4. RECOMMENDED GUIDELINES FOR CONTROLLING INFECTIOUS DISEASE HAZARDS IN HOSPITALS

CDC, through its Center for Infectious Diseases and NIOSH, is developing new recommended guidelines for protecting health care workers from infectious diseases. For the present, the reader is referred to guidelines that CDC has already published on this topic. This information is reprinted in Appendices 5, 6, and 8.

Appendix 5 contains the Joint Advisory Notice from the Department of Labor and the Department of Health and Human Services entitled Protection Against Occupational Exposure to Hepatitis B Virus (HBV) and Human Immunodeficiency Virus (HIV), published October 19, 1987.

Appendix 6 contains nine articles from the Morbidity and Mortality Weekly Report with recommended guidelines for protecting health care workers against AIDS and hepatitis, published between 1983 and 1988.

Appendix 8 contains three Guidelines in a series of CDC recommendations for preventing and controlling nosocomial infections: infection control in hospital personnel (1983), isolation precautions in hospitals (1983), and guidelines for handwashing and hospital environmental control (1985).

5. RECOMMENDED GUIDELINES FOR CONTROLLING NONINFECTIOUS HEALTH HAZARDS IN HOSPITALS

Workers encounter many noninfectious health hazards in hospitals, including chemical hazards, physical hazards, mutagens and teratogens, dermatologic hazards, and stress. The following subsections describe these hazards in terms of their location in the hospital, potential health effects, existing standards and recommendations for safe use, recommended environmental monitoring, existing exposure control methods, and recommended medical surveillance.

5.1 CHEMICAL HAZARDS

5.1.1 Introduction

Chemicals may exert either acute or chronic effects on workers. The effects depend on (1) extent (concentration and duration) of exposure, (2) the route of exposure, and (3) the physical and chemical properties of the substance. The effects exerted by a substance may also be influenced by the presence of other chemicals and physical agents or by an individual's use of tobacco, alcohol, or drugs. Basic principles of toxicology are reviewed in Doull et al. (1980).

5.1.1.1 Extent of Exposure

The exposure concentration of a substance is the mass per unit volume of air to which a worker is exposed. In the workplace, airborne concentrations are usually expressed in terms of milligrams of substance per cubic meter of air (mg/m^3) or parts of substance per million parts of air (ppm). In the case of asbestos, concentration is expressed as fibers per cubic centimeter (f/cc) or fibers per cubic meter (f/m^3) of air. The exposure dose is the amount of a substance that actually enters the body during the period of exposure. The substance continues to be present in the body until it is metabolized or eliminated. Although some chemicals are rapidly metabolized, others are not and may be excreted unchanged or stored in the fatty tissues (solvents), lungs (dusts and fibers), bone (lead and radium), or blood (soluble gases).

5.1.1.2 Route of Entry into the Body

Toxic substances can enter the body through several routes, including the intact skin, the respiratory system (inhalation), the mouth (inhalation and ingestion), the eyes, and by accidental needle punctures. Some substances can also damage the skin or eyes directly without being absorbed. Not all substances can enter the body through all routes. Inorganic lead, for example, can be inhaled or swallowed, but it does not penetrate the skin. (It should be noted that tetraethyl lead, a component of automotive gasolines, can be absorbed through the skin and therefore can contribute to the total absorbed dose.) Sometimes a chemical substance can enter through more than one route. Asbestos, for example, can be swallowed or inhaled, but the latter route appears to be more hazardous.

5.1.1.3 Physical and Chemical Properties

The physical properties of a chemical or physical agent include such characteristics as vapor pressure, solubility in water and organic solvents, boiling point, melting point, molecular weight, specific gravity, and morphology. Chemical properties describe the reactivity of a substance with other chemicals.

5.1.1.4 Warning Properties

Some chemicals have characteristics that can be perceived by workers and can serve as a warning of the chemical's presence. The most commonly discussed warning property is odor. Depending on a person's ability to detect the odor of a substance, a chemical is considered to provide either good or poor warning of its presence. The lowest concentration at which the odor of a chemical can be detected is called the odor threshold. Some substances, such as asbestos, have no odor and therefore provide no warning of their presence. In many cases, the concentration of a chemical that can be detected by odor and the concentration that is capable of causing adverse effects are similar. For example, the odor threshold of ethylene oxide is about 700 ppm (Jay et al. 1982), a concentration that has been demonstrated to cause a variety of severe effects among exposed workers. In other cases, exposure to a chemical can cause olfactory fatigue that prevents a worker from continuing to smell the chemical. People cannot detect odors equally well. Thus some may be able to detect the odor of chlorine at a concentration of 0.02 ppm, and others cannot detect its presence until the concentration reaches 0.2 ppm (NIOSH 1976b). For these reasons, workers should not rely on their sense of smell to warn them of the presence of hazardous substances. Nevertheless, available information on odor thresholds has been included for the substances discussed here. A more complete discussion of odor as a warning property can be found in, Odor as an Aid to Chemical Safety: Odor Thresholds Compared with Threshold Limit

Values and Volatilities for 214 Industrial Chemicals in Air and Water Dilution (Amoore and Hautala 1983) and Odor Threshold Determinations of 53 Odorant Chemicals (Leonardos et al. 1969).

5.1.1.5 Synergistic Effects of Various Hazards

Possible interactions may occur as a result of the multiple exposures that exist in a hospital environment. These interactions may involve (1) exposures to chemical and/or physical agents, (2) an individual's use of tobacco, alcohol, or drugs, or (3) the physiological or psychological state of the worker. Limited data are available on interactions of physical and chemical agents; however two studies of other occupations have shown increased toxicity resulting from the synergistic effects of solvent mixtures (Murphy 1984; Struwe and Wennberg 1983). Information is also available on the interactions of chemical and physical agents and the consumption of tobacco, alcohol, or drugs (Bos et al. 1982; Robbin 1979; Hills and Venable 1982). NIOSH Current Intelligence Bulletin 31 (NIOSH 1979b) includes a discussion of the adverse health effects of smoking in the work environment. To determine an exposure, it is imperative to consider other possible exposures or factors that might influence the results.

5.1.2 Asbestos

Asbestos refers to a group of impure magnesium silicate minerals that occur in fibrous form. Asbestos is defined to be chrysotile, crocidolite, and fibrous cummingtonite-grunerite including amosite, fibrous tremolite, fibrous actinolite, and fibrous anthophyllite (NIOSH 1980b). Because of the limitations of the analytical method, only fibers that are 5 micrometers or more in length and have a length-to-diameter ratio of 3:1 or greater are considered when determining a worker's asbestos exposure (29 CFR* 1910.1001).

Because asbestos is an extremely hazardous material and compliance with all relevant aspects of the OSHA asbestos regulations must be assured, hospitals should develop a policy for working with asbestos. All workers who may have reason to work with this substance should receive training.

A hospital asbestos policy must outline specific OSHA requirements (29 CFR 1910.1001) for the following:

- Reports of each asbestos use or exposure (a log of all jobs in which personnel are exposed)

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*Code of Federal Regulations. See CFR in references.

- Work practices for handling asbestos, such as wet handling, development of cleanup protocols, use of plastic sheeting to seal off work areas, and bagging of removed insulation during routine operations, maintenance, and repair
- Asbestos waste collection, labeling, and disposal
- Respiratory protective equipment (types of respirators, maintenance, training programs, use, and recordkeeping)
- Dressing rooms and special clothing
- Air monitoring
- Recordkeeping and maintenance of records (30 years)
- Medical surveillance (requirements are set by OSHA according to the level of asbestos exposure)
- Training

Asbestos removal must only be conducted by fully trained personnel as specified by OSHA (29 CFR 1910.1001).

5.1.2.1 Hazard Location

Hospitals use asbestos for many purposes, including the noncombustible, nonconducting, or chemically resistant materials required for fireproof clothing, curtains, and roofing. Before the early 1970's, asbestos was used as insulation throughout most buildings (including hospitals). Significant asbestos exposures can occur when insulation in old buildings is removed during renovation. Maintenance personnel in most hospitals do not know and often are not trained in the proper methods of performing repairs on systems that contain asbestos. They frequently perform spot repairs without protecting themselves, patients, or staff from exposure. Asbestos is also used to make heat-resistant protective gloves for central supply and laboratories. With time, these gloves may become worn and disintegrate, releasing fibers into the air.

5.1.2.2 Potential Health Effects

Asbestos causes asbestosis (a fibrosis or scarring of the lung tissue) and cancer. These diseases may develop 15 to 30 years after the first exposure.

Asbestosis belongs to the group of pulmonary diseases called pneumoconioses; these include coal workers' pneumoconiosis (often called black lung disease) among coal workers and silicosis among workers with prolonged exposure to sand blasting or other operations in which silica-containing rock is

crushed, drilled, or used. Pneumoconiosis is characterized by restriction of lung function, which eventually increases the load on the circulatory system so that the fully developed disease usually involves heart failure as well. The only hospital workers most likely to encounter enough asbestos to produce asbestosis are engineers who work in furnace rooms where boilers are lined with asbestos, and maintenance workers who frequently repair old piping or do minor renovation. These workers must take special care to protect themselves and to ensure that asbestos is not spread throughout the facility when they perform tasks involving this substance.

Inhaling asbestos, even in small amounts, may result in lung cancer, gastrointestinal cancer, or mesothelioma (a cancer of the lung and abdomen lining). An association has also been suggested between the ingestion of asbestos and the development of gastrointestinal cancer, but no studies have yet confirmed this. Persons with less than a month of exposure have been known to develop mesotheliomas 20 or 30 years later. Because there is no known safe level of asbestos exposure, any hospital worker who is exposed to moderate or high concentrations of asbestos for even a relatively short time may be at increased risk of developing asbestos-related diseases.

All asbestos-exposed workers have a higher risk of lung cancer than nonexposed workers, but exposed workers who smoke cigarettes have a markedly greater risk of lung cancer than nonsmoking exposed workers (29 CFR 1910.1001). Thus smoking cessation and counseling should be targeted especially to workers who have already been exposed to asbestos. Such programs do not rule out the need to comply with the OSHA asbestos standard (29 CFR 1910.1001).

5.1.2.3 Standards and Recommendations

The current OSHA PEL for asbestos is an 8-hour TWA concentration of 0.2 f/cc (200,000 f/m^3) for fibers that are 5 micrometers or longer and that have a length-to-diameter ratio of 3:1 (29 CFR 1910.1001). The asbestos standard is very detailed and has specific requirements for training, labeling, protective equipment, medical surveillance, and environmental monitoring. Questions regarding the implementation of the standard should be referred to the State or Federal OSHA program, which has a consultation service. The NIOSH REL for asbestos (fibers longer than 5 micrometers with a length-to-diameter ratio of 3:1 or greater) is an 8-hr TWA concentration of 100,000 f/m^3 (0.1 f/cc) (NIOSH 1984b).

5.1.2.4 Environmental Monitoring

Sampling should be conducted in a manner and on a schedule that will provide an accurate depiction of job-specific asbestos exposures. All analyses should be done by laboratories accredited by the American Industrial Hygiene Association (AIHA). The minimum schedule for monitoring is established by OSHA regulation (29 CFR 1910.1001).

5.1.2.5 Exposure Control Methods

5.1.2.5.1 Removal and encapsulation

Whenever asbestos fibers are exposed, they present a hazard that can be eliminated by removing or encapsulating (covering) them so that they will not be released. Asbestos must only be removed by fully trained personnel using methods and protective equipment mandated by OSHA (29 CFR 1910.1001).

5.1.2.5.2 Protective equipment

Complete physical covering and a NIOSH/MSHA-certified, positive-pressure, air-supplied respirator are required for any worker exposed to asbestos. The OSHA asbestos standard should be consulted along with the NIOSH/EPA document entitled A Guide to Respiratory Protection for the Asbestos Abatement Industry (NIOSH/EPA 1986).

5.1.2.5.3 Work practices

Only workers fully trained in asbestos handling should be allowed in areas where asbestos is exposed. The work practices appropriate for handling asbestos are set out in detail in the OSHA regulation (29 CFR 1910.1001).

5.1.3 Chemical Disinfectants

Because of the variety of needs for disinfectants within the hospital, a number of different substances are used. The most important are:

- Isopropyl alcohol
- Sodium hypochlorite (chlorine)
- Iodine
- Phenolics
- Quaternary ammonium compounds
- Glutaraldehydes
- Formaldehyde

Many of the following descriptions of disinfectants refer to the lowest concentration at which the odor of these substances can be detected; however, workers should not rely on odor as a warning of exposure because many persons are unable to detect odors.

5.1.3.1 Isopropyl Alcohol

5.1.3.1.1 Hazard location

Isopropyl alcohol is a widely used antiseptic and disinfectant; it is used mostly to disinfect thermometers, needles, anesthesia equipment, and various other instruments.

5.1.3.1.2 Potential health effects

The odor of isopropyl alcohol may be detected at concentrations of 40 to 200 ppm [NIOSH 1976a]. Exposure to isopropyl alcohol can cause irritation of the eyes and mucous membranes. Contact with the liquid may also cause skin rashes.

5.1.3.1.3 Standards and recommendations

The OSHA PEL for isopropyl alcohol is 400 ppm (980 mg/m^3) as an 8-hr TWA (29 CFR 1910.1000, Table Z-1). The NIOSH REL for isopropyl alcohol is 400 ppm (984 mg/m^3) for up to a 10-hr TWA with a ceiling of 800 ppm (1,968 mg/m^3) for 15 min (NIOSH 1976a).

5.1.3.1.4 Exposure control methods

Workers should be provided with and required to use appropriate protective clothing (see Section 2.3.5) such as gloves and face shields to prevent repeated or prolonged skin contact with isopropyl alcohol. Splash-proof safety goggles should also be provided and required for use where isopropyl alcohol may contact the eyes.

Any clothing that becomes wet with isopropyl alcohol should be removed immediately and reworn only after the compound has been removed. Clothing wet with isopropyl alcohol should be stored in closed containers until it can be discarded or cleaned. The worker who is laundering or cleaning such clothes should be informed of isopropyl alcohol's hazardous properties.

Skin that becomes wet with liquid isopropyl alcohol should be promptly washed or showered.

Adequate exhaust ventilation must be supplied in the hospital to remove isopropyl alcohol vapor in the work area.

5.1.3.2 Sodium Hypochlorite (Chlorine)

Chlorine can be generated from solutions of sodium hypochlorite. Chlorine is effective against bacteria and viruses, and it can destroy some spores, depending on the concentration.

5.1.3.2.1 Hazard location

Chlorine is used for disinfecting water tanks, bathtubs, toilets, and bathrooms; it is also used as a bleach for laundries, a sanitizer for dishwashing, and a disinfectant for floors. Chlorine-containing cleaning materials should never be mixed with ammonia or ammonia-containing materials because the reaction may produce a toxic gas.

5.1.3.2.2 Potential health effects

Chlorine is released slowly from cleaning and bleaching solutions as they are used. Repeated exposure to chlorine may cause a runny nose, coughing, wheezing, and other respiratory problems (NIOSH 1976b). Mild irritation of the mucous membranes can occur at exposure concentrations of 0.5 ppm (ACGIH 1986).

5.1.3.2.3 Standards and recommendations

The OSHA PEL for chlorine is a ceiling of 1 ppm (3 mg/m^3) (29 CFR 1910.1000, Table Z-1). The NIOSH REL is a ceiling of 0.5 ppm for 15 min (NIOSH 1976b). Chlorine has an odor threshold between 0.02 and 0.2 ppm, but since the sense of smell is dulled by continued chlorine exposure, odor does not provide adequate warning (NIOSH 1976b).

The ACGIH recommends a TLV of 1 ppm (3.0 mg/m^3) as an 8-hr TWA and a short-term exposure limit (STEL) of 3 ppm (9 mg/m^3) but has published a notice of intended change to a TLV of 0.5 ppm (1.5 mg/m^3) as an 8-hr TWA and a STEL of 1 ppm (3 mg/m^3) (ACGIH 1987).

5.1.3.2.4 Exposure control methods

Workers should be provided with and required to use splash-proof safety goggles where there is any possibility that chlorine-containing solutions may contact the eyes. To prevent any possibility of skin contact with chlorine-containing liquids, workers should be provided with and required to use appropriate personal protective equipment (see Section 2.3.5), such as gloves, face shields, and respirators (see Section 2.3.5.6) as necessary. Nonimpervious clothing that becomes contaminated with chlorine-containing solutions should be removed immediately and reworn only after the chlorine-containing solution is removed from the clothing.

Skin that becomes contaminated with chlorine should be immediately washed to remove any chlorine. Additional control measures for chlorine include process enclosure and good exhaust ventilation.

5.1.3.3 Iodine

Iodine is a general disinfectant; it can be mixed with alcohol for use as a skin antiseptic or with other substances for general disinfecting purposes.

5.1.3.3.1 Hazard location

Iodine can be found throughout the hospital.

5.1.3.3.2 Potential health effects

Symptoms of iodine exposure include irritation of the eyes and mucous membranes, headaches, and breathing difficulties (ACGIH 1986). Crystalline iodine or strong solutions of iodine may cause severe skin irritation: it is not easily removed from the skin and may cause burns.

5.1.3.3.3 Standards and recommendations

The OSHA PEL for iodine is a ceiling of 0.1 ppm (1.0 mg/m^3) (29 CFR 1910.1001, Table Z-1). The ACGIH recommends a TLV of 0.1 ppm (1.0 mg/m^3) as a ceiling (ACGIH 1987). NIOSH has no REL for iodine.

5.1.3.3.4 Exposure control methods

To prevent skin contact with solids or liquids containing iodine, workers should be provided with and required to use personal protective equipment such as gloves, face shields, and any other appropriate protective clothing deemed necessary (see Section 2.3.5).

If there is any possibility that clothing has been contaminated with solid iodine or liquids containing iodine, a worker should change into uncontaminated clothing before leaving the work area. Clothing contaminated with iodine should be stored in closed containers until provision is made to remove the iodine. The person laundering or cleaning such clothes should be informed of iodine's hazardous properties.

Skin that becomes contaminated with solids or liquids containing iodine should be immediately washed with soap or mild detergent and rinsed with water. Workers who handle solid iodine or liquids containing iodine should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

5.1.3.4 Phenolics

Phenolics were among the first disinfectants used in hospitals. Certain detergent disinfectants belong to the phenol group, including phenol, para-tertiary butylphenol (ptBP), and para-tertiary amylphenol (ptAP). They are generally used for a wide range of bacteria, but they are not effective against spores.

5.1.3.4.1 Hazard location

Phenolics are widely used on floors, walls, furnishings, glassware, and instruments.

5.1.3.4.2 Potential health effects

Phenol may be detected by odor at a concentration of about 0.05 ppm. Serious health effects may follow exposure to phenol through skin adsorption, inhalation, or ingestion. These effects may include local tissue irritation and necrosis, severe burns of the eyes and skin, irregular pulse, stertorous breathing (harsh snoring or gasping sound), darkened urine, convulsions, coma, collapse, and death (NIOSH 1976d). Both ptBP and ptAP have caused hospital workers to experience loss of skin pigment that was not reversed one year after use of the compounds was discontinued (Kahn 1970).

5.1.3.4.3 Standards and recommendations

The OSHA PEL for phenol is 5 ppm (19 mg/m^3) as an 8-hr TWA (Skin) (29 CFR 1910.1000, Table Z-1). The NIOSH REL for phenol is 20 mg/m^3 (5.2 ppm) for up to a 10-hr TWA with a 15-min ceiling of 60 mg/m^3 (15.6 ppm) (NIOSH 1976d). Neither OSHA nor NIOSH has established exposure limits for ptBP or ptAP.

5.1.3.4.4 Exposure control methods

When working with phenol, workers should be provided with and required to use protective clothing (see Section 2.3.5), gloves, face shields, splash-proof safety goggles, and other appropriate protective clothing necessary to prevent any possibility of skin or eye contact with solid or liquid phenol or liquids containing phenol.

If there is any possibility that the clothing has been contaminated with phenol, a worker should change into uncontaminated clothing before leaving the work area and the suspect clothing should be stored in closed containers

until it can be discarded or until provision is made for removal of the phenol. The worker laundering or cleaning such clothes should be informed of phenol's hazardous properties.

Skin that becomes contaminated with phenol should be immediately washed with soap or mild detergent and rinsed with water. Eating and smoking should not be permitted in areas where solid or liquid phenol or liquids containing phenol are handled, processed, or stored. Workers who handle solid or liquid phenol or liquids containing phenol should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

Additional measures to control phenol exposure include process enclosure, local exhaust ventilation, and personal protective equipment.

5.1.3.5 Quaternary Ammonium Compounds

5.1.3.5.1 Hazard location

Quaternary ammonium compounds are widely used as disinfectants in hospitals, and they have the major disadvantage of being ineffective against tuberculosis and gram-negative bacteria. Quaternary ammonium compounds are most likely to be encountered by workers in central supply, housekeeping, patient, and surgical services areas. The detergent benzalkonium chloride is the most widely used quaternary ammonium compound and is found in the following commercial products (Cohen 1987):

- Zephiran chloride
- Zephirol
- BTC
- Roccal
- Benirol
- Enuclen
- Germitol
- Drapolene
- Drapolex
- Cequartyl
- Paralkan
- Germinol
- Rodalon
- Osvan

5.1.3.5.2 Potential health effects

Quaternary ammonium compounds can cause contact dermatitis, but they tend to be less irritating to hands than other substances. They can also cause nasal irritation.

5.1.3.5.3 Standards and recommendations

No OSHA PEL, NIOSH REL, or ACGIH TLV exists for quaternary ammonium compounds.

5.1.3.6 Glutaraldehyde

Although glutaraldehyde is available in 50%, 25%, 10%, and 2% solutions, most hospitals use 2% glutaraldehyde solutions buffered to pH 7.5 to 8.5 before use. Glutaraldehyde solutions also contain surfactants to promote wetting and rinsing of surfaces, sodium nitrite to inhibit corrosion, peppermint oil as an odorant, and FD&C yellow and blue dyes to indicate activation of the solution (NIOSH 1983b). One disadvantage of buffered glutaraldehyde solutions is that they are stable for less than 2 weeks, so solutions must be dated and made as needed (Gorman et al. 1980). Another disadvantage is that at 20°C (68°F), a 50% solution of glutaraldehyde has a vapor pressure of 0.015 mmHg (ACGIH 1986) and thus can generate an atmosphere that contains as much as 20 ppm of glutaraldehyde. This concentration is well above that shown to cause adverse health effects in animals and humans.

5.1.3.6.1 Hazard location

Glutaraldehyde is a newer disinfectant that is especially effective for cold sterilization of instruments; it has recently been used as a substitute for formaldehyde during embalming. Glutaraldehyde has been used in pulmonary physiology units, at nurses' stations, and in research laboratories. As a disinfectant, glutaraldehyde has been used to clean sputum mouthpieces, suction bottles and tubing, and equipment used for ear, nose, and throat treatment (NIOSH 1983b).

5.1.3.6.2 Potential health effects

Glutaraldehyde may be absorbed into the body by inhalation, ingestion, and skin contact. Extensive skin contact may cause allergic eczema and may also affect the nervous system. Glutaraldehyde has an odor threshold of about 0.04 ppm, is highly toxic, and is irritating to the skin and mucous membranes at concentrations of about 0.3 ppm (1.05 mg/m^3) (ACGIH 1986). In a study of 541 members of a hospital cleaning department, 39.1% of the workers had skin disease during their employment. In 21% of the workers, contact dermatitis was attributed to the use of glutaraldehyde, formaldehyde, and chloramine (Hansen, 1983).

A NIOSH investigation (NIOSH 1983b) determined that airborne glutaraldehyde concentrations of 0.4 ppm (1.5 mg/m^3) were responsible for symptoms of irritation in 9 of 11 (82%) exposed workers. Eye, throat, and lung

irritation were reported among 45% of the workers. Other symptoms, including cough, chest tightness, headache, skin irritation, and asthma-like symptoms, were also reported.

Glutaraldehyde exposure has been associated with fetotoxicity in mice, DNA damage in chickens and hamsters, and mutagenicity in microorganisms (NIOSH 1985).

5.1.3.6.3 Standards and recommendations

The ACGIH recommended ceiling limit for glutaraldehyde is 0.2 ppm (0.8 mg/m^3) (ACGIH 1986). OSHA does not have a PEL for glutaraldehyde, and NIOSH has no REL.

5.1.3.6.4 Exposure control methods

Workers should avoid breathing glutaraldehyde vapors. They should also be provided with and required to use splash-proof safety goggles where there is any possibility of contaminating the eyes with glutaraldehyde. To prevent any possibility of skin contact, workers should be provided with and required to use protective clothing (see Section 2.3.5). If clothing becomes contaminated with glutaraldehyde, it should be promptly removed and not reworn until the glutaraldehyde has been removed. The worker who is laundering or cleaning such clothes should be informed of glutaraldehyde's hazardous properties. Skin that becomes contaminated with glutaraldehyde should be washed immediately or showered.

5.1.3.7 Formaldehyde

Formaldehyde is used for cold sterilization of various instruments and as an embalming agent. This compound is fully discussed later in this Section (5.1.6).

5.1.4 Antineoplastic Drugs

Nurses and pharmacists face a variety of potential hazards from contact with pharmaceuticals. The drugs of greatest concern are those associated with cytotoxicity and fetotoxicity (e.g., folate antagonists, 6-mercaptopurine, and some alkylating agents), and teratogenicity (e.g., actinomycin-D, mitomycin-C, nitrogen mustard, prednisone, procarbazine, streptomycin, and vincristine). Many chemotherapeutic agents have been reported to cause cancer in animals and thus can be considered to be potential human carcinogens (e.g., cyclophosphamide and chlorambucil) (Sorsa et al. 1985).

Antineoplastic drugs derive their name from the fact that they interfere with or prevent the growth and development of malignant cells and

neoplasms. They may also be called cytotoxic or cytostatic because they have the ability to prevent the growth and proliferation of cells. Approximately 30 antineoplastic drugs are currently available commercially. Each year some 200,000 to 400,000 cancer patients are treated with antineoplastic drugs (Sorsa et al. 1985; Devita 1982).

5.1.4.1 Effects of antineoplastic drugs

Many antineoplastic drugs are reported to cause mutations in test systems and are carcinogenic and teratogenic in experimental animals (see Table 5-1). Evidence indicates that cyclophosphamide, chlorambucil, 1,4-butanediol dimethylsulfonate, and melphalan are human carcinogens (Sorsa et al. 1985). When given to patients in therapeutic doses, many antineoplastic drugs (e.g., cyclophosphamide) have been associated with an increased incidence of malignant tumors that develop at a later date (IARC 1981). Available human evidence suggests that cyclophosphamide is also a teratogen.

Toxic effects have been observed in patients treated with antineoplastic drugs. These effects include lack of sperm production, reduced sperm counts, amenorrhea, and adverse effects on the bone marrow, heart, central nervous system, liver, skin, ears, pancreas, lungs, kidneys, and endocrine glands (Stellman and Zoloth 1986). Treatment with antineoplastic drugs has also resulted in depression of the hematopoietic system (LaFond 1978; Caro 1980).

The acute effects of accidental exposure to these drugs can be severe. For example, an accidental needle prick of a patient's finger with mitomycin-C has been reported to cause the eventual loss of function of that hand (Duvall and Baumann 1980). Some antineoplastic drugs (e.g., mustine hydrochloride and doxorubicin) are strong vesicants that can cause varying degrees of local tissue necrosis upon direct contact (Knowles and Virden 1980).

Little is known about the potential health hazards of chronic exposure to antineoplastic drugs, but Selevan et al. (1985) observed a statistically significant association between fetal loss and the occupational exposure of nurses to these drugs. Sotaniemi et al. (1983) documented liver damage in three oncology nurses who had handled antineoplastic drugs for a number of years. Light-headedness, dizziness, nausea, headache, skin and mucous membrane reactions, hair loss, cough, and possible allergic reactions have been reported by nurses handling antineoplastic drugs (Crudi 1980). These side effects observed in nurses are the same as those noted by patients receiving antineoplastic drugs (Crooke and Prestayko 1981).

Table 5-1. Carcinogenicity, teratogenicity, and embryo toxicity of anticancer agents*

Compound used in chemotherapy	Degree of evidence for carcinogenicity in Humans	Degree of evidence for carcinogenicity in Animals	Teratogenicity and embryotoxicity†
Actinomycin-D	Inadequate	Limited	T,E†
Adriamycin	Inadequate	Sufficient	....
BCNU	Inadequate	Sufficient	T,E
Bleomycin	Inadequate	Inadequate	....
1,4-Butanediol dimethylsulfonate (Myleran, Busulfan)	Sufficient	Limited	T
Chlorambucil	Sufficient	Sufficient	T,E
CCNU	Inadequate	Sufficient	T,E
Cisplatin	Inadequate	Limited	E
Cyclophosphamide	Sufficient	Sufficient	T,E
Dacarbazine	Inadequate	Sufficient	T,E
5-Fluorouracil	Inadequate	Inadequate	T,E
Melphalan	Sufficient	Sufficient	T
6-Mercaptopurine	Inadequate	Inadequate	T,E
Methotrexate	Inadequate	Inadequate	T,E
Nitrogen mustard	Inadequate	Sufficient	T,E
Procarbazine	Inadequate	Sufficient	T,E
Thiotepa	Inadequate	Sufficient	T
Uracil mustard	Inadequate	Sufficient	T
Vinblastine	Inadequate	Inadequate	T,E
Vincristine	Inadequate	Inadequate	T,E

*Adapted from Sorsa et al. (1985).

†Teratogenicity (T) and embryotoxicity (E) in experimental animals as summarized by IARC (1975, 1976, 1981).

Several other antineoplastic drugs (e.g., methotrexate and vincristine) are skin and mucous membrane irritants (Knowles and Virden 1980). Bleomycin and cisplatin may cause allergic reactions following skin contact (Knowles and Virden 1980).

5.1.4.2 Methods for estimating exposure to antineoplastic drugs

At present, few economically feasible tests are available for monitoring the exposures of nurses and pharmacy technicians who work with a variety of antineoplastic drugs. Primary routes of worker exposure to antineoplastic drugs are inhalation and dermal absorption.

Exposures by inhalation can occur during drug preparation or administration. Aerosols can be generated when inserting needles into or withdrawing them from vials, and when expelling air from syringes before injection (Hirst et al. 1984; Stellman et al. 1984). In one study, for example, low levels of the antineoplastic drugs cyclophosphamide and fluorouracil were measured in workroom air (deWerk et al. 1983).

Skin absorption may occur when antineoplastic drugs are spilled during their preparation or administration (Jardine et al. 1978). Skin exposure may also occur as a result of contact with the urine of patients being treated with antineoplastic drugs (Hirst et al. 1984). Because of the relatively large number of antineoplastic drugs in use and the variety of metabolites formed, it is not economically feasible for the hospital laboratory to conduct biological monitoring for each drug in use. However, methods have been developed for detecting platinum (from cisplatin exposure) and cyclophosphamide in the urine of exposed workers (Venitt et al. 1984).

Mutagenicity assays using urine can detect excreted mutagenic parent compounds or their mutagenic metabolites. Several studies have analyzed mutagenic constituents in the urine as a measure of exposure to antineoplastic drugs. Five studies reported that nurses or pharmacy technicians handling antineoplastic drugs have increased urine mutagenicity compared with a control population (Nguyen et al. 1982; Falck et al. 1979; Kolmodin-Hedman 1983; Bos et al. 1982; Anderson et al. 1982). However, negative results were reported in five other studies of similar groups of nurses or pharmacy technicians (Venitt et al. 1984; Staiano et al. 1981; Rorth et al. 1983; Ratcliffe 1983; Gibson et al. 1984). Evidence is still insufficient to recommend routine urine mutagenicity testing for estimating exposure to antineoplastic drugs.

Sister chromatid exchange (SCE) analysis using human peripheral blood lymphocytes is thought to provide an estimate of DNA damage produced by mutagens and carcinogens. Increased frequencies of SCE and chromosome aberrations were found in hospital personnel handling antineoplastic drugs (Norppa et al. 1980; Waksvik et al. 1981; Nikula et al. 1984). However,

these observations were not confirmed by other investigators (Barale et al. 1985; Kolmodin-Hedman et al. 1983). Thus evidence is still insufficient to recommend routine SCE analysis for estimating exposure to antineoplastic drugs.

5.1.4.3 Methods for preventing exposure to antineoplastic drugs

Methods for preventing exposure to antineoplastic drugs are detailed in the OSHA work practice guidelines attached to this document as Appendix 7 (OSHA 1986). These guidelines address drug preparation, drug administration, waste disposal, spills, medical surveillance, storage and transport, training, and information dissemination. Recommendations have also been issued by the National Institutes of Health (NIH), the Society of Hospital Pharmacists, the American Society of Hospital Pharmacists, the National Study Commission on Cytotoxic Exposure, and individual directors of hospital pharmacies (Knowles and Virden 1980, Waksvik et al. 1981; Crudi 1980; Crooke and Prestayko 1981; Caro 1980; Vaughn and Christensen 1985).

5.1.4.4 Medical monitoring

Workers exposed to antineoplastic drugs should receive preplacement and periodic medical evaluations that include at least the following:

- A complete work history and medical history
- An examination that emphasizes the skin, the liver, and the hematopoietic, reproductive, and nervous systems

Other tests may be performed at the discretion of the examining physician, who should be particularly alert for symptoms of liver disease, skin and mucous membrane irritation, central nervous system depression, teratogenic effects, and cancer.

5.1.5 Ethylene Oxide

Ethylene oxide, which is a colorless gas with a distinctive sweet, ether-like odor (NIOSH 1981j), is used to sterilize medical instruments, particularly those made of heat-labile materials (Gross et al. 1979). This compound is regulated by OSHA as a carcinogen (29 CFR 1910.1047). Ethylene oxide is typically supplied to U.S. hospitals in compressed gas cylinders that contain 88% Freon® (see Section 5.1.7) and 12% ethylene oxide, or in single-dose cartridges of 100% ethylene oxide (NIOSH 1977d).

5.1.5.1 Hazard Location

Workers in central supply, dental operatories, and surgical suites who use ethylene oxide are at risk of potential exposure. In 1983, OSHA estimated that approximately 62,370 workers were directly exposed to ethylene oxide and that 25,000 others may have been incidentally exposed in U.S. hospitals (Federal Register 1983). An estimated 7,700 ethylene oxide sterilizers are in operation in 6,300 hospitals in the United States (Federal Register 1983).

The typical source of ethylene oxide exposure in the hospital environment is through the operation of sterilizing equipment. Unless good engineering controls and good work practices are used, workers may encounter relatively high concentrations of ethylene oxide over relatively brief periods. A study by Yager et al. (1983) highlights the need to control short-term peak exposures to ethylene oxide.

5.1.5.2 Potential Health Effects

Exposure to ethylene oxide occurs primarily through inhalation, but exposure of moist skin to the vapors can also cause irritation.

5.1.5.2.1 Acute effects

Although ethylene oxide has an odor threshold of about 700 ppm (Jay et al. 1982), exposure at 200 ppm may cause irritation of the eyes and upper respiratory system. High concentrations can cause severe skin burns, rashes, sores, headache, nausea, and hemolysis (the destruction of red blood cells). Very high exposures may cause vomiting, shortness of breath, weakness, drowsiness, lack of coordination, cyanosis, bluish skin color resulting from oxygen insufficiency, and pulmonary edema (NIOSH 1977d).

Contact with ethylene-oxide-sterilized equipment or wrappings that have not been adequately aerated to remove residual ethylene oxide may cause severe skin burns with large blisters and peeling skin. Healing may leave hyperpigmentation (brown discoloration of skin).

Ethylene oxide may also pose a fire hazard, depending on how it is stored and used (see Section 3).

5.1.5.2.2 Chronic effects

Ethylene oxide is a mutagen in many assay systems and causes reproductive damage in both male and female experimental animals. Some data also suggest that ethylene oxide may adversely affect human reproduction (Hemminki et al. 1982). Thiess et al. (1981) found chromosomal abnormalities in workers

exposed to alkylene oxides (including ethylene oxide), and Garry et al. (1979) found a dose-response relationship between ethylene oxide concentrations and chromosomal abnormalities. The significance of these chromosomal abnormalities is not known, but concern exists over a possible link between them and the ability to cause cancer and adverse reproductive effects (Hogstedt et al. 1979b). An increased incidence of spontaneous abortion has also been associated with ethylene oxide exposure (Hemminki et al. 1982).

In 1981, NIOSH published a Current Intelligence Bulletin stating that ethylene oxide should be considered a potential occupational carcinogen (NIOSH 1981j). An increased rate of leukemia has been found in workers exposed to levels below the former OSHA PEL of 50 ppm as an 8-hr TWA, but this result has not been confirmed by other studies (Hogstedt et al. 1979a).

The neurotoxicity of ethylene oxide has been documented in four exposed workers (Gross et al. 1979). Findings included acute encephalopathy and peripheral neuropathy. Nerve conduction velocity was abnormal in most patients. Decreasing the amount of exposure relieved symptoms, but only total removal from exposure caused nerve conduction velocities to return to normal.

Chronic exposure to ethylene oxide increases the risk of sensitization and cataract development (Jay et al. 1982).

5.1.5.3 Standards and Recommendations

The OSHA PEL for ethylene oxide is an 8-hr TWA of 1 ppm with an excursion limit of 5 ppm for any 15-min period (29 CFR 1910.1047). The NIOSH REL for ethylene oxide is a ceiling of 5 ppm for no more than 10 min in any working day, and an 8-hr TWA less than 0.1 ppm (NIOSH 1983e).

5.1.5.4 Environmental Monitoring

A comprehensive monitoring program is an important part of the overall ethylene oxide control strategy. A detailed discussion of hospital sampling procedures and methods appears in the Technical Industrial Processes Sourcebook (Wood 1984).

Three types of monitoring are generally used for ethylene oxide: direct-reading instruments (e.g., infrared analyzers), samples collected on activated charcoal for subsequent analysis, and passive dosimeters. Portable infrared analyzers are direct-reading instruments that may be used for area monitoring of ethylene oxide concentrations. Note, however, that these instruments may not be accurate at ethylene oxide concentrations below 1 ppm (1.8 mg/m^3) because they are sensitive to high humidity and may produce false readings. Activated charcoal tubes are used to determine

exposure for the entire sampling period (an 8-hr day, for example). Passive dosimeters are generally worn on a worker's lapel; after chemical analyses, they can provide a semi-quantitative indication of exposure.

5.1.5.5 Exposure Control Methods

A NIOSH study of hospitals with good engineering controls has shown that ethylene oxide exposures can be kept below 0.1 ppm (0.18 mg/m^3) for an 8-hr TWA and below 5 ppm (9 mg/m^3) for short-term exposures of less than 2 min (Kercher and Mortimer 1987).

5.1.5.5.1 Substitution

In most cases, no acceptable substitute exists for ethylene oxide in the sterilization of heat-sensitive equipment.

5.1.5.5.2 Engineering controls

The following engineering controls are recommended:

- The sterilizer should be enclosed either in a mechanical access room or a cabinet, and the enclosure should be exhausted to a dedicated ventilation system.*
- Sterilizing operations should be centralized and access to sterilizer rooms should be restricted.
- The sterilizer should be checked with the infrared analyzer at least once every 3 months.
- Floor drains should have a cover with an anti-siphon air gap. The air gap, at the junction of the vacuum pump discharge line with the floor drain, should be enclosed. Dedicated exhaust ventilation should be provided for the enclosure.
- Local exhaust ventilation sufficient to effectively remove ethylene oxide should be as close as possible to the top of the sterilizer door.

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* A dedicated exhaust system is one that serves the sterilizer area only and routes ethylene oxide directly to the outside of the building at a location where prevailing winds will not carry the exhaust into populated areas or into the air intakes of other buildings.

- The number of exhaust cycles recommended by the sterilizer manufacturer should be completed before the door is opened; the door should remain only slightly open for at least 15 min.

- Supply cylinders should be located in a ventilated enclosure (either a ventilated cabinet or a hood that covers the point where the cylinder is connected to the sterilizer supply line).

- Aerators and the overpressure relief valves (if present) should be vented to a dedicated exhaust system.

- Sensors should be provided to identify a ventilation failure and to detect ethylene oxide. Both audible and visual alarms should be activated by the sensors.

- Ventilation air from the sterilizing room should not be recirculated.

- Exhaust gases should preferably be vented directly to the outside of the building (away from intake vents); this procedure is strongly recommended for all sterilizers.

- Sterilized material and its packaging should be aerated in aeration cabinets, since approximately 5% of the ethylene oxide in the sterilizer remains in these items. Aeration times depend on the composition, form, and weight of the material. Refer to the recommendations from the Association for the Advancement of Medical Instrumentation (AAMI 1982), and follow the manufacturer's recommendations for each type of equipment sterilized. Materials that do not absorb ethylene oxide (metal and glass) need no aeration unless they are wrapped.

- Sterilizers that use glass ampules in a plastic bag (flash bag) have a high potential for worker exposure to ethylene oxide. If they are used, all sterilization procedures should be conducted in a ventilated enclosure.

5.1.5.5.3 Protective equipment

A worker should use protective gloves (see Section 2.3.5) and splash-proof goggles and/or a face shield when changing ethylene oxide supply cylinders. If good engineering controls are used (i.e., if the cylinder is located in a ventilated hood), a respirator should not be necessary. If a respirator is necessary or desired, the worker should use a chemical cartridge respirator with an end-of-service-life indicator that has been approved by NIOSH/MSHA. The end-of-service-life indicator is needed because the odor threshold for ethylene oxide is about 700 ppm (Jay et al. 1982), and failure of the adsorbent material will not be detected by the user.

Protective gloves and long-sleeved garments should be worn when removing items from the sterilizer or transferring them to the aerator.

When cleaning up liquid spills that contain ethylene oxide, workers should wear protective outer clothing and dispose of or launder it immediately afterward. If leather shoes become contaminated with ethylene oxide, they should be discarded.

A positive-pressure, self-contained breathing apparatus should be available for emergency situations and should be stored in an area away from the sterilizer and the ethylene oxide supply location.

5.1.5.5.4 Work practices

Sterilizers should be operated only by personnel trained in sterilization procedures and in the health and safety hazards of ethylene oxide. If local exhaust ventilation has been provided above the sterilizer door, a worker should open the door slightly and step away for an established time period. The time period should be determined by monitoring and should be at least 15 min. The door opening should be smaller than the capture distance of the hood.

To clean the sterilizer (especially the back surfaces), a worker must often reach inside the chamber with the whole upper body. Ethylene oxide exposure during this cleaning can be controlled by (1) scheduling the cleaning activity as long as possible after processing a load, (2) leaving the sterilizer door fully open for at least 30 min before cleaning, and (3) wearing a respirator.

5.1.5.6 Medical Monitoring

Employers should obtain pre-employment baseline data on workers who will be handling ethylene oxide. This information should include data on the eyes, skin, blood, and respiratory tract. Periodic examinations thereafter should include the following organs and systems:

Organ or system	Suspicious symptoms
Skin	Rashes, cracking, burns, blisters
Eyes	Swelling or irritation
Respiratory system	Breathing difficulty, nose or throat irritation, prolonged or dry cough, chest pains, wheezing

Neurological system.	.Drowsiness, numbness or tingling of hands or feet, weakness or lack of coordination, headaches
Reproductive system.	.Spontaneous abortions, birth defects

5.1.6 Formaldehyde

NIOSH regards formaldehyde as a potential occupational carcinogen (NIOSH 1981; NIOSH 1986c). Formaldehyde is used for cold sterilization of some instruments, but it is not used as a general disinfectant because it is very caustic.

5.1.6.1 Hazard location

Formaldehyde may be encountered in the laboratory as a tissue preservative, in central supply as a sterilant, and in the dialysis unit as a sterilant. Formaldehyde is often combined with methanol and water to make formalin.

5.1.6.2 Potential Health Effects

5.1.6.2.1 Acute effects

The odor of formaldehyde can be detected in air at about 0.8 ppm (Amoore and Hautala 1983). Formalin solutions splashed in the eyes may cause severe injury and corneal damage. Low ambient concentrations of formaldehyde (0.1 to 5 ppm) may cause burning and tearing of the eyes and irritation of the upper respiratory tract. Higher concentrations (10 to 20 ppm) may cause coughing, chest tightness, increased heart rate, and a sensation of pressure in the head. Exposures of 50 to 100 ppm may cause pulmonary edema, pneumonitis, and death (NIOSH 1981i).

5.1.6.2.2 Chronic effects

Repeated exposure to formaldehyde may cause some persons to become sensitized. Sensitization may occur days, weeks, or months after the first exposure. Sensitized individuals will experience eye or upper respiratory irritation or an asthmatic reaction at levels of exposure that are too low to cause symptoms in most people. Reactions may be quite severe with swelling, itching, wheezing, and chest tightness (NIOSH 1976f).

One study (Hendrick et al. 1982) reported that two nurses working in a renal dialysis unit developed asthmatic symptoms associated with their work with formaldehyde. The symptoms completely resolved for the nurse who spent 5 to 7 years without further exposure to formaldehyde, but the other nurse, who continued the exposure, continued to have symptoms.

Dermatitis (including red, sore, cracking, and blistered skin) is also a common problem with formaldehyde exposure. Repeated exposure may make the fingernails soft and brown (NIOSH 1976f). A NIOSH health hazard evaluation of a hospital hemodialysis unit (NIOSH 1983a) indicated that respiratory irritation, eye irritation, and dermatological problems were the primary health problems associated with formaldehyde exposure.

Formaldehyde is a mutagen in many assay systems and has caused nasal and other cancers in experimental animals. In 1981, NIOSH published the Current Intelligence Bulletin 34 (NIOSH 1981i), which recommended that formaldehyde be handled as a suspect carcinogen in the workplace.

5.1.6.3 Standards and Recommendations

The OSHA standard for formaldehyde is 1 ppm as an 8-hr TWA with a ceiling concentration of 2 ppm as a 15-min short-term exposure limit (29 CFR 1910.1048).

The NIOSH REL for formaldehyde is 0.1 ppm as determined in any 15-min air sample and 0.016 ppm as an 8-hr TWA (NIOSH 1986d). In the Current Intelligence Bulletin 34, NIOSH recommended that engineering controls and stringent work practices be used to reduce occupational exposure to the lowest feasible limit (NIOSH 1981i).

The ACGIH has designated formaldehyde a suspected human carcinogen and has recommended a TLV of 1 ppm (1.5 mg/m^3) as an 8-hour TWA with a short term exposure limit (STEL) of 2 ppm (3 mg/m^3) (ACGIH 1987).

The odor of formaldehyde can be detected at about 0.8 ppm (Amoore and Hautala 1983), but even a short period of exposure will decrease the worker's ability to smell it. Thus odor is not a reliable warning for the presence of formaldehyde (NIOSH 1976f).

5.1.6.4 Environmental Monitoring

NIOSH industrial hygiene surveys have found formaldehyde concentrations ranging from 2.2 to 7.9 ppm in hospital autopsy rooms (NIOSH 1981i). Passive dosimeters, direct-reading colorimetric detector tubes, and the personal sampling pump may be used to monitor exposures. Although some colorimetric detector tubes can detect as little as 0.05 ppm formaldehyde, personal sampling pumps and charcoal tubes are preferred for measuring low-level exposures. For a more detailed description of sampling procedures for formaldehyde, refer to the Technical Industrial Processes Sourcebook (Wood 1984), or Air Sampling Instruments for Evaluation of Atmospheric Contaminants (ACGIH 1983).

5.1.6.5 Exposure Control Methods

Phenols may be substituted for formaldehyde in some cases, and dilute bleach solutions can be used to disinfect the exteriors of dialyzers. Other cold sterilants such as glutaraldehyde are also available. These substitutes should be used with caution (see Sections 5.1.3.4 and 5.1.3.6).

5.1.6.5.1 Engineering controls

The following engineering controls are recommended to minimize formaldehyde exposure:

- Local exhaust ventilation should be installed over work stations using formalin or specimens preserved in formalin.
- Small quantities of formaldehyde should be purchased in plastic containers for ease of handling and safety.
- Traps should be placed in floor drains.
- Spill-absorbent bags should be available for emergencies.
- Engineering controls in hemodialysis units should include (1) isolating the main system from personnel and patients in case of inadvertent spills or (2) disconnecting the dialyzers before the sterilization process is completed. Also, formaldehyde vapors should be prevented from entering the room from the drains serving the main system and the dialysis consoles. The air should be regularly monitored for formaldehyde, and in-service education should be conducted periodically on the effects of formaldehyde.

5.1.6.5.2 Protective equipment

Skin and eye contact with formaldehyde should be avoided. Goggles, face shields, aprons, NIOSH certified positive-pressure air-supplied respirators (see Section 2.3.4.6), and boots should be used in situations where formaldehyde spills and splashes are likely. Appropriate protective gloves (see Section 2.3.4) should be used whenever hand contact is possible; latex examination gloves are too fragile.

5.1.6.6 Medical Monitoring

Pre-employment baseline data should be recorded for the respiratory tract, liver, and skin condition of any worker who will be exposed to formaldehyde. Thereafter, periodic monitoring should be conducted to detect symptoms of pulmonary or skin sensitization or effects on the liver.

5.1.7 Freon®

Freon® includes a number of gaseous, colorless chlorofluorocarbons. Those most commonly used in hospitals are Freon 12 (dichlorodifluoromethane), Freon 11 (fluorotrichloromethane), and Freon 22 (chlorodifluoromethane).

5.1.7.1 Hazard Location

Workers may encounter Freon hazards in the pathology laboratory (where it is used to prepare frozen tissue sections), in aerosol cans (where it is used as a propellant), in central supply departments (where it is used in combination with ethylene oxide for sterilization), and in refrigerant gas. Freon can freeze the skin and also cause defatting.

5.1.7.2 Potential Health Effects

Exposure to Freon may cause eye and skin irritation or sensitization. High concentrations of Freon cause severe depression of the central nervous system, weakness, dizziness, convulsions, and cardiac arrhythmia (irregular heart beat) (ACGIH 1986). In one study of pathology residents in a Boston hospital, all residents in their second and third years experienced palpitations that appeared to be associated with the addition of the surgical pathology rotation to their schedules. On this rotation, the only procedure that could have possibly caused palpitations was the preparation of frozen sections in which a Freon-22-based aerosol was used to decrease work time. Freon exposures of 300 ppm were measured over a 2-min period for workers engaged in tissue preparation. Four residents experienced palpitations severe enough to prompt electrocardiograms (Speizer et al. 1975). A number of deaths (7 in 1967, 31 in 1968, and 27 in 1969) have been reported among persons "sniffing" Freons intentionally (Reinhardt et al. 1971).

5.1.7.3 Standards and Recommendations

The OSHA PEL for Freon 11 (fluorotrichloromethane) is 1,000 ppm (5600 mg/m^3) as an 8-hr TWA; the OSHA PEL for Freon 12 (dichlorodifluoromethane) is 1,000 ppm (4,950 mg/m^3) as an 8-hr TWA (29 CFR 1910.1000, Table Z-1). The ACGIH TLV's for Freon 11 and Freon 12 are identical to the respective OSHA PEL's (ACGIH 1987). There is no OSHA PEL for Freon 22, but the ACGIH TLV for Freon 22 (chlorodifluoromethane) is 1,000 ppm (3,500 ppm) as an 8-hr TWA (ACGIH 1987). There are no NIOSH REL's for the Freon compounds.

5.1.7.4 Environmental Monitoring

Freon concentrations can be estimated using direct-reading colorimetric detector tubes or determined by charcoal-tube adsorption and gas chromatography analysis.

5.1.7.5 Exposure Control Methods

5.1.7.5.1 Engineering controls

Local exhaust ventilation hoods should be installed to carry Freon vapors away from laboratory workers. Ventilation controls that protect workers adequately from ethylene oxide during sterilizing procedures will also protect them from Freon.

5.1.7.5.2 Protective equipment

Goggles, aprons, and protective gloves (see Section 2.3.5) should be provided to workers exposed to large amounts of Freon such as those encountered in the repair of refrigerant systems. Because Freon does not have adequate warning properties, only approved atmosphere-supplying respirators should be used.

5.1.7.5.3 Work practices

Hand contact should be minimized because of the possibility of sensitization. Workers should be warned against touching their eyes with contaminated hands or gloves for the same reason.

5.1.7.6 Medical Monitoring

A cardiovascular history should be obtained from each worker exposed to Freon because exposure may pose a greater risk to those with cardiovascular problems. Eyes, skin, cardiac symptoms, and electrocardiograms should be monitored periodically for exposed workers.

5.1.8 Mercury

Elemental mercury is a metallic element that is liquid at room temperature.

5.1.8.1 Hazard Location

Mercury is used in many types of hospital equipment and can be found in thermometers, Coulter counters, Van Slyke apparatus, Miller-Abbot and Cantor tubes, and sphygmomanometers (Notani-Sharma 1980). Mercury is also used in dental amalgams. Exposure to mercury in the hospital is usually the result of an accidental spill. The two procedures during which such exposures usually occur are (1) repair of broken sphygmomanometers in central supply or maintenance, and (2) sterilization and centrifugation of thermometers in central supply (Notani-Sharma 1980).

5.1.8.2 Potential Health Effects

Although inhalation is the major route of entry for mercury, the element can also be absorbed through the skin.

Exposure to short-term high levels of mercury can produce severe respiratory irritation, digestive disturbances, and marked renal damage (NIOSH 1973a).

Long-term exposure to low levels of mercury results in the classic mad hatter syndrome (named for the makers of felt hats who used mercury in processing). This syndrome is characterized by emotional instability and irritability, tremors, inflammation of the gums (gingivitis), excessive salivation, anorexia, and weight loss. Mercury has also been reported as a cause of sensitization dermatitis (NIOSH 1973a).

5.1.8.3 Standards and Recommendations

The current OSHA PEL for mercury is 0.1 mg/m^3 as a ceiling value (29 CFR 1910.1000, Table Z-2). The NIOSH REL is 0.05 mg/m^3 as an 8-hr TWA (NIOSH 1973a).

5.1.8.4 Environmental Monitoring

Mercury vapors can be measured with a direct-reading colorimetric dosimeter, diffusion tubes, or mercury vapor analyzer (mercury "sniffer") or with charcoal tubes impregnated with iodine. Particulate contamination can be collected on a filter for subsequent analysis.

If mercury spills are not promptly cleaned up, mercury may accumulate in the carpeting, on floors, and on other surfaces such as porous laboratory sinks and counters. In most cases, workers in these situations were unaware that mercury vaporizes easily at room temperatures.

In one investigation (Harrington 1974), several workers in a quality-control laboratory noticed their jewelry becoming "silvered" with no apparent cause. A source of mercury vapor was found when droplets of mercury were

observed in the sink, on a bench, on the floor, and in the clothing of the lab assistants. The floor was removed, and pools of mercury were discovered. In another laboratory, nearly 7 lb of mercury was discovered beneath the floor (Harrington 1974). A study of 298 dentists reported that 30% of those with urine mercury levels above 20 micrograms/g had polyneuropathies (nervous system symptoms) (Shapiro et al. 1982). Other surveys have found high background levels of mercury in the air of about 10% of the dental offices and elevated mercury levels in the urine and hair of workers in these offices (Shapiro et al. 1982).

5.1.8.5 Exposure Control Methods

5.1.8.5.1 Engineering controls

Emergency engineering procedures for handling mercury contamination should include procedures for cleanup as well as for respirator selection. Exhaust systems should be designed and maintained to prevent the accumulation or recirculation of mercury vapor into the workroom.

5.1.8.5.2 Protective equipment

Disposable protective equipment such as shoe covers, protective gloves (see Section 2.3.5), special mercury vapor respirators (see Section 2.3.5.6), and gowns and hoods should be used while cleaning up mercury spills.

5.1.8.5.3 Work practices

Spills should be cleaned up promptly with special mercury vacuum cleaners, disposable protective equipment, and a water-soluble mercury decontaminant. Mercury wastes must be disposed of according to U.S. Environmental Protection Agency regulations (40 CFR 261.24).

All spill areas should be clearly posted until adequate cleanup has been accomplished. If the spill is extensive, patients and personnel other than the cleanup crew should be removed from the area.

5.1.8.6 Medical Monitoring

Pre-exposure data should be recorded for the respiratory tract, nervous system, kidneys, and skin of any worker who may be exposed to mercury. Urine mercury levels should be monitored periodically in workers who are routinely or accidentally exposed to this element. Although there is no critical level of mercury in urine that indicates mercury poisoning, observers have suggested that 0.1 to 0.5 mg of mercury/liter of urine has clinical significance (NIOSH 1973a).

5.1.9 Methyl Methacrylate

5.1.9.1 Hazard Location

Methyl methacrylate is an acrylic cement-like substance commonly used in operating rooms to secure surgical prostheses to bone (e.g., in total hip replacements). This compound is also used in dental prostheses (NIOSH 1977e). The two components, a liquid and a powder, are mixed immediately before use.

In a study of operating room exposures, concentrations of methyl methacrylate reached 280 ppm immediately after the components were mixed, but fell below 50 ppm within 2 min and to 2 ppm after 6 min (ACGIH 1986). The mixing process usually takes no more than 2 min.

5.1.9.2 Potential Health Effects

5.1.9.2.1 Acute effects

Methyl methacrylate has been reported to have an odor threshold of about 0.08 ppm (Amoore and Hautala 1983). At concentrations in excess of 400 ppm, methyl methacrylate affects the central nervous system (ACGIH 1986). Methyl methacrylate is an eye, skin, and mucous membrane irritant in concentrations at or above 170 to 250 ppm. Patients exposed to this compound have suffered acute episodes of hypotension (low blood pressure) and cardiac arrest (Hyderally and Miller 1976).

5.1.9.2.2 Chronic effects

Methyl methacrylate has been reported to produce degenerative liver changes in experimental animals (NIOSH 1977e). This chemical has also been reported to be mutagenic, but has not been found to be carcinogenic in rats or mice (NTP 1986). Methyl methacrylate has also been reported to be teratogenic (Singh et al. 1972).

5.1.9.3 Standards and Recommendations

The OSHA PEL, as well as the ACGIH TLV, for methyl methacrylate is 100 ppm (410 mg/m^3) as an 8-hr TWA (29 CFR 1910.1000, Table Z-1; ACGIH 1987). NIOSH has not recommended a standard for methyl methacrylate.

5.1.9.4 Environmental Monitoring

Methyl methacrylate is monitored in the environment by sampling with an adsorption tube and analyzing with gas chromatography (NIOSH 1980a).

5.1.9.5 Exposure Control Methods

5.1.9.5.1 Engineering controls

A local exhaust hood should be used to conduct exhaust fumes from the area in which methyl methacrylate is mixed. A tent hood may be used unless mixing can be done in a separately ventilated area. Portable hoods are available for operating room use.

5.1.9.5.2 Protective equipment

Workers who handle methyl methacrylate should wear personal protective equipment and clothing (see Section 2.3.5). This may include gloves, goggles, face shields, and respirators, as appropriate. Portable hoods are available for operating room use.

5.1.9.5.3 Work practices

Workers should be instructed to avoid touching contaminated hands or gloves to their eyes or mouths.

5.1.9.6 Medical Monitoring

Pre-exposure data should be recorded for the skin and respiratory systems of workers who may be exposed to methyl methacrylate. Periodic monitoring thereafter should emphasize the skin and respiratory systems.

5.1.10 Peracetic Acid (PAA)

5.1.10.1 Hazard Location

Peracetic acid (peroxyacetic acid) is used in hospitals to sterilize the surfaces of medical instruments and may be found in laboratories, central supply, and patient care units.

5.1.10.2 Potential Health Effects

Peracetic acid (peroxyacetic acid) is a strong skin, eye, and mucous membrane irritant in both humans and animals. Continued skin exposure may cause liver, kidney, and heart problems. Peracetic acid has been observed to promote wart-like tumors (skin papillomas) in rats (NIOSH 1985). As a result, direct skin contact and exposure to vapors should be restricted.

5.1.10.3 Standards and Recommendations

Currently no standards exist for regulating exposures to peracetic acid, and no recommendations have been made by others such as NIOSH, ACGIH, or ANSI.

5.1.10.4 Exposure Control Methods

Use of an isolation chamber should eliminate major exposure to peracetic acid vapors in hospitals. This chamber should be checked frequently for defects. Peracetic acid should never be used outside this chamber.

5.1.11 Solvents

5.1.11.1 Hazard Location

The generic term "solvent" refers to a large number of chemicals used in medical laboratories. Some are used widely as cleaning agents in housekeeping and maintenance, and some are present in inks and in cleaning agents in print shops.

5.1.11.2 Potential Health Effects

Most solvents can be absorbed through the skin or by inhalation and ingestion.

5.1.11.2.1 Acute effects

Many solvents act as central nervous system depressants, causing headaches, dizziness, weakness, nausea, and other symptoms (NIOSH 1986c). Solvents may also irritate eyes, skin, and the upper respiratory tract. Prolonged contact may result in defatting and dehydration of the skin.

5.1.11.2.2 Chronic effects

Long-term exposure to some solvents has been associated with cancer, adverse reproductive effects, cardiovascular problems, and damage to the liver, kidneys, central nervous system, and hematopoietic system (see Table 5-2) (NIOSH 1974, 1975a, 1977a).

5.1.11.3 Standards and Recommendations

The hospital safety officer should develop an inventory of solvents in use and consult 29 CFR 1910.1000 for the pertinent OSHA PEL. The safety officer

Table 5-2. Health effects and exposure limits for certain solvents

Solvent	Specific effect	OSHA PEL*	NIOSH REL†
Dioxane	Suspected carcinogenic effects, liver and kidney effects	100 ppm (360 mg/m^3) as 8-hr TWA (Skin)	1-ppm (3.6 mg/m^3) ceiling for 30 min
Xylene	Cardiovascular and reproductive effects, central nervous system depressant	100 ppm (435 mg/m^3) as 8-hr TWA	100 ppm (434 mg/m^3) for up to a 10-hr TWA; 200-ppm (868 mg/m^3) ceiling for 10 min
Benzene	Cancer (leukemia) and blood changes, including aplastic anemia	1 ppm as 8-hr TWA; 5-ppm short-term exposure limit (15 min)	0.1 ppm (0.32 mg/m^3) as 8-hr TWA; 1-ppm (3.2 mg/m^3) ceiling for 15 min

*29 CFR 1910.1000, Tables Z-1 and Z-2.
†CDC (1986).

should also consult the NIOSH criteria documents, Current Intelligence Bulletins, and other documents on solvents, which are listed by compound in NIOSH Recommendations for Occupational Safety and Health Standards (CDC 1986).

5.1.11.4 Environmental Monitoring

NIOSH investigations have found high concentrations of solvents, either as TWA's or as peaks during certain processes in medical laboratories (NIOSH 1981f). The effects reported by workers are frequently those of a combination of solvents, each one of which is present at a concentration below the established standard. No regulation exists to cover the additive or synergistic effects of similar chemicals.

Solvents can be collected on adsorbent charcoal for later analysis, or they can be directly measured with colorimetric detector tubes or passive dosimeters. For a more detailed description of sampling procedures for solvents, refer to the Technical Industrial Processes Sourcebook (Wood 1984) and Air Sampling Instruments for Evaluation of Atmospheric Contaminants (ACGIH 1983).

5.1.11.5 Exposure Control Methods

5.1.11.5.1 Substitution

A less hazardous solvent can frequently be substituted for one of those discussed.

5.1.11.5.2 Engineering controls

Local exhaust ventilation and enclosure of solvent vapor sources are the preferred methods for controlling exposures to solvents in laboratories. When selecting engineering and other controls, consideration must be given to not only the toxicity of the solvent, but to its flammability and explosion potential as well.

5.1.11.5.3 Protective equipment

Protective gloves (see Section 2.3.4) help prevent absorption of solvents through the skin. Respirators (see Section 2.3.4.6), rubber aprons, goggles, and boots may be required during certain procedures or during cleanup of spills.

5.1.11.5.4 Work practices

Workers should be thoroughly trained to recognize the symptoms of solvent exposure, to avoid eating in potentially contaminated areas, to work only under exhaust hoods when handling solvents and to follow those work practices recommended for specific solvents.

5.1.11.6 Medical Monitoring

Pre-exposure information should be recorded for workers who will be exposed to solvents and should include baseline and current data on the skin, kidney, liver, and nervous and hematopoietic systems (NIOSH 1986b). Kidney and liver function tests and a complete blood count should be performed.

5.1.12 Waste Anesthetic Gases

The principal source of waste anesthetic gas in the hospital is leakage from anesthetic equipment. Nitrous oxide, enflurane, halothane, and isoflurane are currently the most widely used inhalation anesthetic agents in the United States (NIOSH 1977c, Whitcher 1987b). Methoxyflurane, once in general use, is now used primarily in veterinary procedures (Whitcher 1987b).

5.1.12.1 Hazard Location

In 1977, NIOSH estimated that some 50,000 operating-room personnel (excluding surgeons) were exposed each year to waste anesthetic gases (NIOSH 1977c). Exposures occur in operating rooms; labor, delivery, and recovery rooms; dental operatories; emergency rooms; outpatient clinics; and miscellaneous locations.

Leakage from anesthetic equipment is in most cases associated with the work practices and habits of the anesthesiologists and nurse anesthetists. Incorrect installation and maintenance of scavenging systems is also a major factor.

Exposures may occur in the following ways:

- Gas may escape during hook-up and check-out of the system.
- Excess gas may seep over the lip of the patient's mask.
- The patient may exhale gas into the room.
- Leaks may occur in the anesthetic breathing system.
- Scavenging systems may be misused or not used at all.

The degree of exposure in the operating room depends on the amount of leakage, the adequacy of the ventilation system, and the type of operation being done. Gas leakage occurs primarily when face masks are used for short procedures and a problem exists with the anesthetist's technique or with the patient's facial anatomy (e.g., when the patient has no teeth).

A related problem is the exposure of recovery room personnel to waste gases in the exhaled breath of post-operative patients. Nitrous oxide, halothane, and methoxyflurane have all been found in the exhaled breath of both patients and operating room staff for periods ranging from hours to several days after the administration of the anesthetic (NIOSH 1977c). This phenomenon may pose a significant health hazard to staff in crowded recovery rooms with a high patient turnover rate.

5.1.12.2 Potential Health Effects

5.1.12.2.1 Acute effects

Workers exposed to excessive amounts of anesthetic gases begin to feel like anesthetized patients, experiencing drowsiness, irritability, depression, headache, nausea, fatigue, and problems of judgment and coordination (NIOSH 1977c). These behavioral effects are of particular concern because both the success of the surgery and health of the operating room staff may be compromised.

5.1.12.2.2 Chronic effects

Epidemiologic studies have found increased incidences of embryo toxicity, liver and kidney disease, and cancer among groups of female personnel working in the operating room (Cohen et al. 1975). Some observers have suggested a relationship between exposure to waste anesthetic gases and reports of increased cancer rates and adverse effects on reproduction among exposed workers (NIOSH 1977c).

5.1.12.2.3 Reproductive effects

A 1975 survey (Cohen et al. 1975) indicated an increased risk of spontaneous abortion among female anesthesiologists, nurse-anesthetists, and other staff personnel who worked in operating rooms during their first trimester of pregnancy and the year preceding. An increased risk of congenital abnormalities also existed among the live-born babies of exposed female participants in the survey. Studies have also shown a higher incidence of miscarriage in the wives of male operating-room personnel (Cohen et al. 1975).

5.1.12.3 Standards and Recommendations

NIOSH has recommended exposure limits for the following anesthetic gases (NIOSH 1977c):

Chloroform . . . . . .2 ppm (9.76 mg/m^3) ceiling (1 hr)

Trichloroethylene* . . . .2 ppm (10.75 mg/m^3) ceiling (1 hr)

Halothane. . . . . .2 ppm (16.15 mg/m^3) ceiling (1 hr)

Methoxyflurane . . . . . .2 ppm (13.5 mg/m^3) ceiling (1 hr)

Enflurane. . . . . .2 ppm (15.1 mg/m^3) ceiling (1 hr)

Fluroxene. . . . . .2 ppm (10.31 mg/m^3) ceiling (1 hr)

Nitrous oxide. . . . . 25 ppm (30 mg/m^3) as a TWA over period of use

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*NIOSH recommends that trichloroethylene be regarded as a potential occupational carcinogen (NIOSH 1978b).

When nitrous oxide is used in combination with the halogenated agents described above, control of nitrous oxide to 25 ppm during the administration period will result in concentrations of the halogenated agents of about 0.5 ppm.

5.1.12.4 Environmental Monitoring

The vapors of anesthetic agents such as enflurane, halothane and isoflurane can be monitored with charcoal tubes. Nitrous oxide can be monitored with a direct-reading infrared analyzer or by passive dosimeters.

Records of all collected air samples should be kept, and results should be noted in the medical records of the corresponding workers. Detailed descriptions of sampling procedures for nitrous oxide are available from several sources (Eger 1985; Saidman and Smith 1984; Wood 1984; Whitcher 1987a).

5.1.12.5 Exposure Control Methods

The following documents detail the components of a control program for waste anesthetic gases: Development and Evaluation of Methods for the Elimination of Waste Anesthetic Gases and Vapors in Hospitals (NIOSH 1975b), Criteria for a Recommended Standard: Occupational Exposure to Waste Anesthetic Gases and Vapors (NIOSH 1977c), Controlling Waste Anesthetic Gases (AHA 1980), ANSI Standard for Anesthetic Equipment: Scavenging Systems for Excess Anesthetic Gases (ANSI 1982), Nitrous Oxide, N_2O (Eger 1985), Occupational Exposure to Inhalation Anesthetics: An Update (Whitcher 1987a), and Monitoring Exposure to Inhalation Anesthetics (Saidman and Smith 1984).

5.1.12.5.1 Engineering controls

A scavenging system is the basic engineering control for waste anesthetic gases. Such systems collect waste gas and ventilate it from the operating room. Although some scavenging systems are elaborate and costly, adequate systems can be inexpensive and can dramatically reduce contamination of the operating room environment. A scavenging system should be selected, installed, used, and maintained according to the references listed above in 5.1.12.5.

The equipment must be regularly monitored for leakage, improper design, or tubing defects. In some cases, poor wall connections and compression fittings or other defective equipment may be the sources of leakage.

The 1977 NIOSH document entitled Criteria for a Recommended Standard: Occupational Exposure to Waste Anesthetic Gases and Vapors (NIOSH 1977c) contains information on control procedures and work practices that have been demonstrated to reduce anesthetic gas concentrations to the NIOSH recommended exposure limits. A more thorough discussion of ventilation

systems for anesthetic gases and their disposal can be found in the NFPA Health Care Facilities Handbook (NFPA 1984), which contains the complete text of NFPA 99 (Standard for Health Care Facilities). Stoner et al. (1982) provide a general description of the control of anesthetic gases, including discussions of physiological effects, anesthetic methods, and monitoring techniques.

The International Labour Office proposes three steps to control exposure to waste anesthetic gases (Parmeggiani 1983): (1) installing a proper nonrecirculating air conditioning system with a minimum of 20 room air exchanges per hour; (2) installing a scavenging system for collecting waste gases at the the anesthetic breathing level, and (3) using low-flow rates of anesthetic gases.

5.1.12.5.2 Personal protective equipment

Personal protective equipment is not needed or recommended if an adequate control program is in place. However, monitoring should be done, and personal protective equipment should be available for use in case of an emergency.

5.1.12.5.3 Work practices

Operating-room workers can protect themselves from excess exposure by properly connecting the scavenging equipment, turning the gas off when the breathing system is disconnected from the patient, and ensuring that all patients have properly fitting masks.

5.1.12.5.4 Training programs

Workers involved with waste anesthetic gases should be trained to recognize, understand, monitor, and reduce the health and safety risks of exposure to these substances.

5.1.12.6 Medical Monitoring

Workers exposed to anesthetic gases should have complete medical histories on file. These should include family, genetic, and occupational histories and the outcomes of all pregnancies of female workers or of the wives of male workers. Baseline data should be obtained on the hepatic, renal, and hematopoietic systems. Exposed workers should be monitored periodically for liver and kidney function.