any 15-minute sampling

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period. This REL represents the lowest reliably quantifiable concentration at the present time. The American Conference of Governmental Industrial Hygienists (ACGIH) has designated formaldehyde as an A2 substance (suspected human carcinogen) having an assigned threshold limit value (TLV®) of 1 ppm (1.5 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek; the ACGIH short-term exposure limit (STEL) is 2 ppm (3 mg/m³) (Table 1).

Table 1.—Occupational exposure limits for formaldehyde

	Exposure Limits	
	ppm	mg/m³
OSHA PEL TWA	1	—
STEL (15 min)	2	—
NIOSH REL TWA (Ca)*	0.016	0.02
Ceiling (15 min)	0.1	0.12
ACGIH TLV® TWA (A2)†	1	1.5
STEL (A2)	2	3

* (Ca): NIOSH recommends treating as a potential human carcinogen.
† (A2): Suspected human carcinogen.

HEALTH HAZARD INFORMATION

• Routes of exposure
Formaldehyde may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• Summary of toxicology
1. *Effects on animals:* Chronic inhalation of formaldehyde by rats produced cancer of the nasal cavity.
2. *Effects on humans:* Acute inhalation of formaldehyde has caused bronchitis, pulmonary edema, pneumonitis, pneumonia, and death due to respiratory failure. Formaldehyde solutions have caused eye burns, permanent corneal opacification, and loss of vision.

Signs and symptoms of exposure
1. *Short-term (acute):* Exposure to formaldehyde gas can cause irritation of the eyes and respiratory tract, tearing, coughing, dry throat, tightening of the chest, headache, sensation of pressure in the head, and palpitations of the heart. Ingestion of formaldehyde can cause irritation of the mouth, throat, and stomach, nausea, vomiting, convulsions, and coma.
2. *Long-term (chronic):* Exposure to formaldehyde can cause dermatitis and sensitization of the skin and respiratory tract.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program
Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation
Prior to placing a worker in a job with a potential for exposure to formaldehyde, the physician 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 surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to formaldehyde. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of asthma or of chronic skin disease, concurrent dermatitis, and significant breathing impairment due to preexisting chronic lung disease. Skin patch testing with formaldehyde is *not* recommended because of the risk of sensitization.

• Periodic medical screening and/or biologic monitoring
Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to formaldehyde. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an ex-

cessive decrease or adverse trend in the physiologic function of the eyes, skin, and respiratory system as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and ATS: standardized questionnaires and pre- and post-shift tests of lung function. Because formaldehyde gas is rapidly metabolized to naturally occurring compounds in the nasopharyngeal tissues and therefore does not accumulate in the blood, biologic monitoring would not be effective in detecting the presence of formaldehyde or its metabolites in the blood or urine.

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

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

• Sentinel health events

1. Acute SHE's include: Extrinsic asthma and allergic and/or contact dermatitis.
2. Delayed-onset SHE's include: Extrinsic asthma.

MONITORING AND MEASUREMENT PROCEDURES

• TWA exposure evaluation

Measurements to determine worker exposure to formaldehyde should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

• Ceiling concentration evaluation

Measurements to determine worker exposure should be taken during periods of maximum expected airborne concentrations of formaldehyde. Each measurement to determine the NIOSH REL (ceiling exposure) in the worker's breathing zone (air that most nearly represents that inhaled by the worker) should consist of a 15-minute sample or a series of consecutive samples that total 15 minutes. A minimum of three measurements should be taken during one workshift, and the highest of all measurements taken is an estimate of the worker's exposure. If the periods of maximum exposure are not clearly defined, a statistical procedure which can be used as a peak exposure detection strategy is given in the *Occupational Exposure Sampling Strategy Manual*.

• Method

Sampling and analysis may be performed by collecting formaldehyde with solid sorbent tubes filled with 2-(benzylamino) ethanol on Chromosorb 102 or XAD-2, followed by desorption with isooctane, ultrasonic bath, or shaking, and analyzing by using a gas chromatograph with a hydrogen-air flame ionization detector. Direct reading devices calibrated to measure formaldehyde may also be used if available. A detailed sampling and analytical method for formaldehyde may be found in the *NIOSH Manual of Analytical Methods* (method number 2502).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, and other appropriate protective clothing necessary to prevent skin contact with formaldehyde.

SANITATION

Clothing which is contaminated with formaldehyde should be removed immediately and placed in sealed containers for storage until it can be discarded or until provision is made for the removal of formaldehyde from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of formaldehyde's hazardous properties. Reusable clothing and equipment should be checked for residual contamination before reuse or storage.

A change room with showers, washing facilities, and lockers that permit separation of street and work clothes should be provided.

Workers should be required to shower following a workshift and prior to putting on street clothes. Clean work clothes should be provided daily.

Skin that becomes contaminated with formaldehyde should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle formaldehyde should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to formaldehyde may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for formaldehyde

Operations	Controls
During the synthesis and handling of formaldehyde resins; during the synthesis of chelating agents and dyes	Process enclosure, local exhaust ventilation, personal protective equipment
During use in textile manufacturing and handling and in tanning operations	Process enclosure, local exhaust ventilation, personal protective equipment
During the manufacture of particle board, soft wood plywood, sandpaper, and grinding wheels	Process enclosure, local exhaust ventilation, personal protective equipment
During use as an embalming fluid	Process enclosure, local exhaust ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to formaldehyde, an eye-wash fountain should be provided within the immediate work area for emergency use.

If formaldehyde gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to formaldehyde, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If formaldehyde gets on the skin, wash it immediately with soap and water. If formaldehyde penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If formaldehyde is spilled or leaked, the following steps should be taken:

1. If formaldehyde is in the gaseous form, stop the flow of gas If the source of the leak is a cylinder and the leak cannot be stopped in place, remove the leaking cylinder to an area with local exhaust ventilation and repair the leak or allow the cylinder to empty.
2. Remove all ignition sources.
3. Ventilate area of spill or leak.
4. For small quantities of liquids containing formaldehyde, absorb on paper towels and place in an appropriate container.
5. Large quantities of liquids containing formaldehyde may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container.
6. Liquids containing formaldehyde may be collected by vacuuming with an appropriate system. If a vacuum system is used to remove formaldehyde, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic enviromental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

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Table 3.—Respiratory protection for formaldehyde

Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR 2-HEXANONE

INTRODUCTION

This guideline summarizes pertinent information about 2-hexanone for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_6H_{12}O$
- **Structure:**

$$CH_3—\overset{\overset{O}{\|}}{C}—CH_2—CH_2—CH_2—CH_3$$

- **Synonyms:** Butyl methyl ketone, MBK, methyl butyl ketone, methyl n-butyl ketone
- **Identifiers:** CAS 591-78-6; RTECS MP1400000; DOT not assigned
- **Appearance and odor:** Colorless liquid with an odor like acetone but more pungent

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 100.18
2. Boiling point (at 760 mmHg): 127.8°C (262°F)
3. Specific gravity (water = 1): 0.8
4. Vapor density (air = 1 at boiling point of 2-hexanone): 3.5
5. Melting point: -57°C (-71°F)
6. Vapor pressure at 20°C (68°F): 3.0 mmHg; at 25°C (77°F), 3.8 mmHg
7. Solubility in water, g/100 g water at 20°C (68°F): 1.4
8. Evaporation rate (butyl acetate = 1): Approximately 1
9. Saturation concentration in air (approximate) at 20°C (68°F): 0.4% (4,000 ppm); at 25°C (77°F), 0.5% (5,000 ppm)

- **Reactivity**

1. Incompatibilities: Contact with strong oxidizers may cause fires and explosions.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving 2-hexanone.
3. Caution: 2-Hexanone will dissolve some forms of plastics, resins, and rubber.

- **Flammability**

1. Flash point: 25°C (77°F) (closed cup)
2. Autoignition temperature: 425°C (795°F)
3. Flammable limits in air, % by volume: Lower, 1.2; upper, 8
4. Extinguishant: Carbon dioxide, dry chemical, or alcohol foam
5. Class IC Flammable Liquid (29 CFR 1910.106), Flammability Rating 3 (NFPA)

- **Warning properties**

1. Odor threshold: 0.076 ppm
2. Eye irritation levels: 1,000 ppm
3. Evaluation of warning properties for respirator selection: Because of its odor, 2-hexanone can be detected below the National Institute for Safety and Health (NIOSH) recommended exposure limit (REL); thus, 2-hexanone is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for 2-hexanone is 100 parts of 2-hexanone per million parts of air (ppm) [410 milligrams of 2-hexanone per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The NIOSH REL is 1 ppm (4 mg/m³) as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 5 ppm (20 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek (Table 1).

Table 1.—Occupational exposure limits for 2-hexanone

	Exposure limits	
	ppm	mg/m³
OSHA PEL TWA	100	410
NIOSH REL TWA	1	4
ACGIH TLV® TWA	5	20

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

HEALTH HAZARD INFORMATION

• **Routes of exposure**

2-Hexanone may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• **Summary of toxicology**

1. *Effects on animals:* Acute inhalation of 2-hexanone by guinea pigs caused central nervous system depression, narcosis, coma, and death. Subchronic inhalation of 2-hexanone by rats, cats, dogs, chickens, and monkeys produced peripheral neuropathy, characterized by paralysis, nerve swelling, and loss of nerve sheath covering.

2. *Effects on humans:* Chronic inhalation or dermal exposure of workers has caused peripheral neuropathy.

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to 2-hexanone can cause headaches, drowsiness, and unconsciousness. Moderate irritation of the eyes, nose, and throat can also occur.

2. *Long-term (chronic):* Exposure to 2-hexanone can cause lightheadedness, weight loss, fatigue, intermittent tingling or prickling sensations in the arms or legs, and progressive weakness of the limbs. Dryness, irritation, and inflammation of the skin can also occur.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to 2-hexanone, the physician 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, liver, kidneys, and nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to 2-hexanone at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or chronic concurrent dermatitis, or a history and physical findings consistent with peripheral neuropathy. In addition to the medical interview and physical examination, the means to identify these conditions may include electromyography of the extremities using standardized methods and evaluation criteria.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to 2-hexanone. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, liver, kidneys, and respiratory and nervous systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

• **Medical practices recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic and laboratory tests which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population. Because occupational exposure to 2-hexanone may cause peripheral neuropathy after a prolonged period of induction-latency, the need for medical surveillance may extend well beyond termination of employment.

• **Sentinel health events**

1. Acute SHE's include: Contact and/or allergic dermatitis.
2. Delayed-onset SHE's include: Inflammatory and toxic neuropathy.

MONITORING AND MEASUREMENT PROCEDURES

• **TWA exposure evaluation**

Measurements to determine worker exposure to 2-hexanone should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

• **Method**

Sampling and analysis may be performed by collecting 2-hexanone vapors with charcoal adsorption tubes followed by desorption with carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure 2-hexanone may also be used if available. A detailed sampling and analytical method for 2-hexanone may be found in the *NIOSH Manual of Analytical Methods* (method number 1300).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with 2-hexanone.

Workers should be provided with and required to use splash-proof safety goggles where 2-hexanone may come in contact with the eyes.

SANITATION

Clothing which is contaminated with 2-hexanone should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of 2-hexanone from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of 2-hexanone's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with 2-hexanone should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or use of smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle 2-hexanone should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to 2-hexanone may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for 2-hexanone

Operations	Controls
During use as a commercial solvent for nitrocellulose, natural and synthetic resins, oils, waxes, vinyl polymers and copolymers, and cellulose acetates	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During use as a solvent in the manufacture of varnish removers, vinyl lacquers, and nitrate wood lacquers	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During use as an extractive solvent for paraffin wax; during use in the separation and purification of certain metals	Local exhaust ventilation, general dilution ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to 2-hexanone, an eye-wash fountain should be provided within the immediate work area for emergency use.

If 2-hexanone gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to 2-hexanone, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If 2-hexanone gets on the skin, wash it immediately with soap and water. If 2-hexanone penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If 2-hexanone is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing 2-hexanone, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from 2-hexanone vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing 2-hexanone may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. 2-Hexanone should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing 2-hexanone may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for 2-hexanone

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 10 ppm	Any supplied-air respirator
	Any self-contained breathing apparatus
Less than or equal to 25 ppm	Any supplied-air respirator operated in a continuous flow mode
Less than or equal to 50 ppm	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
	Any supplied-air respirator with a tight-fitting facepiece operated in a continuous flow mode
Less than or equal to 1,000 ppm	Any supplied-air respirator with a half-mask and operated in a pressure-demand or other positive pressure mode
Less than or equal to 2,000 ppm	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 2,000 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
† The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 1 ppm (4 mg/m^3) (TWA).

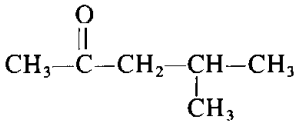
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR HEXONE

INTRODUCTION

This guideline summarizes pertinent information about hexone for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_6H_{12}O$
- **Structure:**



- **Synonyms:** Isobutyl methyl ketone; isopropylacetone; methyl isobutyl ketone; 4-methyl-2-pentanone; MIBK
- **Identifiers:** CAS 108-10-1; RTECS SA9275000; DOT 1245, label required: "Flammable Liquid"
- **Appearance and odor:** Colorless liquid with a sweet, pungent odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 100.18
2. Boiling point (at 760 mmHg): 118°C (244°F)
3. Specific gravity (water = 1): 0.8
4. Vapor density (air = 1 at boiling point of hexone): 3.5
5. Melting point: -84°C (-119°F)
6. Vapor pressure at 25°C (77°F): 7.5 mmHg
7. Solubility in water, g/100 g water at 20°C (68°F): 1.9
8. Evaporation rate (butyl acetate = 1): 1.64
9. Saturation concentration in air (approximate) at 25°C (77°F): 1.0% (10,000 ppm)

- **Reactivity**

1. Incompatibilities: Contact with strong oxidizing agents may cause fires and explosions.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving hexone.
3. Caution: Hexone will dissolve some plastics, resins, and rubber.

- **Flammability**

1. Flash point: 18°C (64°F) (closed cup)
2. Autoignition temperature: 460°C (860°F)
3. Flammable limits in air, % by volume: Lower, 1.4; upper, 7.5
4. Extinguishant: Carbon dioxide, dry chemical, or alcohol foam
5. Class IB Flammable Liquid (29 CFR 1910.106), Flammability Rating 3 (NFPA)

- **Warning properties**

1. Odor threshold: 0.68 ppm
2. Eye irritation level: 200-400 ppm
3. Nose and throat irritation may occur at 400 ppm.
4. Evaluation of warning properties for respirator selection: Because of its odor, hexone can be detected below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus, hexone is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for hexone is 100 parts of hexone per million parts of air (ppm) [410 milligrams of hexone per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The NIOSH REL is 50 ppm (200 mg/m³) as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 50 ppm (205 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek; and the ACGIH short-term exposure limit (STEL) is 75 ppm (300 mg/m³) (Table 1).

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

Table 1.—Occupational exposure limits for hexone

	Exposure limits	
	ppm	mg/m³
OSHA PEL TWA	100	410
NIOSH REL TWA	50	200
ACGIH TLV® TWA	50	205
STEL	75	300

HEALTH HAZARD INFORMATION

• Routes of exposure

Hexone may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• Summary of toxicology

1. *Effects on animals:* Subchronic inhalation of hexone by rats produced degeneration and necrosis of kidney tubules and increased kidney and liver weights.

2. *Effects on humans:* Inhalation exposure of workers to hexone has produced narcosis and slight liver enlargement.

• Signs and symptoms of exposure

1. *Short-term (acute):* Exposure to hexone can cause nausea, vomiting, headaches, weakness, dizziness, incoordination, and drowsiness. Irritation of the eyes, nose, throat, and respiratory tract can also occur.

2. *Long-term (chronic):* Exposure to hexone can cause dryness, irritation, and inflammation of the skin.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to hexone, the physician 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, liver, kidneys, and reproductive, nervous, and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to hexone at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis.

• Periodic medical screening and/or biologic monitoring

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to hexone. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, liver, kidneys, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

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

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

• Sentinel health events

Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• TWA exposure evaluation

Measurements to determine worker exposure to hexone should be taken so that the TWA exposure is based on a single entire

workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

- **Method**

Sampling and analysis may be performed by collecting hexone vapors with charcoal adsorption tubes followed by desorption with carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure hexone may also be used if available. A detailed sampling and analytical method for hexone may be found in the *NIOSH Manual of Analytical Methods* (method number 1300).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with hexone.

Workers should be provided with and required to use splash-proof safety goggles where hexone may come in contact with the eyes.

SANITATION

Clothing which is contaminated with hexone should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of hexone from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of hexone's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with hexone should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or use of smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle hexone should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to hexone may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for hexone

Operations	Controls
During application and drying of lacquers, varnishes, epoxy, acrylic, vinyl, or other cellulose- or resin-based coatings, finishes, and adhesives	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During use as a separating agent for certain inorganic salts	General dilution ventilation
During extraction in the manufacture of antibiotics and purification of petroleum products (dewaxing)	General dilution ventilation
During the manufacture of dry cleaning preparations, germicides, fungicides, and electroplating solutions	General dilution ventilation
During use in blending raw materials for molded plastics	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During use in cleaning and maintaining ketone processing equipment	General dilution ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to hexone, an eye-wash fountain should be provided within the immediate work area for emergency use.

If hexone gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to hexone, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If hexone gets on the skin, wash it immediately with soap and water. If hexone penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If hexone is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing hexone, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from hexone vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing hexone may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. Hexone should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing hexone may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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• Scientific Assembly on Environmental and Occupational Health: "Surveillance for Respiratory Hazards in the Occupational Setting," *American Review of Respiratory Diseases*, 126:952-956, 1982.
• Shell Chemical Company: *Material Safety Data Sheet—Hexone*.

Table 3.—Respiratory protection for hexone

Condition	Minimum Respiratory Protection*†
Concentration:	
Less than or equal to 500 ppm	Any chemical cartridge respirator with organic vapor cartridge(s) (substance reported to cause eye irritation or damage—may require eye protection)
	Any supplied-air respirator (substance reported to cause eye irritation or damage—may require eye protection)
	Any self-contained breathing apparatus (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 1,000 ppm	Any powered air-purifying respirator with organic vapor cartridge(s) (substance reported to cause eye irritation or damage—may require eye protection)
	Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s)
Less than or equal to 1,250 ppm	Any supplied-air respirator operated in a continuous flow mode (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 2,500 ppm	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
	Any supplied air respirator with a tight-fitting facepiece operated in a continuous flow mode (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 3,000 ppm	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 3,000 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
† The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 50 ppm 200 mg/m^3) (TWA).

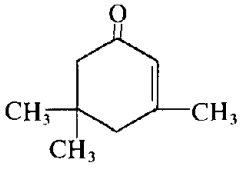
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ISOPHORONE

INTRODUCTION

This guideline summarizes pertinent information about isophorone for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_9H_{14}O$
- **Structure:**



- **Synonyms:** Isoacetophorone; isoforon; 3,5,5-trimethyl-2-cyclohexene-1-one
- **Identifiers:** CAS 78-59-1; RTECS GW7700000; DOT not assigned
- **Appearance and odor:** Colorless to pale yellow liquid with an odor like peppermint or camphor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 138.23
2. Boiling point (at 760 mmHg): 215°C (419°F)
3. Specific gravity (water = 1): 0.92
4. Vapor density (air = 1 at boiling point of isophorone): 4.77
5. Melting point: -8.1°C (17°F)
6. Vapor pressure at 20°C (68°F), 0.26 mmHg; at 25°C (77°F), 0.44 mmHg
7. Solubility in water, g/100 g water at 20°C (68°F): 1.2
8. Evaporation rate (butyl acetate = 1): 0.03
9. Saturation concentration in air (approximate): At 20°C (68°F), 0.034% (340 ppm); at 25°C (77°F), 0.06% (600 ppm)

- **Reactivity**

1. Incompatibilities: Contact with strong oxidizers may cause fires and explosions.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving isophorone.
3. Caution: Isophorone will dissolve some forms of plastics, resins, and rubber.

- **Flammability**

1. Flash point: 84.4°C (184°F) (closed cup)
2. Autoignition temperature: 460°C (860°F)
3. Flammable limits in air, % by volume: Lower, 0.8; upper, 3.8
4. Extinguishant: Carbon dioxide, dry chemical, or alcohol foam
5. Class IIIA Combustible Liquid (29 CFR 1910.106), Flammability Rating 2 (NFPA)

- **Warning properties**

1. Odor threshold: 0.2 ppm
2. Eye irritation level: 25 ppm
3. Evaluation of warning properties for respirator selection: Because of its odor, isophorone can be detected below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus it is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for isophorone is 25 parts of isophorone per million parts of air (ppm) [140 milligrams of isophorone per cubic meter of air (mg/m³)] as a time-weighted average (TWA) over an 8-hour workshift. The NIOSH REL is 4 ppm (23 mg/m³) as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value ceiling (TLV®-C), the concentration that should not be exceeded during any part of the working exposure, is 5 ppm (25 mg/m³) (Table 1).

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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

Table 1.—Occupational exposure limits for isophorone

	Exposure limits ppm	mg/m³
OSHA PEL TWA	25	140
NIOSH REL TWA	4	23
ACGIH TLV®-ceiling	5	25

HEALTH HAZARD INFORMATION

• Routes of exposure

Isophorone may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• Summary of toxicology

Effects on animals: Acute inhalation of isophorone by rats caused narcosis and death. Subchronic inhalation of isophorone by guinea pigs and rats caused injury to the kidneys (congestion, dilated Bowman's capsules, or cloudy swelling of convoluted tubules) and lungs (congestion, hemorrhage, desquamation, or pneumonia).

• Signs and symptoms of exposure

1. *Short-term (acute):* Exposure to isophorone can cause depressed appetite and body weight, headache, dizziness, fatigue, nausea, and diarrhea. Irritation of the skin, eyes, and upper and lower respiratory tracts can also occur.
2. *Long-term (chronic):* Exposure to isophorone can cause drying, irritation, and inflammation of the skin.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to isophorone, the physician 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, liver, kidneys, and nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to isophorone at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease, concurrent dermatitis, and significant breathing impairment due to preexisting chronic lung disease. In addition to the medical interview and physical examination, the means to identify respiratory conditions may include the methods recommended by NIOSH and ATS.

• Periodic medical screening and/or biologic monitoring

Occupational health interviews and physical examinations should be performed at regular intervals. Additional frequent examinations may be necessary should a worker develop symptoms that may be attributed to exposure to isophorone. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, liver, kidneys, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and ATS: standardized questionnaires, tests of lung function, and chest X-rays.

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

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

• Sentinel health events

Acute SHE's include contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **TWA exposure evaluation**

Measurements to determine worker exposure to isophorone should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

• **Method**

Sampling and analysis may be performed by collecting isophorone vapors with a charcoal tube followed by desorption with carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure isophorone may also be used if available. A detailed sampling and analytical method for isophorone may be found in the *NIOSH Manual of Analytical Methods* (method number 2508).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with isophorone.

Workers should be provided with and required to use splash-proof safety goggles where isophorone may come in contact with the eyes.

SANITATION

Clothing which is contaminated with isophorone should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of isophorone from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of isophorone's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with isophorone should be promptly washed with soap and water.

Workers who handle isophorone should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle isophorone should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to isophorone may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for isophorone

Operations	Controls
During use as a solvent in the manufacture of vinyl resins, nitrocellulose, fats, chlorinated rubber, herbicides, coatings, roll-coating finishes, siding, paint, adhesives, and inks	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During use in organic synthesis in the manufacture of lubricating oil additives, fungicides, and tetramethylquanidine	Local exhaust ventilation, general dilution ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to isophorone, an eye-wash fountain should be provided within the immediate work area for emergency use.

If isophorone gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to isophorone, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If isophorone gets on the skin, wash it immediately with soap and water. If isophorone penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If isophorone is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing isophorone, absorb on paper towels and place in an appropriate container. Place towels in a safe place (such as a fume hood) for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from isophorone vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing isophorone may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. Isophorone should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing isophorone may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for isophorone

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 40 ppm	Any supplied-air respirator (substance reported to cause eye irritation or damage—may require eye protection)
	Any self-contained breathing apparatus (substance reported to cause eye irritation or damage—may require eye protection)
	Any chemical cartridge respirator with organic vapor cartridge(s) (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 100 ppm	Any supplied-air respirator operated in a continuous flow mode (substance reported to cause eye irritation or damage—may require eye protection)
	Any powered air-purifying respirator with organic vapor cartridge(s) (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 200 ppm	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
	Any powered air-purifying respirator with a tight-fitting facepiece and organic vapor cartridge(s) (substance reported to cause eye irritation or damage—may require eye protection)
	Any supplied air respirator with a tight-fitting facepiece and operated in a continuous flow mode (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 800 ppm	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 800 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
† The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 4 ppm (23 mg/m^3) (TWA).

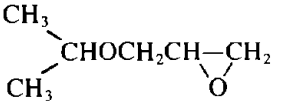
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ISOPROPYL GLYCIDYL ETHER

INTRODUCTION

This guideline summarizes pertinent information about isopropyl glycidyl ether (IGE) for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_6H_{12}O_2$
- **Structure:**



- **Synonyms:** 1,2-epoxy-3-isopropoxypropane; glycidyl isopropyl ether; IGE; (isopropoxymethyl)oxirane; isopropyl epoxypropyl ether
- **Identifiers:** CAS 4016-14-2; RTECS TZ3500000; DOT not assigned
- **Appearance:** Colorless liquid

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 116.18
2. Boiling point (at 760 mmHg): 137°C (270°F)
3. Specific gravity (water = 1): 0.9
4. Vapor density (air = 1 at boiling point of IGE): 4.0
5. Vapor pressure at 25°C (77°F): 9.4 mmHg
6. Solubility in water, g/100 g water at 20°C (68°F): 18.8
7. Evaporation rate (butyl acetate = 1): 0.99
8. Saturation concentration in air (approximate) at 25°C (77°F): 1.237% (12.370 ppm)

- **Reactivity**

1. Incompatibilities: Contact with strong oxidizing agents may cause fires and explosions. Contact with strong caustics may cause polymerization. IGE should not be exposed to air or light because explosive peroxides may be formed.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving IGE.
3. Caution: IGE will cause some forms of plastics, coatings, and rubber to deteriorate.

- **Flammability**

1. Flash point: 33°C (92°F) (closed cup)
2. Extinguishant: Dry chemical, carbon dioxide, or alcohol foam
3. Class IC Flammable Liquid (29 CFR 1910.106)

- **Warning properties**

Evaluation of warning properties for respirator selection: Based on lack of information on odor threshold and eye irritation levels, IGE should be considered to have poor warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for IGE is 50 parts of IGE per million parts of air (ppm) [240 milligrams of IGE per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) is 50 ppm (240 mg/m³) as a ceiling concentration determined in any 15-minute sampling period. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 50 ppm (240 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek; the ACGIH short-term exposure limit (STEL) is 75 ppm (360 mg/m³) (Table 1).

Table 1.—Occupational exposure limits for isopropyl glycidyl ether

	Exposure limits	
	ppm	mg/m³
OSHA PEL TWA	50	240
NIOSH REL ceiling (15 min)	50	240
ACGIH TLV® TWA	50	240
STEL	75	360

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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

HEALTH HAZARD INFORMATION

• **Routes of exposure**
IGE may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• **Summary of toxicology**
Effects on animals: Acute oral administration of IGE to mice, rats, and rabbits caused central nervous system depression. Subchronic inhalation of IGE by rats caused decreased weight gain, inflammation of the lungs, pneumonia, and respiratory distress.

• **Signs and symptoms of exposure**
1. *Short-term (acute):* Exposure to IGE can cause mental confusion and moderate irritation of the eyes, skin, and respiratory tract.
2. *Long-term (chronic):* Exposure to IGE can cause dermatitis and skin sensitization.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**
Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**
Prior to placing a worker in a job with a potential for exposure to IGE, the physician 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 nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to IGE at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis.

• **Periodic medical screening and/or biologic monitoring**
Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to IGE. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

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

• **Sentinel health events**
Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **Ceiling concentration evaluation**
Measurements to determine worker exposure should be taken during periods of maximum expected airborne concentrations of IGE. Each measurement to determine the NIOSH REL (ceiling exposure) in the worker's breathing zone (air that most nearly represents that inhaled by the worker) should consist of a 15-minute sample or a series of consecutive samples that total 15 minutes. A minimum of three measurements should be taken during one workshift, and the highest of all measurements taken is an estimate of the worker's exposure. If the periods of maximum exposure are not clearly defined, a statistical procedure which can be used as a peak exposure detection strategy is given in the *Occupational Exposure Sampling Strategy Manual*.

• **Method**
Sampling and analysis may be performed by collecting IGE vapors with charcoal tubes followed by desorption with car-

bon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure IGE may also be used if available. A detailed sampling and analytical method for IGE may be found in the *NIOSH Manual of Analytical Methods* (method number S77).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum) and other appropriate protective clothing necessary to prevent skin contact with IGE.

Workers should be provided with and required to use splash-proof safety goggles where IGE may come in contact with the eyes.

SANITATION

Clothing which is contaminated with IGE should be removed immediately and placed in closed containers for storage until provision is made for the removal of IGE from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of IGE's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with IGE should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage of smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle IGE should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to IGE may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for isopropyl glycidyl ether

Operations	Controls
During use as a reactive diluent for epoxy resins; during use as a chemical intermediate for the synthesis of esters and ethers	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During use as a stabilizing agent for organic chemicals	Local exhaust ventilation, general dilution ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to IGE, an eye-wash fountain should be provided within the immediate work area for emergency use.

If IGE gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to IGE, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If IGE gets on the skin, wash it immediately with soap and water. If IGE penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If IGE is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing IGE, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from IGE vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing IGE may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. IGE should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing IGE may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flash back prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed

to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for isopropyl glycidyl ether

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 1,250 ppm	Any supplied-air respirator operated in a continuous flow mode (substance causes eye irritation or damage—eye protection needed)
Less than or equal to 1,500 ppm	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
Planned or emergency entry into environments containing unknown concentrations or levels above 1,500 ppm	Any self-contained breathing apparatus with a full facepiece and operated in pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
† The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 50 ppm (240 mg/m^3) (ceiling).

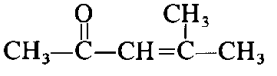
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR MESITYL OXIDE

INTRODUCTION

This guideline summarizes pertinent information about mesityl oxide for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_6H_{10}O$
- **Structure:**



- **Synonyms:** Isobutenyl methyl ketone, isopropylidene acetone, methyl isobutenyl ketone, 4-methyl-3-penten-2-one
- **Identifiers:** CAS 141-79-7; RTECS SB4200000; DOT 1229, label required: "Flammable Liquid"
- **Appearance and odor:** Oily, colorless or pale yellow liquid with a strong odor like peppermint

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 98.16
2. Boiling point (at 760 mmHg): 130°C (266°F)
3. Specific gravity (water = 1): 0.856
4. Vapor density (air = 1 at boiling point of mesityl oxide): 3.4
5. Melting point: -46°C (-50.8°F)
6. Vapor pressure at 20°C (68°F): 8 mmHg; at 25°C (77°F), 9.5 mmHg
7. Solubility in water, g/100 g water at 20°C (68°F): 3
8. Evaporation rate (butyl acetate = 1): 0.85
9. Saturation concentration in air (approximate): At 20°C (68°F), 1.05% (10,500 ppm); at 25°C (77°F), 1.25% (12,500 ppm)
10. Ionization potential: 9.08 eV

- **Reactivity**

1. Incompatibilities: Contact with oxidizing agents may cause fires and explosions.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving mesityl oxide.
3. Caution: Mesityl oxide may dissolve some forms of plastics, resins, and rubber.

- **Flammability**

1. Flash point: 30.6°C (87°F) (closed cup)
2. Autoignition temperature: 344°C (652°F)
3. Flammable limits in air, % by volume: Lower, 1.3; upper, 8.8
4. Extinguishant: Carbon dioxide, dry chemical, or alcohol foam
5. Class IC Flammable Liquid (29 CFR 1910.106), Flammability Rating 3 (NFPA)

- **Warning properties**

1. Odor threshold: 0.45 ppm
2. Eye irritation level: 25 ppm
3. Evaluation of warning properties for respirator selection: Because of its odor, mesityl oxide can be detected below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus it is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for mesityl oxide is 25 parts of mesityl oxide per million parts of air (ppm) [100 milligrams of mesityl oxide per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The NIOSH REL is 10 ppm (40 mg/m³) as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 15 ppm (60 mg/m³) as a TWA for a normal 8-hour workday or a 40-hour workweek; the ACGIH short-term exposure limit (STEL) is 25 ppm (100 mg/m³) (Table 1).

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

Table 1.—Occupational exposure limits for mesityl oxide

	Exposure limits ppm	mg/m³
OSHA PEL TWA	25	100
NIOSH REL TWA	10	40
ACGIH TLV® TWA	15	60
STEL	25	100

HEALTH HAZARD INFORMATION

• Routes of exposure

Mesityl oxide may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• Summary of toxicology

1. *Effects on animals:* Acute inhalation of mesityl oxide by mice or rabbits produced narcosis, tissue destruction (necrosis) of the liver, hemorrhage and edema of the lungs, alimentary tract distention, and death. Subchronic inhalation of mesityl oxide by rats, mice, or guinea pigs caused congestion of the liver and lungs and damage to the kidney tubules.

2. *Effects on humans:* Exposure of workers to mesityl oxide has caused centeral nervous system depression and narcosis.

• Signs and symptoms of exposure

1. *Short-term (acute):* Exposure to mesityl oxide can cause headache, dizziness, breathing difficulty (dyspnea), and unconsciousness. Irritation of the eyes, nose, and throat can also occur.

2. *Long-term (chronic):* Exposure to mesityl oxide can cause dryness, irritation, and inflammation of the skin.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to mesityl oxide, the physician 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, liver, kidneys, and nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to mesityl oxide at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis.

• Periodic medical screening and/or biologic monitoring

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to mesityl oxide. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, liver, kidneys, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

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

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

MONITORING AND MEASUREMENT PROCEDURES

• TWA exposure evaluation

Measurements to determine worker exposure to mesityl oxide should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of

consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

• **Method**

Sampling and analysis may be performed by collecting mesityl oxide vapors with charcoal tubes followed by desorption with carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure mesityl oxide may also be used. A detailed sampling and analytical method for mesityl oxide may be found in the *NIOSH Manual of Analytical Methods* (method number 1301).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with mesityl oxide.

Workers should be provided with and required to use splash-proof safety goggles where mesityl oxide may come in contact with the eyes.

SANITATION

Clothing which is contaminated with mesityl oxide should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of mesityl oxide from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of mesityl oxide's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with mesityl oxide should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle mesityl oxide should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to mesityl oxide may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for mesityl oxide

Operations	Controls
During spray application of lacquers and stains; during use as a solvent	Process enclosure, local exhaust ventilation, personal protective equipment
During use as a paint and varnish remover and carburetor cleaner	General dilution ventilation, personal protective equipment
During preparation and application of roll-coating inks	Process enclosure, local exhaust ventilation, personal protective equipment
During flotation processes for selective benefaction of ores	Natural ventilation

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to mesityl oxide, an eye-wash fountain should be provided within the immediate work area for emergency use.

If mesityl oxide gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to mesityl oxide, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If mesityl oxide gets on the skin, wash it immediately with soap and water. If mesityl oxide penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If mesityl oxide is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing mesityl oxide, absorb on paper towels and place in appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from mesityl oxide vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing mesityl oxide may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. Mesityl oxide should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. Liquids containing mesityl oxide may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for mesityl oxide

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 250 ppm	Any supplied-air respirator operated in a continuous flow mode (substance causes eye irritation or damage—eye protection needed)
Less than or equal to 500 ppm	Any powered air-purifying respirator with organic vapor cartridge(s) (substance causes eye irritation or damage—eye protection needed)
	Any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s)
	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
Less than or equal to 5,000 ppm	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 5,000 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
† The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 10 ppm (40 mg/m^3) (TWA).

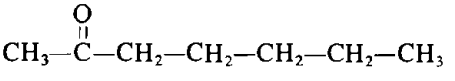
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR METHYL (n-AMYL) KETONE

INTRODUCTION

This guideline summarizes pertinent information about methyl (n-amyl) ketone for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_7H_{14}O$
- **Structure:**



- **Synonyms:** n-Amyl methyl ketone, 2-heptanone
- **Identifiers:** CAS 110-43-0; RTECS MJ5075000; DOT 1110
- **Appearance and odor:** Clear, colorless liquid with a penetrating, fruity odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 114.21
2. Boiling point (at 760 mmHg): 151°C (304°F)
3. Specific gravity (water = 1): 0.82
4. Vapor density [air = 1 at boiling point of methyl (n-amyl) ketone]: 3.93
5. Melting point: -35°C (-31°F)
6. Vapor pressure at 20°C (68°F): 2 mmHg
7. Solubility in water, g/100 g water at 20°C (68°F): 0.43
8. Evaporation rate (butyl acetate = 1): 0.4
9. Saturation concentration in air (approximate) at 20°C (68°F): 0.27% (2,700 ppm)
10. Ionization potential: 9.33 eV

- **Reactivity**

1. Incompatibilities: Contact with strong acids, alkalies, and oxidizing agents may cause fires and explosions.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving methyl (n-amyl) ketone.
3. Caution: Methyl (n-amyl) ketone will dissolve some forms of plastics, resins, and rubber.

- **Flammability**

1. Flash point: 39°C (102°F) (closed cup)
2. Autoignition temperature: 393°C (740°F)
3. Flammable limits in air, % by volume: Lower, 1.1; upper, 7.9
4. Extinguishant: Dry chemical, carbon dioxide, or alcohol foam
5. Class II Combustible Liquid (29 CFR 1910.106), Flammability Rating 2 (NFPA)

- **Warning properties**

1. Odor threshold: 0.35 ppm
2. Evaluation of warning properties for respirator selection: Because of its odor, methyl (n-amyl) ketone can be detected below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL); thus, it is treated as a chemical with adequate warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for methyl (n-amyl) ketone is 100 parts of methyl (n-amyl) ketone per million parts of air (ppm) [465 milligrams of methyl (n-amyl) ketone per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The NIOSH REL is 100 ppm (465 mg/m³) as a TWA for up to a 10-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 50 ppm (235 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek.

Table 1.—Occupational exposure limits for methyl (n-amyl) ketone

	Exposure limits	
	ppm	mg/m³
OSHA PEL TWA	100	465
NIOSH REL TWA	100	465
ACGIH TLV® TWA	50	235

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HEALTH HAZARD INFORMATION

• Routes of exposure

Methyl (n-amyl) ketone may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• Summary of toxicology

Effects on animals: Acute inhalation of methyl (n-amyl) ketone by guinea pigs caused irritation of the mucous membranes, narcosis, and death.

• Signs and symptoms of exposure

1. *Short-term exposure (acute):* Exposure to methyl (n-amyl) ketone can cause headaches, dizziness, and irritation of the eyes, nose, and throat.

2. *Long-term exposure (chronic):* Exposure to methyl (n-amyl) ketone can cause dryness and irritation of the skin.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to methyl (n-amyl) ketone, the physician 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, liver, kidneys, and nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to methyl (n-amyl) ketone at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis.

• Periodic medical screening and/or biologic monitoring

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to methyl (n-amyl) ketone. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, liver, kidneys, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

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

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

• Sentinel health events

Acute SHE's include contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• TWA exposure evaluation

Measurements to determine worker exposure to methyl (n-amyl) ketone should be taken so that the TWA exposure is based on a single entire workshift sample or an appropriate number of consecutive samples collected during the entire workshift. Under certain conditions, it may be appropriate to collect several short-term interval samples (up to 30 minutes each) to determine the average exposure level. Air samples should be taken in the worker's breathing zone (air that most nearly represents that inhaled by the worker).

• Method

Sampling and analysis may be performed by collecting methyl (n-amyl) ketone vapors with charcoal tubes followed by desorption with carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated

to measure methyl (n-amyl) ketone may also be used if available. A detailed sampling and analytical method for methyl (n-amyl) ketone may be found in the *NIOSH Manual of Analytical Methods* (method number 1301).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with methyl (n-amyl) ketone.

Workers should be provided with and required to use splash-proof safety goggles where methyl (n-amyl) ketone may come in contact with the eyes.

SANITATION

Clothing which is contaminated with methyl (n-amyl) ketone should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of methyl (n-amyl) ketone from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of methyl (n-amyl) ketone's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with methyl (n-amyl) ketone should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle methyl (n-amyl) ketone should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to methyl (n-amyl) ketone may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for methyl (n-amyl) ketone

Operations	Controls
During use in the spray application of lacquers	Local exhaust ventilation, personal protective equipment
During use in the preparation of synthetic resins, especially for metal roll-coating	Process enclosure, local exhaust ventilation
During use as a solvent for rubber and nitrocellulose	Local exhaust ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to methyl (n-amyl) ketone, an eye-wash fountain should be provided within the immediate work area for emergency use.

If methyl (n-amyl) ketone gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to methyl (n-amyl) ketone, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If methyl (n-amyl) ketone gets on the skin, wash it immediately with soap and water. If methyl (n-amyl) ketone penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

- **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If methyl (n-amyl) ketone is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing methyl (n-amyl) ketone, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from methyl (n-amyl) ketone vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing methyl (n-amyl) ketone may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. Methyl (n-amyl) ketone should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.

5. Liquids containing methyl (n-amyl) ketone may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for methyl (n-amyl) ketone

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 1,000 ppm	Any chemical cartridge respirator with organic vapor cartridge(s) (substance reported to cause eye irritation or damage—may require eye protection)
	Any supplied-air respirator (substance reported to cause eye irritation or damage—may require eye protection)
	Any self-contained breathing apparatus (substance reported to cause eye irritation or damage—may require eye protection)
	Any powered air-purifying respirator with organic vapor cartridge(s) (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 2,500 ppm	Any supplied-air respirator operated in a continuous flow mode (substance reported to cause eye irritation or damage—may require eye protection)
Less than or equal to 4,000 ppm	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
Planned or emergency entry into environments containing unknown concentrations or levels above 4,000 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
† The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 100 ppm (465 mg/m^3) (TWA).

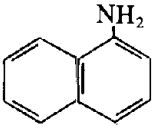
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR alpha-NAPHTHYLAMINE POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about alpha-naphthylamine for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_{10}H_9N$
- **Structure:**



- **Synonyms:** 1-Naphthylamine; 1-aminonaphthalene; naphthalidam; naphthalidine
- **Identifiers:** CAS 134-32-7; RTECS QM1400000; DOT 2077, label required: "St. Andrew's Cross (X)"
- **Appearance and odor:** Colorless to yellow crystals which darken in air to a reddish purple color with a weak ammonia-like odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 143.20
2. Boiling point (at 760 mmHg): 301°C (573.8°F)
3. Specific gravity (water = 1): 1.2
4. Vapor density (air = 1 at boiling point of alpha-naphthylamine): 4.93
5. Melting point: 50°C (122°F)
6. Vapor pressure at 104°C (219°F): 1 mmHg
7. Solubility in water, g/100 g water at 25°C (77°F): 0.17

- **Reactivity**

1. Incompatibilities: alpha-naphthylamine oxidizes in air
2. Hazardous decomposition products: Toxic vapors and gases (e.g., oxides of nitrogen and carbon monoxide) may be released in a fire involving alpha-naphthylamine.

- **Flammability**

1. Flash point: 157°C (315°F) (closed cup)
2. Extinguishant: Water, dry chemical, carbon dioxide, or alcohol foam
3. Combustible solid, Flammability Rating 1 (NFPA)

- **Warning properties**

Evaluation of warning properties for respirator selection: Warning properties are not considered in recommending respirators for use with carcinogens.

EXPOSURE LIMITS

The Occupational Safety and Health Administration (OSHA) does not have a specific permissible exposure limit (PEL) for alpha-naphthylamine; however, the OSHA standard requires implementation of stringent controls wherever alpha-naphthylamine or solid or liquid mixtures containing at least 0.1% by weight or volume of alpha-naphthylamine are manufactured, processed, repackaged, released, handled, or stored (see "General Control Procedure"). Details of this standard can be found in the Code of Federal Regulations, 29 CFR 1910.1004, alpha-Naphthylamine. The National Institute for Occupational Safety and Health (NIOSH) concurs with the OSHA standard. The American Conference of Governmental Industrial Hygienists (ACGIH) does not have an assigned threshold limit value (TLV®) for alpha-naphthylamine.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

alpha-Naphthylamine may cause adverse health effects following exposure via inhalation, ingestion, or dermal contact.

- **Summary of toxicology**

1. *Effects on animals:* In mice and dogs, chronic oral administration or subcutaneous injection of alpha-naphthylamine produced inconclusive evidence of liver, bladder, lung, or lymphatic cancer; however, beta-naphthylamine, which is a contaminant in commercial grade alpha-naphthylamine, is a recognized animal carcinogen. In addition, certain metabolites of alpha-naphthylamine have been shown to be carcinogenic in animals (e.g., N-(1-naphthyl)-hydroxylamine induces bladder cancer in mice, and 1-nitrosonaphthalene induces tumors in rats).

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2. *Effects on humans:* Long-term exposure of workers to commercial alpha-naphthylamine (which contains 4%-10% beta-naphthylamine) has been associated with an increased incidence of bladder cancer.

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to alpha-naphthylamine can cause mild skin and eye irritation.

2. *Long-term (chronic):* Exposure to alpha-naphthylamine can cause headache, dizziness, a feeling of euphoria, weakness, impaired muscular coordination (ataxia), bluish discoloration of skin and mucous membranes (due to methemoglobinemia), breathing difficulty (dyspnea), blood in the urine, and painful, difficult, or frequent urination.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to alpha-naphthylamine, the physician 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, liver, lymphatic system, and urinary tract.

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to alpha-naphthylamine. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to alpha-naphthylamine. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the skin, liver, lymphatic system, and urinary tract as compared to the baseline status of the individual worker or to expected values for a suitable reference population.

• **Medical practices recommended at the time of job transfer or termination**

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

• **Sentinel health events**

1. Acute SHE's include: Contact and/or allergic dermatitis.
2. Delayed-onset SHE's include: Bladder cancer.

MONITORING AND MEASUREMENT PROCEDURES

• **Method**

Sampling and analysis may be performed by collecting alpha-naphthylamine dust with glass-fiber filters and silica gel tubes followed by elution with acetic acid in 2-propanol and analysis by gas chromatography. Direct-reading devices calibrated to measure alpha-naphthylamine may also be used if available. A detailed sampling and analytical method for alpha-naphthylamine may be found in the *NIOSH Manual of Analytical Methods* (method number 264).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

In operations involving "laboratory-type hoods" or in locations where alpha-naphthylamine is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, OSHA requires that workers: (1) be provided with and required to use clean, full-body

CPC (smocks, coveralls, or long-sleeved shirts and long pants), shoe covers, and gloves prior to entering a regulated area; (2) be provided with and required to use approved respirators (a respirator affording higher levels of protection may be substituted); and (3) remove the protective clothing and equipment prior to exiting a regulated area, and at the last exit of the day, place used clothing and equipment in impervious containers for decontamination or disposal.

SANITATION

For closed system operations or in locations where alpha-naphthylamine is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, OSHA requires that workers: (1) wash their hands, forearms, faces, and necks prior to exiting the regulated area and before engaging in other activities, and (2) shower in designated facilities after the last exit of the day.

In isolated systems, such as a "glove box," OSHA requires that workers wash their hands and arms with soap and water upon completion of the assigned task and before engaging in other activities not associated with the isolated system.

If it is necessary for workers to wear protective clothing, OSHA requires that a clean change room be provided and equipped with showers and washing facilities. NIOSH recommends that lockers that permit separation of street and work clothes be provided for the worker.

Clothing which is contaminated with alpha-naphthylamine should be removed immediately and placed in sealed containers for storage until it can be discarded or until provision is made for the removal of alpha-naphthylamine from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of alpha-naphthylamine's hazardous properties. Reusable clothing and equipment should be checked for residual contamination before reuse or storage.

Decontamination and disposal procedures should be established and implemented to remove alpha-naphthylamine from materials and equipment. Contaminated material should be removed from regulated areas without further contamination of the facility.

OSHA requires that workers wash their faces, necks, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

In regulated areas, OSHA prohibits the storage or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing.

OSHA prohibits the location of drinking fountains in regulated areas.

GENERAL CONTROL PROCEDURES

The following control procedures are derived from OSHA requirements as stated in 29 CFR 1910.1004:

Areas where alpha-naphthylamine is manufactured, processed, used, repackaged, released, handled, or stored shall be designated as regulated areas, and entry into and exit from these areas shall be restricted and controlled. Only authorized workers shall be permitted access to regulated areas.

Workers authorized to enter regulated areas shall receive a training and indoctrination program including but not limited to the nature of the carcinogenic hazards of alpha-naphthylamine, local and systemic toxicity, the specific nature of the operation which could result in exposure, and the purpose for and the significance of decontamination and emergency practices and procedures.

Entrances to regulated areas shall be posted with signs indicating that a cancer-suspect agent is present and that only authorized workers wearing appropriate protective clothing and equipment shall be admitted.

Appropriate signs and instructions shall be posted at the entrance to and exit from regulated areas to inform workers of the procedures that must be followed when entering or leaving a regulated area.

Open vessel system operations involving alpha-naphthylamine which are not in an isolated system, laboratory-type hood, or other system affording equivalent protection against the entry of alpha-naphthylamine into regulated areas, nonregulated areas, or the external environment are prohibited.

In operations involving "laboratory-type hoods" or in locations where alpha-naphthylamine is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, each operation shall be provided with continuous local exhaust ventilation so that air movement is always from ordinary work areas to the operation. Exhaust air shall not be discharged to regulated areas, nonregulated areas, or the external environment unless decontaminated. Clean makeup air shall be introduced in sufficient volume to maintain the correct operation of the local exhaust system.

Containers of alpha-naphthylamine shall be identified as to contents and shall contain a hazard warning.

Regulated areas (with the exception of outdoor operations) shall be operated under negative pressure with respect to nonregulated areas. Local exhaust ventilation may be used to satisfy this requirement. Clean makeup air in equal volume shall replace air that is removed.

The introduction or removal of any equipment, materials, or other items to or from a regulated area shall be done in a manner that does not cause contamination of nonregulated areas or the external environment.

Decontamination procedures shall be established and implemented to remove alpha-naphthylamine from the materials, equipment, and decontamination facility.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to alpha-naphthylamine may occur and control methods which may be effective in each case are listed in Table 1.

Table 1.—Operations and methods of control for alpha-naphthylamine

Operations	Controls
During use in the manufacture of dyes, herbicides, and rubber antioxidants; during use in research facilities and laboratories	Process enclosure, restricted access, local exhaust ventilation where appropriate, personal protective equipment, good housekeeping and personal hygiene practices, substitution with less toxic substances

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures. If a worker comes in contact with alpha-naphthylamine, OSHA requires that the worker shower as soon as possible, unless contraindicated by physical injuries.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to alpha-naphthylamine, an eye-wash fountain should be provided within the immediate work area for emergency use.

If alpha-naphthylamine gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to alpha-naphthylamine, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If alpha-naphthylamine gets on the skin, wash it immediately with soap and water. If alpha-naphthylamine penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

- **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

OSHA requires that hazardous conditions created by spills or leaks be eliminated and that potentially affected areas be decontaminated prior to the resumption of normal operations.

OSHA requires that affected areas of spills or leaks be evacuated as soon as an emergency has been determined.

OSHA requires that only authorized workers provided with and wearing clean, impervious garments (including gloves, boots, and supplied-air respirators) enter areas of spills or leaks.

OSHA requires that workers authorized to enter areas of spills or leaks be decontaminated before removing the protective garments and hoods and showering.

If alpha-naphthylamine is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. If in solid form, alpha-naphthylamine may be collected and placed in an appropriate container.
4. alpha-Naphthylamine solid or liquid may be collected by vacuuming with an appropriate high-efficiency filtration system or by using wet methods; it may then be placed in an appropriate container. Dry sweeping and dry mopping of alpha-naphthylamine are prohibited by OSHA. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.
5. For small quantities of liquids containing alpha-naphthylamine, absorb on paper towels and place in an appropriate container.
6. Large quantities of liquids containing alpha-naphthylamine may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 2).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and

cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

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Table 2.—Respiratory protection for alpha-naphthylamine

Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator with a high-efficiency particulate filter
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.

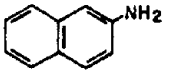
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR beta-NAPHTHYLAMINE POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about beta-naphthylamine for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_{10}H_9N$
- **Structure:**



- **Synonyms:** 2-Naphthylamine, 2-aminonaphthalene, 2-naphthalamine, 2-naphthalenamine
- **Identifiers:** CAS 91-59-8; RTECS QM2100000; DOT 1650, label required: "Poison"
- **Appearance and odor:** Odorless, white to reddish, crystals which darken in air to a reddish-purple color

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 143.20
2. Boiling point (at 760 mmHg): 306°C (583°F)
3. Specific gravity (water = 1): 1.061
4. Vapor density (air = 1 at boiling point of beta-naphthylamine): 4.95
5. Melting point: 110.2°C (230.4°F)
6. Vapor pressure at 108°C (226.4°F): 1 mmHg
7. Soluble in water

- **Reactivity**

1. Incompatibilities: beta-Naphthylamine oxidizes slowly in the presence of air and light.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide and oxides of nitrogen) may be released in a fire involving beta-naphthylamine.

- **Flammability**

1. Extinguishant: Dry chemical, foam, carbon dioxide, water
2. Combustible solid, no NFPA flammability rating

- **Warning properties**

Evaluation of warning properties for respirator selection: Warning properties are not considered in recommending respirators for use with carcinogens.

EXPOSURE LIMITS

The Occupational Safety and Health Administration (OSHA) does not have a specific permissible exposure limit (PEL) for beta-naphthylamine; however, the OSHA standard requires implementation of stringent controls wherever beta-naphthylamine or solid or liquid mixtures containing at least 0.1% by weight or volume of beta-naphthylamine are manufactured, processed, repackaged, packaged, released, handled, or stored (see "General Control Procedures"). Details of this standard can be found in the Code of Federal Regulations, 29 CFR 1910.1009, beta-Naphthylamine. The National Institute for Occupational Safety and Health (NIOSH) concurs with the OSHA standard. The American Conference of Governmental Industrial Hygienists (ACGIH) has designated beta-naphthylamine as an A1 substance (confirmed human carcinogen). The ACGIH recommends that no exposure or contact by any route be permitted.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

beta-Naphthylamine may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

- **Summary of toxicology**

1. *Effects on animals:* Chronic oral administration of beta-naphthylamine produced liver cancer in mice and bladder cancer in hamsters, dogs, and monkeys.
2. *Effects on humans:* Acute exposure to beta-naphthylamine dust or vapor has caused bladder inflammation with bleeding (hemorrhagic cystitis). Chronic exposure to beta-naphthylamine alone or to beta-naphthylamine as an impurity in other compounds has been associated with an increased incidence of bladder cancer.

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

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to beta-naphthylamine can cause weakness, dizziness, feeling of euphoria, breathing difficulty (dyspnea), bluish discoloration of the skin and mucous membranes (due to methemoglobinemia), and irritation of the skin and eyes.
2. *Long-term (chronic):* Exposure to beta-naphthylamine can cause frequent, painful, or difficult urination or blood in the urine.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to beta-naphthylamine, the physician 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, liver, lymphatic system, and urinary tract.

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to beta-naphthylamine. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to beta-naphthylamine. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the skin, liver, lymphatic system, and urinary tract as compared to the baseline status of the individual worker or to expected values for a suitable reference population.

• **Medical practices recommended at the time of job transfer or termination**

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

• **Sentinel health events**

1. Acute SHE's include: Contact and/or allergic dermatitis.
2. Delayed-onset SHE's include: Bladder cancer.

MONITORING AND MEASUREMENT PROCEDURES

• **Method**

Sampling and analysis may be performed by collecting beta-naphthylamine dust with glass fiber filters and silica gel tubes followed by elution with acetic acid in 2-propanol and analysis by gas chromatography. Direct-reading devices calibrated to measure beta-naphthylamine may also be used if available. A detailed sampling and analytical method for beta-naphthylamine may be found in the *NIOSH Manual of Analytical Methods* (method number 264).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

In operations involving "laboratory-type hoods" or in locations where beta-naphthylamine is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, OSHA requires that workers: (1) be provided with and required to use clean, full-body CPC (smocks, coveralls, or long-sleeved shirts and long pants), shoe covers, and gloves prior to entering a regulated area; (2) be provided with and required to use approved respirators (a respirator affording higher levels of protection may be substituted); and (3) remove the protective clothing and equipment prior to exiting from a regulated area, and at the last exit of the day, place used clothing and equipment in impervious containers for decontamination or disposal.

SANITATION

For closed system operations or in locations where beta-naphthylamine is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, OSHA requires that workers: (1) wash their hands, forearms, faces, and necks prior to exiting from the regulated area and before engaging in other activities, and (2) shower after the last exit of the day in designated facilities.

In isolated systems, such as a "glove box," OSHA requires that workers wash their hands and arms with soap and water upon completion of the assigned task and before engaging in other activities not associated with the isolated system.

If it is necessary for workers to wear protective clothing, OSHA requires that a clean change room be provided and equipped with showers and washing facilities. NIOSH recommends that lockers that permit separation of street and work clothes be provided for the worker.

Clothing which is contaminated with beta-naphthylamine should be removed immediately and placed in sealed containers for storage until it can be discarded or until provision is made for the removal of beta-naphthylamine from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of beta-naphthylamine's hazardous properties. Reusable clothing and equipment should be checked for residual contamination before reuse or storage.

Decontamination and disposal procedures should be established and implemented to remove beta-naphthylamine from materials and equipment. Contaminated material should be removed from regulated areas without further contamination of the facility.

OSHA requires that workers wash their faces, necks, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

In regulated areas, OSHA prohibits the storage or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, and the storage or use of products for chewing.

OSHA prohibits the location of drinking fountains in regulated areas.

GENERAL CONTROL PROCEDURES

The following control procedures are derived from OSHA requirements as stated in 29 CFR 1910.1009:

Areas where beta-naphthylamine is manufactured, processed, used, repackaged, released, handled, or stored shall be designated as regulated areas, and entry into and exit from these areas shall be restricted and controlled. Only authorized workers are permitted access to regulated areas.

Workers authorized to enter regulated areas shall receive a training and indoctrination program including but not limited to the nature of the carcinogenic hazards of beta-naphthylamine, local and systemic toxicity, the specific nature of the operation which could result in exposure, and the purpose for and the significance of decontamination and emergency practices and procedures.

Entrances to regulated areas shall be posted with signs indicating that a cancer-suspect agent is present and that only authorized workers wearing appropriate protective clothing and equipment shall be admitted.

Appropriate signs and instructions shall be posted at the entrance to and exit from regulated areas to inform workers of the procedures that must be followed when entering or leaving a regulated area.

Open vessel system operations involving beta-naphthylamine which are not in an isolated system, laboratory-type hood, or other system affording equivalent protection against the entry of beta-naphthylamine into regulated areas, nonregulated areas, or the external environment are prohibited.

In operations involving "laboratory-type hoods" or in locations where beta-naphthylamine is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, each operation shall be provided with continuous local exhaust ventilation so that air movement is always from ordinary work areas to the operation. Exhaust air shall not be discharged to regulated areas, nonregulated areas, or the external environment unless decontaminated. Clean makeup air shall be introduced in sufficient volume to maintain the correct operation of the local exhaust system.

Containers of beta-naphthylamine shall be identified as to contents and shall contain a hazard warning.

Regulated areas (with the exception of outdoor operations) shall be operated under negative pressure with respect to nonregulated areas. Local exhaust ventilation may be used to satisfy this requirement. Clean makeup air in equal volume shall replace air that is removed.

The introduction or removal of any equipment, materials, or other items to or from a regulated area shall be done in a manner that does not cause contamination of nonregulated areas or the external environment.

Decontamination procedures shall be established and implemented to remove beta-naphthylamine from materials, equipment, and the decontamination facility.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to beta-naphthylamine may occur and control methods which may be effective in each case are listed in Table 1.

Table 1.—Operations and methods of control for beta-naphthylamine

Operations	Controls
During use in the manufacture of dyes, acids, and rubber; during use in research facilities and laboratories	Process enclosure, restricted access, local exhaust ventilation where appropriate, personal protective equipment, good housekeeping and personal hygiene practices, substitution with less toxic substances

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1. Remove all ignition sources.
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Table 2.—Respiratory protection for beta-naphthylamine

Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiecc and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator with high-efficiency particulate filter
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.

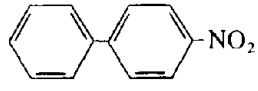
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR 4-NITROBIPHENYL POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about 4-nitrobiphenyl for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_{12}H_9NO_2$
- **Structure:**



- **Synonyms:** p-Nitrobiphenyl; p-nitrodiphenyl; 4-nitrodiphenyl; p-phenyl-nitrobenzene; 4-phenylnitrobenzene; PNB
- **Identifiers:** CAS 92-93-3; RTECS DV560000; DOT not assigned
- **Appearance and odor:** White to yellow needle-like crystals with a sweetish odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 199.22
2. Boiling point (at 760 mmHg): 340°C (644°F)
3. Specific gravity (water = 1): 1.2
4. Vapor density (air = 1 at boiling point of 4-nitrobiphenyl): 6.87
5. Melting point: 113.8°C (236.8°F)
6. Insoluble in water

- **Reactivity**

Hazardous decomposition products: Toxic vapors and gases (e.g., oxides of nitrogen) may be released in a fire involving 4-nitrobiphenyl.

- **Flammability**

1. Flash point: 143°C (290°F) (closed cup)
2. Extinguishant: Water or foam (may cause frothing)
3. Flammability Rating 1 (NFPA)

- **Warning properties**

Evaluation of warning properties for respirator selection: Warning properties are not considered in recommending respirators for use with carcinogens.

EXPOSURE LIMITS

The Occupational Safety and Health Administration (OSHA) does not have a specific permissible exposure limit (PEL) for 4-nitrobiphenyl; however, the OSHA standard requires implementation of stringent controls wherever 4-nitrobiphenyl or solid or liquid mixtures containing at least 0.1% by weight or volume of 4-nitrobiphenyl are manufactured, processed, repackaged, released, handled, or stored (see "General Control Procedures"). Details of this standard can be found in the Code of Federal Regulations, 29 CFR 1910.1003, 4-Nitrobiphenyl. The National Institute for Occupational Safety and Health (NIOSH) concurs with the OSHA standard. The American Conference of Governmental Industrial Hygienists (ACGIH) has designated 4-nitrobiphenyl as an A1 substance (confirmed human carcinogen). The ACGIH recommends that virtually no exposure to 4-nitrobiphenyl be permitted.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

4-Nitrobiphenyl may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

- **Summary of toxicology**

Effects on animals: Chronic oral administration of 4-nitrobiphenyl to dogs produced bladder cancer. In rats exposed to 4-nitrobiphenyl, the chemical is metabolically converted to 4-aminodiphenyl, a recognized animal and human bladder carcinogen.

2. *Effects on humans:* Because of the known metabolic conversion of 4-nitrobiphenyl to 4-aminodiphenyl in animals and the potential conversion in humans, it is not possible to separate the exposure to either substance; thus, the carcinogenicity of 4-nitrobiphenyl alone has not been documented in human epidemiologic studies. Bladder cancer is strongly associated

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

with occupational exposure to 4-aminodiphenyl, and 4-nitrobiphenyl is used in the production of 4-aminodiphenyl.

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to 4-nitrobiphenyl can cause headache, lethargy, painful urination, and blood or pus in the urine.

2. *Long-term (chronic):* Exposure to 4-nitrobiphenyl can cause headache, weakness, dizziness, a feeling of euphoria, breathing difficulty (dyspnea), impaired muscular coordination (ataxia), blood or pus in the urine, and painful, difficult, or frequent urination.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to 4-nitrobiphenyl, the physician 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 urinary tract.

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to 4-nitrobiphenyl. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include chronic diseases of the liver or urinary tract. The physician should obtain baseline values for liver function tests.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to 4-nitrobiphenyl. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the liver and urinary tract as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The physician should consider use of a test which characterizes internal exposure (e.g., benzidine in urine). However, this test should be used and interpreted according to standardized epidemiologic procedures and evaluation criteria.

• **Medical practices recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic and laboratory tests which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population. Because occupational exposure to 4-nitrobiphenyl may cause diseases of prolonged induction-latency, the need for medical surveillance may extend well beyond termination of employment.

• **Sentinel health events**

Delayed-onset SHE's include: Bladder cancer.

MONITORING AND MEASUREMENT PROCEDURES

• **Method**

Sampling and analysis may be performed by collecting 4-nitrobiphenyl dust with glass fiber filters and silica gel tubes followed by elution with 2-propanol and analysis by gas chromatography. Direct-reading devices calibrated to measure 4-nitrobiphenyl may also be used if available. A detailed sampling and analytical method for 4-nitrobiphenyl may be found in the *NIOSH Manual of Analytical Methods* (method number 273).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

In operations involving "laboratory-type hoods" or in locations where 4-nitrobiphenyl is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, OSHA requires that workers: (1) be provided with and required to use clean, full-body CPC (smocks, coveralls, or long-sleeved shirts and long pants), shoe

covers, and gloves prior to entering a regulated area; (2) be provided with and required to use approved respirators (a respirator affording higher levels of protection may be substituted); and (3) remove the protective clothing and equipment prior to exiting from a regulated area, and at the last exit of the day, place used clothing and equipment in impervious containers for decontamination or disposal.

SANITATION

For closed system operations or in locations where 4-nitrobiphenyl is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, OSHA requires that workers: (1) wash their hands, forearms, faces, and necks prior to exiting the regulated area and before engaging in other activities, and (2) shower in designated facilities after the last exit of the day.

In isolated systems, such as a "glove box," OSHA requires that workers wash their hands and arms with soap and water upon completion of the assigned task and before engaging in other activities not associated with the isolated system.

If it is necessary for workers to wear protective clothing, OSHA requires that a clean change room be provided and equipped with showers and washing facilities. NIOSH recommends that lockers that permit separation of street and work clothes be provided for the worker.

Clothing which is contaminated with 4-nitrobiphenyl should be removed immediately and placed in sealed containers for storage until it can be discarded or until provision is made for the removal of 4-nitrobiphenyl from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of 4-nitrobiphenyl's hazardous properties. Reusable clothing and equipment should be checked for residual contamination before reuse or storage.

Decontamination and disposal procedures should be established and implemented to remove 4-nitrobiphenyl from materials and equipment. Contaminated material should be removed from regulated areas without further contamination of the facility.

OSHA requires that workers wash their faces, necks, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

In regulated areas, OSHA prohibits the storage or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, or the storage or use of products for chewing.

OSHA prohibits the location of drinking fountains in regulated areas.

GENERAL CONTROL PROCEDURES

The following control procedures are derived from OSHA requirements as stated in 29 CFR 1910.1003:

Areas where 4-nitrobiphenyl is manufactured, processed, used, repackaged, released, handled, or stored shall be designated as regulated areas, and entry into and exit from these areas shall be restricted and controlled. Only authorized workers shall be permitted access to regulated areas.

Workers authorized to enter regulated areas shall receive a training and indoctrination program including but not limited to the nature of the carcinogenic hazards of 4-nitrobiphenyl, local and systemic toxicity, the specific nature of the operation that could result in exposure, and the purpose for and the significance of decontamination and emergency practices and procedures.

Entrances to regulated areas shall be posted with signs indicating that a cancer-suspect agent is present and that only authorized workers wearing appropriate protective clothing and equipment shall be admitted.

Appropriate signs and instructions shall be posted at the entrance to and exit from regulated areas to inform workers of the procedures that must be followed when entering or leaving a regulated area.

Open vessel system operations involving 4-nitrobiphenyl which are not in an isolated system, laboratory-type hood, or other system affording equivalent protection against the entry of 4-nitrobiphenyl into regulated areas, nonregulated areas, or the external environment are prohibited.

In operations involving "laboratory-type hoods" or in locations where 4-nitrobiphenyl is contained in an otherwise "closed system" but is transferred, charged, or discharged into other normally closed containers, each operation shall be provided with continuous local exhaust ventilation so that air movement is always from ordinary work areas to the operation. Exhaust air shall not be discharged to regulated areas, nonregulated areas, or the external environment unless decontaminated. Clean makeup air shall be introduced in sufficient volume to maintain the correct operation of the local exhaust system.

Containers of 4-nitrobiphenyl shall be identified as to contents and shall contain a hazard warning.

Regulated areas (with the exception of outdoor operations) shall be operated under negative pressure with respect to nonregulated areas. Local exhaust ventilation may be used to satisfy this requirement. Clean makeup air in equal volume shall replace air that is removed.

The introduction or removal of any equipment, materials, or other items to or from a regulated area shall be done in a manner that does not cause contamination of nonregulated areas or the external environment.

Decontamination procedures shall be established and implemented to remove 4-nitrobiphenyl from materials, equipment, and the decontamination facility.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to 4-nitrobiphenyl may occur and control methods which may be effective in each case are listed in Table 1.

Table 1.—Operations and methods of control for 4-nitrobiphenyl

Operations	Controls
During use in the production of rocket fuel; during use as an industrial solvent (especially in the fibers and plastics industries), as an oxidant, and as an additive in lubricants	Process enclosure, restricted access, local exhaust ventilation where appropriate, personal protective equipment, good housekeeping and personal hygiene practices, substitution with less toxic substances

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures. If a worker has contact with 4-nitrobiphenyl, OSHA requires that the worker shower as soon as possible, unless contraindicated by physical injuries.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to 4-nitrobiphenyl, an eye-wash fountain should be provided within the immediate work area for emergency use.

If 4-nitrobiphenyl gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to 4-nitrobiphenyl, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If 4-nitrobiphenyl gets on the skin, wash it immediately with soap and water. If 4-nitrobiphenyl penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

- **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

OSHA requires that hazardous conditions created by spills or leaks be eliminated and that potentially affected areas be decontaminated prior to the resumption of normal operations.

OSHA requires that areas affected by spills or leaks be evacuated as soon as an emergency has been determined.

OSHA requires that only authorized workers provided with and wearing clean, impervious garments (including gloves, boots, and continuous air-supplied hoods) enter areas of spills or leaks.

OSHA requires that workers authorized to enter areas of spills or leaks be decontaminated before removing the protective garments and hoods and showering.

If 4-nitrobiphenyl is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. If in solid form, 4-nitrobiphenyl may be collected and placed in an appropriate container.
4. 4-Nitrobiphenyl solid or liquid may be collected by vacuuming with an appropriate high-efficiency filtration system or by using wet methods; it may then be placed in an appropriate container. Dry sweeping and mopping of 4-nitrobiphenyl are prohibited by OSHA. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.
5. For small quantities of liquids containing 4-nitrobiphenyl, absorb on paper towels and place in an appropriate container.
6. Large quantities of liquids containing 4-nitrobiphenyl may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 2).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

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Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator with a high-efficiency particulate filter
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.

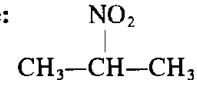
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR 2-NITROPROPANE POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about 2-nitropropane for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_3H_7NO_2$
- **Structure:**



- **Synonyms:** Dimethylnitromethane; isonitropropane; 2-NP
- **Identifiers:** CAS 79-46-9; RTECS TZ5250000; DOT 2608, label required: "Flammable Liquid"
- **Appearance and odor:** Clear, colorless liquid with a fruity odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 89.09
2. Boiling point (at 760 mmHg): 118°-120°C (244°-248°F)
3. Specific gravity (water = 1): 0.992
4. Vapor density (air = 1 at boiling point of 2-nitropropane): 3.07
5. Melting point: -93°C (-135°F)
6. Vapor pressure at 25°C (77°F): 20 mmHg
7. Solubility in water, g/100 g water at 25°C (77°F): 1.7
8. Evaporation rate (butyl acetate = 1): 1.62
9. Saturation concentration in air (approximate) at 25°C (77°F): 2.6% (26,000 ppm)
10. Ionization potential: 10.71eV

- **Reactivity**

1. Incompatibilities: Contact with amines, strong acids, alkalies, or strong oxidizers may cause fire and explosion. Contact with some metal oxides may cause decomposition. Mixtures of 2-nitropropane and hydrocarbons are highly flammable.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide and oxides of nitrogen) may be released in a fire involving 2-nitropropane.
3. Caution: Overheating 2-nitropropane in closed container may cause violent explosion. 2-Nitropropane will attack some forms of plastics, coatings, and rubber.

- **Flammability**

1. Flash point: 24°C (75°F) (closed cup)
2. Autoignition temperature: 428°C (802°F)
3. Flammable limits in air, % by volume: Lower, 2.6; upper, 11.0
4. Extinguishant: Dry chemical, foam, or carbon dioxide
5. Class IC Flammable Liquid (29 CFR 1910.106), Flammability Rating 3

- **Warning properties**

1. Odor threshold: 83 ppm
2. Eye irritation level: 150 ppm
3. Evaluation of warning properties for respirator selection: Warning properties are not considered in recommending respirators for use with carcinogens.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for 2-nitropropane is 25 parts of 2-nitropropane per million parts of air (ppm) [90 milligrams of 2-nitropropane per cubic meter of air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The National Institute for Occupational Safety and Health (NIOSH) recommends that 2-nitropropane be controlled and handled as a potential human carcinogen in the workplace; thus, the recommended exposure limit (REL) is that exposure be minimized to the lowest feasible level. The American Conference of Governmental Industrial Hygienists (ACGIH) has designated 2-nitropropane as an A2 substance (suspected human carcinogen) having an assigned threshold limit value (TLV®) of 10 ppm (35 mg/m³) as TWA for a normal 8-hour workday and a 40-hour workweek (Table 1).

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Table 1.—Occupational exposure limits for 2-nitropropane

	Exposure limits	
	ppm	mg/m³
OSHA PEL TWA	25	90
NIOSH REL (Ca)*	Lowest feasible level	
ACGIH TLV® TWA (A2)†	10	35

* (Ca): NIOSH recommends treating as a potential human carcinogen.
† (A2): Suspected human carcinogen.

HEALTH HAZARD INFORMATION

• Routes of exposure

2-Nitropropane may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• Summary of toxicology

1. *Effects on animals:* In rats, acute inhalation of 2-nitropropane caused progressive weakness, impaired muscular coordination (ataxia), and irregular breathing; in rats, rabbits, and guinea pigs, acute inhalation caused degeneration of the liver (necrosis), pulmonary edema and hemorrhage, selective destruction of brain cells, and vascular epithelial damage in all tissues. Subchronic inhalation of 2-nitropropane by rats produced an increased incidence of liver cancer. Intraperitoneal injection of 2-nitropropane in pregnant rats on days 1 through 15 of gestation caused retarded heart development in unborn fetuses.

2. *Effects on humans:* Acute inhalation exposure of workers to 2-nitropropane has produced toxic hepatitis, gastrointestinal bleeding, pulmonary edema, fatty degeneration and necrosis of the liver, and degeneration of kidney tubules; acute lethal exposure has also occurred. Chronic exposure of workers to 2-nitropropane has been associated with an increased incidence of lymphatic and connective tissue cancers.

• Signs and symptoms of exposure

Short-term (acute): Exposure to 2-nitropropane can cause nausea, vomiting, diarrhea, anorexia, severe headaches, breathing difficulty (dyspnea), impaired muscular coordination, and chest and abdominal pains.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to 2-nitropropane, the physician 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, liver, kidneys, and nervous and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to 2-nitropropane. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic disease of the respiratory tract or liver. In addition to the medical interview and physical examination, the means to identify respiratory conditions may include the methods recommended by NIOSH and ATS. The physician should obtain baseline values for tests of liver function.

• Periodic medical screening and/or biologic monitoring

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker report symptoms that may be attributed to exposure to 2-nitropropane. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the liver, kidneys, and nervous and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires, tests of lung function, and chest X-rays.

• **Medical practices recommended at the time of job transfer or termination.**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic and laboratory tests which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population. Because occupational exposure to 2-nitropropane may cause diseases of prolonged induction-latency, the need for medical surveillance may extend well beyond termination of employment.

MONITORING AND MEASUREMENT PROCEDURES

• **Method**

Sampling and analysis may be performed by collecting 2-nitropropane vapors with Chromosorb 106 tubes followed by desorption with ethyl acetate and analysis by gas chromatography. Direct-reading devices calibrated to measure 2-nitropropane may also be used if available. A detailed sampling and analytical method for 2-nitropropane may be found in the *NIOSH Manual of Analytical Methods* (method number 272).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, and other appropriate protective clothing necessary to prevent skin contact with 2-nitropropane.

SANITATION

Clothing which is contaminated with 2-nitropropane should be removed immediately and placed in sealed containers for storage until it can be discarded or until provision is made for the removal of 2-nitopropane from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of 2-nitropropane's hazardous properties. Reusable clothing and equipment should be checked for residual contamination before reuse or storage.

A change room with showers, washing facilities, and lockers that permit separation of street and work clothes should be provided.

Workers should be required to shower following a workshift and prior to putting on street clothes. Clean work clothes should be provided daily.

Skin that becomes contaminated with 2-nitropropane should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or use of smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle 2-nitropropane should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to 2-nitropropane may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for 2-nitropropane

Operations	Controls
During the manufacture and distribution of 2-nitropropane; during maintenance of equipment and storage containers for 2-nitropropane	Process enclosure, local exhaust ventilation, personal protective equipment
During the manufacture of explosives; during use as a thinner and solvent	Process enclosure, local exhaust ventilation, personal protective equipment
During use in organic chemical synthesis; during use as a propellant in rocket motors	Local exhaust ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to 2-nitropropane, an eye-wash fountain should be provided within the immediate work area for emergency use.

If 2-nitropropane gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to 2-nitropropane, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If 2-nitropropane gets on the skin, wash it immediately with soap and water. If 2-nitropropane penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established

emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If 2-nitropropane is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing 2-nitropropane, absorb on paper towels and place in an appropriate container.
4. Large quantities of liquids containing 2-nitropropane may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container.
5. Liquids containing 2-nitropropane may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

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Table 3.—Respiratory protection for 2-nitropropane

Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.

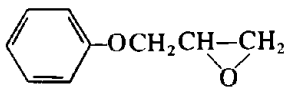
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR PHENYL GLYCIDYL ETHER

INTRODUCTION

This guideline summarizes pertinent information about phenyl glycidyl ether (PGE) for workers, employers, and 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; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** $C_9H_{10}O_2$
- **Structure:**



- **Synonyms:** Glycidyl phenyl ether; PGE; phenyl 2,3-epoxypropyl ether; 1,2-epoxy-3-phenoxypropane; phenoxy-propene oxide
- **Identifiers:** CAS 122-60-1; RTECS TZ3675000; DOT not assigned
- **Appearance:** Colorless liquid

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 150.17
2. Boiling point (at 760 mmHg): 245°C (473°F)
3. Specific gravity (water = 1): 1.1
4. Vapor density (air = 1 at boiling point of PGE): 4.37
5. Melting point: 3.5°C (38°F)
6. Vapor pressure at 25°C (77°F): 0.01 mmHg
7. Solubility in water, g/100 g water at 20°C (68°F): 0.24
8. Saturation concentration in air (approximate) at 25°C (77°F): 0.0013% (13 ppm)

- **Reactivity**

1. Incompatibilities: Contact with strong oxidizing agents may cause fires and explosions. Contact with amines, strong acids, and strong bases may cause polymerization with the liberation of heat and spattering. Exposure to light and air may result in the formation of explosive peroxides.
2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving PGE.
3. Caution: PGE will cause some forms of plastics, coatings, and rubber to deteriorate.

- **Flammability**

1. Flash point: 120°C (248°F) (closed cup)
2. Extinguishant: Dry chemical, carbon dioxide, or alcohol foam
3. Class IIIB Combustible Liquid (29 CFR 1910.106)

- **Warning properties**

Evaluation of warning properties for respirator selection: Based on lack of information on odor threshold and eye irritation levels, PGE should be considered to have poor warning properties.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for PGE is 10 parts of PGE per million parts of air (ppm) [60 milligrams of PGE per cubic meter air (mg/m³)] as a time-weighted average (TWA) concentration over an 8-hour workshift. The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) is 1 ppm (5 mg/m³) as a ceiling concentration determined in any 15-minute sampling period. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV®) is 1 ppm (6 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek (Table 1).

Table 1.—Occupational exposure limits for phenyl glycidyl ether

	Exposure limits	
	ppm	mg/m³
OSHA PEL TWA	10	60
NIOSH REL, ceiling (15 min)	1	5
ACGIH TLV® TWA	1	6

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HEALTH HAZARD INFORMATION

• **Routes of exposure**
PGE may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

• **Summary of toxicology**
Effects on animals: Acute dermal or oral administration of PGE to rats and mice caused tissue destruction (necrosis) at the site of administration, liver damage, and central nervous system (CNS) depression. Subchronic inhalation of PGE by rats produced equivocal evidence of testicular degeneration. Chronic inhalation of PGE by rats produced nasal cancer. NIOSH will continue to monitor the research regarding PGE to determine whether the collective evidence justifies controlling this chemical as an occupational carcinogen.

• **Signs and symptoms of exposure**
1. *Short-term (acute):* Exposure to PGE can cause irritation of the eyes, nose, respiratory tract, and skin.
2. *Long-term (chronic):* Exposure to PGE can cause defatting and drying of the skin, dermatitis, blisters, edema, rash, eczema, and skin sensitization; cross sensitization with other glycidyl ethers can also occur.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**
Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) 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 surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**
Prior to placing a worker in a job with a potential for exposure to PGE, the physician 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, liver, kidneys, and reproductive, nervous, and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to PGE at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis.

• **Periodic medical screening and/or biologic monitoring**
Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to PGE. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the skin, eyes, and reproductive, nervous, and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires and tests of lung function.

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

• **Sentinel health events**
Acute SHE's include: Contact and/or allergic dermatitis.

MONITORING AND MEASUREMENT PROCEDURES

• **Ceiling concentration evaluation**
Measurements to determine worker exposure should be taken during periods of maximum expected airborne concentrations of PGE. Each measurement to determine the NIOSH REL (ceiling exposure) in the worker's breathing zone (air that most nearly represents that inhaled by the worker) should consist of a 15-minute sample or a series of consecutive samples that total 15 minutes. A minimum of three measurements should

be taken during one workshift, and the highest of all measurements taken is an estimate of the worker's exposure. If the periods of maximum exposure are not clearly defined, a statistical procedure which can be used as a peak exposure detection strategy is given in the *Occupational Exposure Sampling Strategy Manual.*

- **Method**

Sampling and analysis may be performed by collecting PGE vapors with charcoal adsorption tubes followed by desorption with carbon disulfide and analysis by gas chromatography. Detector tubes or other direct-reading devices calibrated to measure PGE may also be used if available. A detailed sampling and analytical method for PGE may be found in the *NIOSH Manual of Analytical Methods* (method number S74).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, face shields (8-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with PGE.

Workers should be provided with and required to use splash-proof safety goggles where PGE may come in contact with the eyes.

SANITATION

Clothing which is contaminated with PGE should be removed immediately and placed in closed containers for storage until it can be discarded or until provision is made for the removal of PGE from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of PGE's hazardous properties.

Change and shower rooms should be provided with separate locker facilities for street and work clothes.

Skin that becomes contaminated with PGE should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or use of smoking materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle PGE should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to PGE may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for phenyl glycidyl ether

Operations	Controls
During use as a coupling agent, catalyst, or reactive diluent in curing rubber, thermostable epoxy resins, tire cord, and electric insulating materials	Process enclosure, local exhaust ventilation, general dilution ventilation, personal protective equipment
During use as a stabilizer of halogenated compounds; during use in the treatment of fabric	Local exhaust ventilation, general dilution ventilation, personal protective equipment
During use as a copolymer in the production of epoxy polymers; during use as chemical intermediate	Process enclosure, local exhaust ventilation, general dilution ventilation

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to PGE, an eye-wash fountain should be provided within the immediate work area for emergency use.

If PGE gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to PGE, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If PGE gets on the skin, wash it immediately with soap and water. If PGE penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

- **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If PGE is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities of liquids containing PGE, absorb on paper towels and place in an appropriate container. Place towels in a safe place such as a fume hood for evaporation. Allow sufficient time for evaporation of the vapors so that the hood ductwork is free from PGE vapors. Burn the paper in a suitable location away from combustible materials.
4. Large quantities of liquids containing PGE may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. PGE should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
5. PGE may be collected by vacuuming with an appropriate system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and sufficient flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

For each level of respiratory protection, only those respirators that have the minimum required protection factor and meet other use restrictions are listed. All respirators that have higher protection factors may also be used.

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Table 3.—Respiratory protection for phenyl glycidyl ether

Condition	Minimum respiratory protection*†
Concentration:	
Less than or equal to 25 ppm	Any supplied-air respirator operated in a continuous flow mode (substance causes eye irritation or damage—eye protection needed)
Less than or equal to 50 ppm	Any self-contained breathing apparatus with a full facepiece
	Any supplied-air respirator with a full facepiece
Less than or equal to 500 ppm	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown concentrations or levels above 500 ppm	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.
† The respiratory protection listed for any given condition is the minimum required to meet the NIOSH REL of 1 ppm (5 mg/m³) (ceiling).

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