OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BUTADIENE (1,3-BUTADIENE)

INTRODUCTION

This guideline summarizes pertinent information about butadiene (1,3-butadiene) for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

C_4H_6

- **Structure**

$CH_2=CH-CH=CH_2$

- **Synonyms**

1,3-Butadiene, trans-butadiene, bivinyl, divinyl, erythrene, vinylethylene, biethylene, butadiene monomer, pyrrolylene, 1-methylallene

- **Identifiers**

1. CAS No.: 106-99-0
2. RTECS No.: EI9275000
3. DOT UN: 1010 17 (inhibited butadiene)
4. DOT label: Flammable Gas (inhibited butadiene)

- **Appearance and odor**

Butadiene is a colorless, flammable gas with a mild aromatic odor. It is shipped under its own vapor pressure as a liquefied gas. The odor threshold is reported to be 1.1 parts per million (ppm) parts of air.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 54.1
2. Boiling point (760 mm Hg): -4.4°C (24°F)
3. Specific gravity (water = 1): 0.62 at 20°C (68°F)
4. Vapor density (air = 1 at boiling point of butadiene): 1.9
5. Melting point: -108.9°C (-164.0°F)
6. Vapor pressure at 21°C (69.8°F): 1,840 mm Hg
7. Solubility: Insoluble in water; soluble in alcohol, ether, acetone, and benzene
8. Evaporation rate: Not applicable; butadiene is a gas.

- **Reactivity**

1. Conditions contributing to instability: Heat, sparks, or open flame. When exposed to air, butadiene may form explosive peroxides.

2. Incompatibilities: Fires, explosions, or hazardous polymerization may result from contact of butadiene with air, strong oxidizers, ozone, nitrogen dioxide, copper, copper alloys, phenol, chlorine dioxide, crotonaldehyde, or a free radical polymerization initiator such as hydroquinone.

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

4. Special precautions: Butadiene is self-reactive. To prevent hazardous polymerization, an inhibitor must be added to the butadiene and the concentration of inhibitor (such as tert-butylcatechol) must be monitored to ensure that it remains at effective levels at all times.

- **Flammability**

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

1. Flash point: -156°F (105°C)
2. Autoignition temperature: 420°C (788°F)

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Public Health Service Centers for Disease Control
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3. Flammable limits in air (% by volume): Lower, 2.0; upper, 12.0

4. Extinguishant: Butadiene is a flammable gas. To extinguish a fire involving this substance, the flow of gas must be stopped. Fires involving butadiene should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of butadiene may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. If a tank car or truck is involved in a fire, personnel should isolate an area of a half mile in all directions. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving butadiene. Firefighters' protective clothing may not provide protection against permeation by butadiene.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for buta-diene is 1,000 ppm (2,200 mg/m^3) as an 8-hr time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1-A]. However, OSHA has published a proposed rule on occupational exposure to butadiene that would reduce the PEL to 2 ppm as a TWA and 10 ppm as a short-term exposure limit (STEL) [55 FR 32736, August 10, 1990]. A STEL is a 15-min TWA exposure that should not be exceeded at any time during a workday.

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has recommended that butadiene be considered a potential occupational carcinogen and that exposure be limited to the lowest feasible concentration [NIOSH 1984a, 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has designated butadiene an A2 substance (suspected human carcinogen) and has assigned butadiene a threshold limit value (TLV) of 10 ppm (22 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek [ACGIH 1991b].

• Rationale for limits

The current OSHA limit is based on the risk of irritation and narcosis associated with exposure to butadiene and does not take into account the possible carcinogenic effects of this substance. The proposed OSHA PEL and NIOSH REL are based on butadiene's potential occupational carcinogenicity and reproductive toxicity. The ACGIH TLV is based on potential occupational carcinogenicity.

HEALTH HAZARD INFORMATION

• Routes of exposure

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

• Summary of toxicology

1. *Effects on Animals*: Butadiene is an irritant of the eyes and mucous membranes, and it is a narcotic at high concentrations. This substance is also a carcinogen and reproductive toxin in experimental animals. The 2-hr LC_{50} in rats is 270 g/m^3 (129,000 ppm) [NIOSH 1991]. Rabbits exposed for 8 to 10 min at 200,000 to 250,000 ppm were deeply anesthetized but recovered completely after exposure ceased. If the exposure was continued for 25 to 35 min, the animals died [ACGIH 1991a]. Inhalation of 625 or 1,250 ppm butadiene for 6 hr/day, 5 days/week for 6 weeks caused nonneoplastic effects in mice at several organ sites (ovaries, testes, nasopharynx, lung, and liver) [NIOSH 1984a]. Rats, guinea pigs, rabbits, and a dog exposed to butadiene concentrations ranging from 600 to 6,700 ppm for 7.5 hr/day, 6 days/week for 8 months developed no significant toxic effects [ACGIH 1991a; Proctor et al. 1988]. Inhalation exposure to butadiene at 200 ppm was toxic to pregnant rats and retarded embryonic growth and development; exposure at 8,000 ppm during pregnancy caused a significant increase in major skeletal abnormalities in the offspring [Proctor et al. 1988; ACGIH 1991a]. Butadiene has caused cancers in the mammary glands, uterus, ovaries, testes, thyroid gland, pancreas, liver, Zymbal gland, heart, lungs, lymph system, and hematopoietic system in rats and mice chronically exposed to this substance in inhalation bioassays [NIOSH 1984a]. On this basis, the International Agency for Research on Cancer (IARC) has concluded that butadiene is an animal carcinogen [IARC 1986].

2. *Effects on Humans*: Exposure to butadiene causes irritation of the eyes, mucous membranes, upper respiratory tract, and skin in exposed workers [Cralley and Cralley 1985; ACGIH 1991a]. Volunteers exposed to butadiene at 2,000 ppm experienced irritation of the eyes, nose, throat, and skin [NIOSH 1984a]. In contact with the skin, the liquid may cause frostbite [NIOSH 1984a]. Epidemiological studies of workers exposed to butadiene, styrene, and benzene at two styrene-butadiene rubber facilities (with average

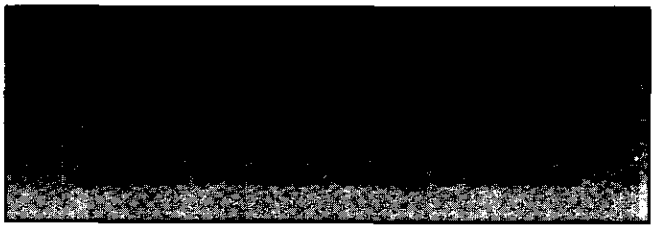
butadiene exposures of 1.24 and 13.5 ppm, respectively) have shown an increased, but not statistically significant, risk of mortality from lymphatic and hematopoietic system cancer and from leukemia [NIOSH 1984a]. IARC has stated that evidence is insufficient to conclude that butadiene is a human carcinogen [IARC 1986].

- **Signs and symptoms of exposure**

1. *Acute exposure*: Acute exposure to butadiene can cause irritation of the eyes, nose, and throat, with redness and tearing of the eyes, runny nose, and cough. Skin contact with butadiene in liquid form may cause burns or frostbite. At high concentrations, butadiene causes blurred vision, nausea, fatigue, headache, dizziness, rapid breathing, decreased blood pressure and pulse, diminished mental alertness, muscular incoordination, unconsciousness, respiratory paralysis, and death.

2. *Chronic exposure*: Prolonged or repeated skin contact with butadiene can induce dermatitis. On the basis of effects seen in animals, butadiene should be considered a potential carcinogen.

- **Emergency procedures**



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

1. *Eye exposure*: If tissue is frozen, seek medical attention ***immediately***; if tissue is not frozen, ***immediately and thoroughly*** flush the eyes with large amounts of water for at least 15 min, occasionally lifting the upper and lower eyelids. If irritation, pain, swelling, lacrimation, or photophobia persists, get medical attention as soon as possible.

2. *Skin exposure*: If frostbite has occurred, seek medical attention ***immediately***; do ***not*** rub the affected areas or flush them with water. If frostbite has ***not*** occurred, ***immediately and thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure*: Move the victim to fresh air ***immediately***.

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

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

EXPOSURE SOURCES AND CONTROL METHODS

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

—Manufacture of styrene-butadiene-rubber (SBR) elastomer, polybutadiene elastomer, neoprene elastomer, nitrile elastomer, styrene-butadiene (SB) copolymer, and acrylonitrile-butadiene-styrene (ABS) resins, which are used as reinforcing and stiffening agents for rubbers

—Manufacture of high-impact polystyrene containing SBR/polybutadiene elastomer and of SBR foams

—Molding and vulcanizing operations that process synthetic rubber products from SBR

—Use of butadiene in latexes and resins to make carpet backing, paper coatings, high-impact-resistant pipes and parts for automobiles, appliances, business machines, telephones, and recreational vehicles

—Manufacture of tires, hoses, belts, gaskets, seals, and oil-resistant textile and paper products

—Manufacture of adiponitrile; cyclo-olefins; 1,4-hexadiene tetramethylene sulfone; tetrahydrophthalic anhydride; hexamethylenediamine; ethylidenenorbornene; and 1,5,9-cyclodecatriene

—Use of butadiene in the Diels-Alder condensation reaction for synthesis of compounds

—Use of butadiene in food wrappings, the latex paint industry, rocket fuels, pesticides, and fungicides

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

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

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

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

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

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

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

MEDICAL MONITORING

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

- **Preplacement medical evaluation**

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

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

- **Periodic medical examinations and biological monitoring**

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

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

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

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

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne butadiene is determined by using charcoal tubes (100/50-mg sections, 20/40 mesh) coated with 10% (w/w) 4-tert-butylcatechol. Samples are collected at a maximum flow rate of 0.05 liter/min until a maximum air volume of 3 liters is collected. The sample is then treated with carbon disulfide to extract the butadiene. Analysis is conducted by gas chromatography using a flame ionization detector. The standard analytical error for this procedure is 0.11. The OSHA method is described in the OSHA Computerized Information System [OSHA 1990] and in Method 56 of the *OSHA Analytical Methods Manual*

[OSHA 1985]. NIOSH has a similiar method for butadiene [NIOSH 1984b]. OSHA Method 56 is compared with NIOSH Method 1024 in the NIOSH comments on the proposed rule for 1,3-butadiene [NIOSH 1990].

PERSONAL HYGIENE

If liquid butadiene contacts the skin, frostbite may occur. Workers should flush the affected areas immediately with plenty of tepid water and then wrap the affected part in a warm dressing. Medical aid should be obtained immediately.

Clothing contaminated with liquid butadiene should be removed immediately.

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

Workers should not eat, drink, or use tobacco products in areas where butadiene cylinders are handled, processed, or stored.

STORAGE

Butadiene should be stored in a cool, dry, well-ventilated area in tightly sealed and pressurized containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Outside, isolated, or detached storage is preferred; inside storage should be in a noncombustible location. Containers of butadiene should be stored upright and should not be stacked. Containers of butadiene should be protected from physical damage and should be stored separately from oxygen, chlorine, phenol, chlorine dioxide, crotonaldehyde, copper, copper alloys, oxidizers, heat, sparks, and open flame. The manufacturer's recommendations regarding shelf life, rotation of inventory, and monitoring of levels of inhibitor should be followed rigorously. Only nonsparking tools may be used to handle butadiene. To prevent static sparks, containers should be grounded and bonded for transfers. Because containers that formerly contained butadiene may hold product residues, they should be handled appropriately.

SPILLS AND LEAKS

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

1. *Do not touch the spilled material.*
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Isolate the area until the gas has dispersed.
5. If butadiene gas is leaking, stop the flow of gas if it is possible to do so without risk.

SPECIAL REQUIREMENTS

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

- **Emergency planning requirements**

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

- **Reportable quantity requirements for hazardous releases**

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

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

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

- **Hazardous waste management requirements**

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

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

Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

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

- **Respiratory protection program**

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

PERSONAL PROTECTIVE EQUIPMENT

Protective clothing should be worn to prevent any possibility of skin contact with butadiene. Protective gloves and clothing are recommended for workers handling this material. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. The following materials have been tested against permeation by butadiene and have demonstrated good-to-excellent resistance for periods of greater than 8 hr: butyl rubber and Viton®. Natural rubber, neoprene, and polyvinyl chloride have demonstrated poor resistance to permeation by butadiene.

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

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

REFERENCES CITED

ACGIH [1991a]. Documentation of the threshold limit values and biological exposure indices. 6th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [1991b]. 1991-1992 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ATS [1987]. Standardization of spirometry—1987 update. American Thoracic Society. Am Rev Respir Dis *136*:1285-1296.

CFR. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Cralley LJ, Cralley LV, eds. [1985]. Patty's industrial hygiene and toxicology. 2nd ed. Vol. 3. New York, NY: John Wiley & Sons.

55 Fed. Reg. 32736 [1990]. Occupational Safety and Health Administration: occupational exposure to 1,3-butadiene; proposed rule and notice of hearing. (To be codified at 29 CFR 1910.)

IARC [1986]. IARC monographs on the evaluation of carcinogenic risk of chemicals to man. Vol. 39. Lyon, France: World Health Organization, International Agency for Research on Cancer.

NIOSH [1984a]. Current Intelligence Bulletin 41: 1,3-butadiene. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 84-105.

NIOSH [1984b]. 1,3-Butadiene: Method 1024 (supplement issued 8/15/87). In: Eller PM, ed. NIOSH manual of analytical methods. 3rd rev. ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 84-100.

NIOSH [1987a]. NIOSH guide to industrial respiratory protection. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-116.

NIOSH [1987b]. Respirator decision logic. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-108.

NIOSH [1990]. NIOSH comments on the Occupational Safety and Health Administration's proposed rule on occupational exposure to 1,3-butadiene, November 9, 1990, OSHA Docket No. H-041. NIOSH policy statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health.

NIOSH [1991]. Registry of toxic effects of chemical substances database: butadiene. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Standards Development and Technology Transfer, Technical Information Branch.

NIOSH [1992]. NIOSH recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

OSHA [1985]. OSHA analytical methods manual. Salt Lake City, UT: U.S. Department of Labor, Occupational Safety and Health Administration, OSHA Analytical Laboratory.

OSHA [1990]. Computerized information system. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration.

Proctor NH, Hughes JP, Fischman ML [1988]. Chemical hazards of the workplace. 2nd ed. Philadelphia, PA: J.B. Lippincott Company.