

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ETHYLENE OXIDE POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about ethylene 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 Recommendations may be superseded by new developments in these fields; therefore, readers are advised to regard these recommendations as general guidelines.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:** C₂H₄O



- **Synonyms:** Anprolene; dihydrooxirene; dimethylene oxide; EO; 1,2-epoxyethane; EtO; oxacyclopropane; oxane; oxiran; oxirane

- **Identifiers:** CAS 75-21-8; RTECS KX2450000; DOT 1040, label required: "Flammable Liquid"

- **Appearance and odor:** Colorless liquid or gas with an etherlike odor

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 44.06
2. Boiling point (at 760 mmHg): 10.7°C (51.3°F)
3. Specific gravity (water = 1): 0.8711
4. Vapor density (air = 1 at boiling point of ethylene oxide): 1.5
5. Melting point: -111.3°C (-168°F)
6. Vapor pressure at 20°C (68°F): 1,095 mmHg
7. Soluble in water
8. Ionization potential: 10.56 eV

- **Reactivity**

1. Incompatibilities: Ethylene oxide reacts readily with alkali metal hydroxides or highly active catalysts (e.g., anhydrous

chlorides of iron, tin, or aluminum and oxides of iron or aluminum); ethylene oxide should not come in contact with copper.

2. Hazardous decomposition products: Toxic vapors and gases (e.g., carbon monoxide) may be released in a fire involving ethylene oxide.

3. Caution: Protect container against physical damage. Store in an outside area in insulated tanks or containers shielded from sun and heat. Ethylene oxide may interact with some plastics, coatings, and rubber.

- **Flammability**

1. Flash point: -6°C (20°F) (open cup)
2. Autoignition temperature: 429°C (804°F)
3. Flammable limits in air, % by volume: Lower, 3; Upper, 100
4. Extinguishant: Alcohol foam, dry chemical, carbon dioxide, or water spray or fog
5. Class IA Flammable Liquid (29 CFR 1910.106), Flammability Rating 4 (NFPA)
6. All ignition sources, including static electricity, should be controlled. Flashback along a vapor trail may occur.

- **Warning properties**

1. Odor threshold: 430 ppm
2. 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 ethylene oxide is 1 part of ethylene oxide per million parts of air (ppm) as a time-weighted average (TWA) concentration over an 8-hour workshift. The National Institute for Occupational Safety and Health (NIOSH) recommends that ethylene oxide be controlled and handled as a potential human carcinogen in the workplace and that exposure be minimized to the lowest feasible limit. The NIOSH recommended exposure limit (REL) is 5 ppm [9 milligrams per cubic meter (9 mg/m³)] as a ceiling concentration determined in any 10-minute sampling period and not to be achieved for more than 10 minutes dur-

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ing any workday. In addition, NIOSH recommends that exposure to ethylene oxide be less than 0.1 ppm (0.18 mg/m³) as a TWA for up to an 8-hour workshift, 40-hour workweek. The American Conference of Governmental Industrial Hygienists (ACGIH) has designated ethylene oxide as an A2 substance (suspected of carcinogenic potential for man) having an assigned threshold limit value (TLV®) of 1 ppm (2 mg/m³) as a TWA for a normal 8-hour workday and 40-hour workweek (Table 1).

Table 1.—Occupational exposure limits for ethylene oxide

| | Exposure limits | |
|----------------------|-----------------|-------------------|
| | ppm | mg/m ³ |
| OSHA PEL TWA | 1 | — |
| NIOSH REL TWA | | |
| (Ca)* | <0.1 | <0.18 |
| Ceiling (10 min/day) | 5 | 9 |
| ACGIH TLV® TWA | | |
| (A2)† | 1 | 2 |

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

† (A2): Suspected of carcinogenic potential for man.

HEALTH HAZARD INFORMATION

• Routes of exposure

Ethylene 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 ethylene oxide by rats and guinea pigs caused pulmonary edema, paralysis, and corneal opacities. Subchronic inhalation of ethylene oxide by male and female rats prior to mating and during pregnancy caused a decrease in the number of pregnant females and in the number of offspring per litter. Chronic oral administration of ethylene oxide to rats produced cancer of the forestomach; chronic inhalation produced brain tumors, leukemia, and cancer of the peritoneum.

2. *Effects on humans:* Chronic exposure to ethylene oxide has caused anemia, peripheral neuropathy, and chromosomal damage in white blood cells (lymphocytes). Exposure to ethylene oxide has been associated with increased incidences of miscarriage, leukemia, and stomach cancer.

• Signs and symptoms of exposure

1. *Short-term (acute):* Exposure to ethylene oxide can cause nausea, headache, weakness, vomiting, drowsiness, incoordination, and irritation of the eyes, nose, throat, and lungs. Skin contact with ethylene oxide can cause blisters, edema, burns, frostbite, and severe dermatitis.

2. *Long-term (chronic):* Exposure to ethylene oxide can cause skin sensitization, numbing of the sense of smell, and respiratory infection.

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 ethylene 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, gastrointestinal tract, and hematopoietic (blood cell forming), nervous, 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 ethylene 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. In addition to the medical interview and physical examination, the physician should consider obtaining additional baseline electrophysiologic and electromyographic studies and an assess-

ment of fertility, 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 ethylene oxide. The interviews, examinations, and appropriate medical screening and/or biologic monitoring test should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the eyes, skin, gastrointestinal tract, and hematopoietic, nervous, 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 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 ethylene oxide may cause diseases of prolonged induction-latency, the need for medical surveillance may extend well beyond termination of employment.

MONITORING AND MEASUREMENT PROCEDURES

- **TWA exposure evaluation**

Measurements to determine worker exposure to ethylene 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).

- **Ceiling concentration evaluation**

Measurements to determine worker exposure should be taken during periods of maximum expected airborne concentrations of ethylene oxide. Each measurement to determine the NIOSH REL (ceiling exposure) in the worker's breathing zone should consist of a 10-minute sample or a series of consecutive samples that total 10 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 ethylene 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 ethylene oxide may be used if available. A detailed sampling and analytical method for ethylene oxide may be found in the *NIOSH Manual of Analytical Methods* (method number 1607).

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 liquid ethylene oxide.

SANITATION

Clothing which is contaminated with liquid ethylene oxide 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 ethylene oxide from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of ethylene oxide'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 ethylene 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 ethylene 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 ethylene 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 ethylene oxide

| Operations | Controls |
|--|---|
| During synthesis and handling of ethylene oxide | Process enclosure, local exhaust ventilation, personal protective equipment |
| During synthesis of ethylene glycols, glycol ethers, ethanolamines, amines, nonionic surface-active agents | Process enclosure, local exhaust ventilation, personal protective equipment |
| During use as a sterilizing agent | 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 ethylene oxide, an eye-wash fountain should be provided within the immediate work area for emergency use.

If ethylene 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 liquid ethylene oxide, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If ethylene oxide gets on the skin, wash it immediately with soap and water. If liquid ethylene 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 ethylene oxide is spilled or leaked, the following steps should be taken:

1. If ethylene oxide 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 ethylene oxide, 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 duct work is free from ethylene oxide vapors. Burn the paper in a suitable location away from combustible materials.
5. Large quantities of liquids containing ethylene oxide may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container. Ethylene oxide should not be allowed to enter a confined space such as a sewer because of the possibility of an explosion.
6. Liquids containing ethylene 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.**

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Table 3.—Respiratory protection for ethylene oxide

| Condition | Minimum respiratory protection*† |
|--|--|
| Concentration: | |
| Less than 5 ppm | <p>Any air-purifying, full-facepiece canister respirator that provides protection against ethylene oxide and is equipped with an effective end-of-service-life indicator (ESLI)</p> <p>Any self-contained breathing apparatus equipped with a full facepiece</p> <p>Any supplied-air respirator with a full facepiece</p> |
| <p>Equal to or greater than 5 ppm, or planned or emergency entry into environments containing unknown concentrations</p> | <p>Any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or positive-pressure mode</p> <p>Any supplied-air respirator equipped 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</p> |
| Firefighting | <p>Any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode</p> |
| Escape only | <p>Any air-purifying, full-facepiece canister respirator that provides protection against ethylene oxide and is equipped with an effective ESLI</p> <p>Any appropriate escape-type, self-contained breathing apparatus</p> |

* 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 <0.1 ppm (<0.18 mg/m³) (TWA).