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NIOSH INVESTIGATORS:
William J. Daniels, CIH
Bobby Gunter, PhD, CIH

I. SUMMARY

On October 4, 1988, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate exposures to waste anesthetic gases and vapors, ethylene oxide, and formaldehyde, and organic solvents at St. Thomas More Hospital, Canyon City, Colorado.

In January 1989, NIOSH investigators conducted an environmental survey at the hospital. Personal breathing zone (PBZ) and area air sampling was conducted for nitrous oxide (N_2O) and halogenated anesthetic agents in the two operating rooms (ORs) where general anesthesia was being administered, as well as in the recovery room. PBZ and area air samples were collected for ethylene oxide (EtO) during the operation of a gas sterilizer, for formaldehyde during tissue dumping in the morgue, and for xylene, toluene, acetone, and isopropyl alcohol in the histology laboratory.

Analysis of sixteen air samples collected in the two ORs and the recovery room revealed time-weighted average concentrations (TWA) of N_2O ranging from less than one part per million (ppm) to 85 ppm, with a mean of 20 ppm. Five of these samples exceeded the NIOSH recommended exposure limit (REL) of 25 ppm for N_2O during the period of anesthetic administration. In the eight PBZ samples collected for halogenated anesthetic agents, TWA concentrations of isoflurane ranged from less than (<) the limit of quantitation (LOQ) of 0.01 milligrams (mg) per sample to 0.60 ppm, with a mean of 0.23 ppm, and halothane ranged from < LOQ of 0.03 mg/sample to 0.38 ppm, with a mean of 0.15 ppm. One of these samples exceeded the NIOSH REL of 0.5 ppm for halogenated anesthetic agents used in combination with N_2O. A TWA concentration of 0.58 ppm EtO was found in a short-term PBZ sample collected during the venting of the sterilizer. This was below the OSHA PEL of 5 ppm for a 15 minute ceiling concentration. NIOSH recommends reducing exposure to EtO to the lowest feasible limit (LFL). The results of the PBZ air sample collected for organic solvents revealed the presence of xylene at a TWA concentration of 1.1 ppm, which is below the NIOSH REL, the OSHA PEL, and the ACGIH TLV of 100 ppm as an 8-hour TWA. Acetone was detected, but at a level below the LOQ of 0.02 mg/sample. Toluene and isopropyl alcohol were found to be below their limits of detection of 0.04 and 0.03 mg/sample, respectively. Formaldehyde was found at a TWA concentration of 4.8 ppm in a 63 minute PBZ sample. This concentration is above the OSHA PEL of 2.0 ppm as a 15-minute ceiling. NIOSH recommends reducing exposure to formaldehyde to the LFL.

On the basis of the data obtained during this investigation, it was determined that a potential for overexposure to waste anesthetic gases and vapors and formaldehyde existed at the time of this survey. Recommendations are included in the full body of this report designed to reinforce the hospital's existing program for controlling employee exposures to waste anesthetic gases and vapors and formaldehyde.

Key Words: SIC 8062 (General Medical & Surgical Hospitals) nitrous oxide, halothane, isoflurane, formaldehyde, ethylene oxide, histology

II. INTRODUCTION

On October 12, 1988, NIOSH received a request from St. Thomas More Hospital, Canyon City, Colorado, for a health hazard evaluation. The requestor was concerned with exposures to waste anesthetic gases in the hospital's operating rooms (ORs), ethylene oxide used in gas sterilization, formaldehyde used in the morgue, and organic solvents in the histology laboratory.

On January 30, 1989, NIOSH investigators conducted an initial survey at the hospital. During this survey, background information on the nature of the hospital operations was obtained. On January 31, an environmental survey was conducted during which personal breathing zone (PBZ) and general area air sampling was conducted for nitrous oxide (N_2O), halogenated anesthetic agents, ethylene oxide (EtO), formaldehyde, xylene, toluene, isopropyl alcohol, and acetone. The requestor was notified of the results of the environmental samples by telephone on April 12, 1989.

III. BACKGROUND

The St. Thomas Moore Hospital, Canyon City, Colorado, was constructed in 1968. The hospital houses 81 patient beds in a two-story building with a basement. The surgery department at the hospital consists of two ORs, a cystoscopy room, a recovery room, lounge and change rooms, and an administrative office. Adjacent to the operating rooms is a central supply area. The operating room employs four full-time registered nurses, three full-time surgical technicians, one full-time anesthesiologist and nurse anesthetist, one part-time anesthetist, and one central supply technician. On average, the hospital conducts 90 to 110 surgeries per month, approximately 80% of which may require the administration of general anesthesia. Each anesthetic cart in the ORs is equipped with a vacuum scavenging system. General ventilation to the ORs is supplied by a system that brings in 100% fresh air with no recirculation. Personnel involved in surgical procedures generally include as a minimum, the surgeon(s), an anesthesiologist, a scrub nurse or surgical technician, and a circulating nurse.

A EtO gas sterilizer is located in the adjacent central supply area. One central supply technician is responsible for operation of this system. The sterilizer operates with a three hour gas cycle, after which the central supply technician cracks the door and leaves the room. Following sterilization, the sterilized items are taken to a different floor for aeration. The sterilizer is equipped with local exhaust ventilation and the room also has its own general ventilation system.

The hospital's histology laboratory is located in the basement of the building. Two employees work in this area. During the preparation of tissues, various organic solvents are used. Approximately once per month, tissue specimens which are stored in a formaldehyde solution are required to be dumped in the morgue area. No local exhaust ventilation is used during this procedure.

IV. MATERIALS AND METHODS

On January 31, 1989, NIOSH investigators conducted an environmental survey at St. Thomas More Hospital. The survey was designed to assess employee exposures to N_2O and the halogenated anesthetic agents used during the course of the surgical procedures, EtO during the operation of the gas sterilizer, formaldehyde in the morgue, and xylene, toluene, acetone, and isopropyl alcohol used in the histology laboratory.

A. Waste Anesthetic Gases and Vapors

During the survey of the operating rooms, both PBZ air samples (collected in the vicinity of the employees breathing zone) and general area air samples (collected on the anesthetic cart) were obtained. The samples for N_2O were collected using battery-powered portable sampling pumps operating at approximately 200 cubic centimeters of air per minute (cc/min). The exhaust port of each pump was attached via Tygon tubing to an inert Tedlar bag. Samples were collected for the duration of the surgical procedures, with bags being changed as necessary for the longer procedures. Bags were immediately analyzed at a location outside of the operating room area using an infrared analyzer (Foxboro Miran 103 Specific Vapor Analyzer) in accordance with NIOSH analytical method 6600.[1] Samples were collected in each of the ORs where N_2O use was anticipated. Additional information pertinent to sample collection is provided in Table 1.

In order to assess employee exposures to the halogenated anesthetic agents used during the surgical procedures, personal and area samples were collected at the locations previously described. Sampling pumps were operated at approximately 200 cc/min, and connected via Tygon tubing to charcoal tube collection media. Samples were later analyzed in accordance with NIOSH analytical method 1003, for halothane and isoflurane, using a gas chromatograph equipped with a flame ionization detector.[1] A listing of information pertinent to sample collection is provided in Table 2.

B. Ethylene Oxide (EtO)

In order to assess employee exposures to ethylene oxide, personal samples were collected near the breathing zones of the supply room technician during the operational cycle of the gas sterilizer and the subsequent loading of the aerator. In addition, area samples were collected in the vicinity of the gas sterilizer. Samples were collected using battery-powered sampling pumps operating from 70 to 150 cc/min. The pumps were connected via Tygon tubing to a sorbent tube containing activated charcoal coated with hydrogen bromide. The samples were analyzed in accordance with NIOSH analytical method 1614 for ethylene oxide.[1] A complete listing of information pertinent to sample collection is provided in Table 3.

C. Organic Solvents

A personal sample was also collected in the histology laboratory for xylene and toluene in the manner previously described using a charcoal tube as the collection medium. This sample was desorbed with carbon disulfide and analyzed by gas chromatography using a fused silica capillary column and a flame ionization detector according to NIOSH methods 1400 and 1501 with modifications.[1]

D. Formaldehyde

PBZ and area samples were also collected during the tissue dumping procedure in the morgue. The samples were collected at a flow rate of approximately 80 cc/min using treated sorbent tubes (Supelco ORBO-22). The samples were desorbed with isooctane and analyzed by gas chromatography using a fused silica capillary column and a flame ionization detector for 3-benzyloxazolidine, a formaldehyde derivative which is produced on the tube. The quantity of formaldehyde was then determined according to NIOSH methods 1400 and 1501 with modifications.[1] A listing of information pertinent to the collection of these samples is provided in Table 4.

V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week, for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus, such contact may increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of

Labor/Occupational Safety and Health Administration (OSHA) occupational health standards [Permissible Exposure Limits (PELs)]. Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended exposure limits (RELs), by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is required by the Occupational Safety and Health Act of 1970 (29 USC 651, et seq.) to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits (STELs) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high, short-term exposures. A discussion of the toxicity and evaluation criteria for the substances examined during this survey is provided below.

A. Anesthetic Gases

Reports by Vaisman and Askrog and Harvald were among the first to identify an increased incidence of spontaneous abortion in women exposed to anesthetic gases and in wives of men exposed to anesthetic gases.[2,3] In 1974, the American Society of Anesthesiologists (ASA) published the results of a study indicating "that female members of the operating room-exposed group were subject to increased risks of spontaneous abortion, congenital abnormalities in their children, cancer, and hepatic and renal disease." This report also showed an increased risk of congenital abnormalities in offspring of male operating room personnel. No increase in cancer was found among the exposed males, but an increased incidence of hepatic disease similar to that in females was found.[4]

In a study published by NIOSH in 1976, "N_2O and halothane in concentrations as low as 50 parts per million (ppm) and 1.0 ppm, respectively, caused measurable decrements in performance on psychological tests taken by healthy male graduate students.[5] Nitrous oxide alone caused similar effects. The functions apparently most sensitive to these low concentrations of anesthetics were visual perception, immediate memory, and a combination of perception, cognition, and motor responses required in a task of divided attention to simultaneous visual and auditory stimuli." Headache, fatigue, irritability, and disturbance of sleep were also reported.[6,7]

Mortality and other epidemiologic studies have raised the question of possible carcinogenicity of anesthetic gases, but sufficient data are presently lacking to list N_2O or halothane as suspected carcinogens.

In a study of dentists, Cohen, et al. compared exposed persons who used inhalation anesthetic more than three hours per week with a control group who used no inhalation anesthetic. The exposed group reported a rate of liver disease of 5.9 percent, in comparison with a rate of 2.3 percent in the control group. Spontaneous abortions were reported in 16 percent of pregnancies of the wives of exposed dentists, in comparison with nine percent of the unexposed.[8] This difference was statistically significant; however, it should be noted that the rate of spontaneous abortions for all pregnancies ranges from 10 to 20 percent.[9] This study did not identify the specific anesthetic being used by the dentists surveyed, that is, whether they used N_20 alone or in combination with a halogenated agent.[8] However, in a review of that study, NIOSH concluded that "the halogenated anesthetics alone do not explain the positive findings of the survey and N_20 exposure must be an important contributing factor, if not the principal factor."[10] This conclusion is based on a calculation which assumed that as many as one in ten of the dentists using an inhalation anesthetic employed a halogenated agent. If the actual fraction is less than one in ten, the conclusion has added strength.

In a document recommending a standard for occupational exposure to waste anesthetic gas, NIOSH recommended a maximum exposure of 50 ppm N_2O on a time-weighted average basis during the anesthetic administration in dental offices.[6] This recommendation is based primarily on available technology in reducing waste anesthetic gas levels in these environments.

When N_2O is used as the sole anesthetic agent in medical procedures, NIOSH recommends that occupational exposure be controlled so that no worker is exposed at TWA concentrations greater than 25 ppm during the period of administration. NIOSH recommends that occupational exposure to halogenated anesthetic agents be controlled so that no worker is exposed at concentrations greater than 2 ppm of any halogenated anesthetic agent during the period of anesthetic administration. When used in combination with N_2O, halogenated anesthetic agents should be controlled to 0.5 ppm, which, generally, can be arrived at by controlling N_2O to a TWA concentration of 25 ppm during the period of anesthetic administration.[6] There is presently no OSHA standard for nitrous oxide or the halogenated anesthetic agents. The ACGIH recommends a TLV of 75 ppm for ethrane, and 50 ppm for halothane. In addition, in its "Notice of Intended Changes" for 1989-89, ACGIH proposes a TLV of 50 ppm for nitrous oxide.[11]

B. Ethylene Oxide (Et0)

The acute toxic effects of Et0 in humans and animals include acute skin, respiratory, and eye irritation; skin sensitization; nausea, vomiting, and diarrhea; and nervous system effects. Nonmalignant chronic effects in humans include anemia and respiratory irritation, with susceptibility to secondary respiratory infection. Further, occupational exposure to Et0 may increase the frequency of mutations in human populations as noted in a 1977 NIOSH document.[12] More recently, cases of peripheral neuropathy among exposed workers have been reported.[13]

A recent study demonstrates that EtO induces cancer in experimental animals.[14] A dose-related increase in mononuclear cell leukemia was established in that study; exposures as low as 10 ppm increased the proportion of female rats with leukemia. Also, experiments indicate that Et0 exposure to either male or female animals results in adverse effects on reproduction.[15,16]

In humans, epidemiologic investigations of cancer mortality among Swedish workers exposed to Et0 suggest an increased risk of leukemia and other cancers.[17,18] Recent information also suggests that Et0 is associated with chromosomal abnormalities in peripheral lymphocytes of exposed workers.[19]

Based on this information, NIOSH recommended in a 1981 Current Intelligence Bulletin that Et0 be regarded in the workplace as a potential occupational carcinogen, and that exposure be reduced to the extent possible.[20] An 8-hour TWA below 0.1 parts per million (ppm), and a ceiling limit not to exceed 5 ppm during any 10 minute period in a working day is recommended.[21] The current OSHA standard for Et0 is 1 ppm as an 8-hour TWA, with an action level of 0.5 ppm which triggers employee exposure monitoring and medical surveillance provisions.[22] OSHA has also proposed an excursion limit of 5 ppm over a 15-minute exposure period (53FR1724, January 21, 1988). Due to its high cancer potency in experimental animals, the ACGIH recommends a TLV of 1.0 ppm as an 8-hour TWA.[11]

C. Organic Solvents

Several different organic solvents are routinely used in hospital laboratory settings. Several of these solvents are capable of causing irritation of the eyes, nose, and throat. Effects of direct skin contact with solvents range from dry skin or mild rash to a dry, scaly, fissured dermatitis. These chemicals can also affect the central nervous system (CNS) such that exposed workers may complain of headache, nausea, lightheadedness, dizziness, and uncoordination.

Simultaneous exposure to substances, such as solvents, which affect the body in a similar fashion may have an additive effect. To evaluate these additive effects, the exposure level of each substance is computed as a percentage of the evaluation criterion for that substance. If the sum of these percentages exceeds 100%, the worker is considered to be overexposed to that mixture of substances.
Recent research on the effects of multiple solvent mixtures has focused on behavioral and psychological effects

which may indicate nervous system damage or deviations from normal CNS function.[23] For example, an epidemiologic study was conducted on Finnish car painters exposed to a mixture of toluene, xylene, butyl acetate, and white spirits for a mean duration of 15 years. Average combined exposures were less than 32% of ACGIH TLVs; however, researchers found more memory disturbances, decreased vigilance, and more absent-mindedness among car painters than among railroad engineers. Visual intelligence and verbal memory were the most affected. The authors concluded that car painters, although not ill in the clinical sense, showed clear signs of central and peripheral nervous system lesions more often than members of the comparison group.[24,25]

D. Formaldehyde

Symptoms of exposure to low concentrations of formaldehyde include irritation of the eyes, throat, and nose; headaches; nausea; congestion; asthma; and skin rashes. It is difficult to ascribe specific health effects to specific concentrations of formaldehyde to which people are exposed, because they vary in their subjective responses and complaints. Irritative symptoms may occur in people exposed to formaldehyde at concentrations as low as 0.1 ppm, but more frequently in exposures of 1.0 ppm and greater. Some sensitive children or elderly, those with preexisting allergies or respiratory diseases, and persons who have become sensitized from prior exposure may have symptoms from exposure to concentrations of formaldehyde between 0.05 and 0.10 ppm. Formaldehyde-induced asthma and bronchial hyperreactivity specific to formaldehyde are uncommon.[26]

Formaldehdye vapor has been found to cause a rare form of nasal cancer in Fischer 344 rats exposed to a 15 ppm concentration for 6 hours per day, 5 days per week, for 24 months. Whether these results can be extrapolated to human exposure is the subject of considerable speculation in the scientific literature. Conclusions cannot be drawn with sufficient confidence from published mortality studies of occupationally exposed adults as to whether or not formaldehyde is a carcinogen. Studies of long term human occupational exposure to formaldehyde have not detected an increase in nasal cancer. Nevertheless, the animal results have prompted NIOSH to recommend that formaldehyde be handled as a potential occupational carcinogen and that workplace exposures be reduced to the lowest feasible level.[27] OSHA has recently reduced its permissible exposure limit (PEL) for formaldehdye to 1.0 ppm as an 8-hour TWA, and 2 ppm as a 15-minute ceiling concentration.[28] However, it should be noted that this standard is currently under appeal to lower these concentrations.

VI. RESULTS

A. Waste Anesthetic Gases

1. Nitrous Oxide

The results of the environmental samples collected for N_2O during the surgical procedures are presented in Table 1. During the procedures monitored, TWA concentrations of N_2O ranged from less than (<) the limit of detection (LOD) estimated at 1 part per million (ppm) to 85 ppm, with an average concentration of 20 ppm, in the sixteen PBZ samples collected. Five of the samples exceeded the NIOSH recommended exposure limit (REL) of 25 ppm for N_2O as a TWA during the period of anesthetic administration. These exposures all took place during two separate surgical procedures which involved anesthetic administration by mask. No masks were used during the other procedures monitored.

2. Halogenated Anesthetics

Table 2 shows the results of the environmental samples collected for halogenated anesthetics used during the surgical procedures. During the procedures monitored, TWA concentrations of isoflurane ranged from less than the limit of quantitation (< LOQ) of 0.03 milligrams (mg) per sample to 0.60 ppm, with an average concentration of 0.23 ppm, in the eight PBZ samples collected. One of these samples exceeded the NIOSH REL of 0.5 ppm for halogenated anesthetics used in combination with nitrous oxide. TWA concentrations of halothane ranged from < LOQ of 0.03 milligrams (mg) per sample to 0.38 ppm, with an average concentration of 0.15 ppm, in the eight PBZ samples collected. None of these samples exceeded the NIOSH REL of 0.5 ppm for halothane used in combination with nitrous oxide. The one sample collected which exceeded the REL for isoflurane was collected during the same procedures where the overexposures to N_2O occurred.

B. Ethylene Oxide

The results of the air samples collected for ethylene oxide during the operation of the gas sterilizer are presented in Table 3. Due to a malfunction in the sampling pump, the long-term sample collected for the central supply technician was invalid. The TWA concentration for the short-term PBZ sample collected during the venting of the sterilizer door was 0.58 ppm. This was below the OSHA PEL of 5 ppm as a 15 minute ceiling. NIOSH recommends reducing exposure to EtO to the lowest feasible level. In addition to the personal samples, two area samples were collected to assess the EtO concentrations in the immediate vicinity of the sterilizer. The sample results indicated a TWA concentration of 0.067 ppm on top of the sterilizer, and a TWA concentration of 0.017 ppm on a work table approximately 10 feet from the sterilizer.

C. Organic Solvents

The results of the PBZ air sample collected for organic solvents revealed the presence of xylene at a TWA concentration of 1.1 ppm, which is below the NIOSH REL, the OSHA PEL, and the ACGIH TLV of 100 ppm as an 8-hour TWA. Acetone was detected, but at a level below the LOQ of 0.02 mg/sample. Toluene and isopropyl alcohol were found to be below their limits of detection of 0.04 and 0.03 mg/sample, respectively.

D. Formaldehyde

The results of the air samples collected for formaldehyde during the tissue dumping procedure in the morgue are presented in Table 4. Formaldehyde was found at a TWA concentration of 4.8 ppm in a 63 minute PBZ sample. This concentration is above the OSHA PEL of 2.0 ppm as a 15-minute ceiling. NIOSH recommends reducing exposure to formaldehyde to the lowest feasible limit. Since no additional exposure would have been expected to occur for this employee, the calculated 8-hour TWA exposure would be 0.63 ppm, which is below the OSHA PEL of 1 ppm for an 8-hour TWA. A TWA concentration of 1.8 ppm was found in both general area samples collected in the room during the procedure.

VII. DISCUSSION AND CONCLUSIONS

A. Waste Anesthetic Gases and Vapors

As evidenced by the results of the environmental survey, concentrations of waste anesthetic gases and vapors were found to be above the NIOSH recommended exposure limits in two of the procedures monitored. Both procedures during which the overexposures occurred involved the used of patient masking for some portion of the anesthesia administration. It is probable that the fitting of the masks with the patient's face was such that substantial leakage of the anesthetic gases occurred. However, since several different factors can influence personnel exposures, it is necessary to regularly examine all areas of exposure control to identify any shortcomings. To assist in the identification of problems, a brief discussion of some of the key areas necessary for controlling employee exposures is presented below.

1. Equipment Maintenance

Of primary importance in maintaining waste anesthetic concentrations within acceptable levels is the regular maintenance of anesthetic equipment in order to prevent leakage. Recent data indicate that leaks from the high and low pressure anesthetic delivery system resulting from poor maintenance of the anesthetic unit are a primary source of employee exposures in the OR.[29] Background N_2O levels of 5 ppm and greater generally have been

associated with leaks in the high pressure gas delivery system, which includes the N_2O supply lines, the connections at and between the ceiling and anesthesia machine, and the connector-control valve from the flowmeter.[30] During anesthetic administration, low pressure leaks occurring between the flowmeters and breathing hoses (including the flowmeter, vaporizer, reservoir bag, popoff valve, endotrachial tube, automatic ventilator, and CO_2 absorber) can be a significant source of exposure.

2. Scavenging

Scavenging systems consist of a collecting device, means of disposal, and pressure balancing device if necessary. Depending on the particular type of anesthetic equipment in use, scavenging adapters should be located at the popoff valve for the circle absorber, nonbreathing valve, T-tube, and ventilator. In addition, scavenging may also be necessary at locations such as the exit port of the CO_2 meter, which may also be a source of waste anesthetic gases in the OR. As with all scavenging systems, it is important to ensure proper pressure balancing so that the gas system does not interfere with the proper operation of the anesthetic delivery system.

3. General Ventilation

While local exhaust ventilation (such as scavenging) is the preferred means of eliminating waste gases at their point of generation, general room ventilation also plays an important role in maintaining acceptable waste gas levels in the OR. Reasons for maintaining good general ventilation exchange rates include the rapid removal of waste gasses generated as a result of anesthesia induction, poorly fitting face masks, improperly inflated endotrachial tubes, and low or high pressure leaks which may occasionally develop in the system. While increasing the number of air changes does not eliminate the source of the anesthetic gases, it does lead to more effective removal of the waste gases and vapors, thereby reducing the magnitude of employee exposures. As a minimum, operating rooms should be provided with at least 20 air changes per hour.[31]

Although no exposures above the NIOSH REL were found in the recovery room during this survey, it is still important to ensure that adequate amounts of fresh air are being brought into this area. Since scavenging systems are not present in recovery rooms, general ventilation is the sole means of removing the waste gases expired by the patient. As a minimum, recovery rooms should be provided with at least 6 air changes per hour.[31]

4. Work Practices

Proper work practices are also a key element in controlling waste anesthetic gas exposures. One study estimated that 94 to 99 percent of all waste gas exposure in ORs equipped with properly designed scavenging components may be the result of poor work practices of the anesthetist.[30] Improper work practices include the use of poorly fitting face masks, insufficient inflation of endotrachial tubes, and spillage of volatile anesthetic agents while filling vaporizers. Despite constant attention to good anesthetic techniques, it is not always possible for the anesthesiologist to be aware of possible leakage from these sources. Therefore, it is important that the general ventilation be adequate to remove any waste anesthetics that might result from this source.

5. Exposure Monitoring

To determine the effectiveness of the overall exposure control program within the hospital, it is necessary to periodically monitor employee exposures as well as monitoring equipment for leakage. Sampling and analytical procedures, such as those provided in the NIOSH criteria document should be referenced for further guidance in the conduct of personal monitoring.[6]

B. Ethylene Oxide

Due to the malfunction of a sampling pump, the 8-hour TWA exposure for the central supply technician could not be determined. However, the short-term sample did indicate an exposure of 0.58 ppm during the 15-minute period involving cracking of the sterilizer door. The results of the area samples also indicated the presence of ethylene oxide near the sterilizer and in adjacent work areas. Due to the potential carcinogenicity of EtO, NIOSH recommends reducing exposure to the lowest feasible level. At the time of the survey, the hospital indicated that a new enclosed EtO sterilization room was to be constructed which would house a new combination EtO sterilizer/aerator. If properly designed and constructed, this should help to further reduce EtO exposures in the central supply area.

C. Organic Solvent Exposure

Exposures to organic solvents in the histology laboratory were found to be well within the evaluation criteria. However, since laboratory workers are potentially exposed to a number of substances on a day to day basis, it is important that a comprehensive laboratory safety program be kept in place in order to minimize exposures to all types of substances. Such a program should include an overall written plan that includes standard safe laboratory practices to be carried out

whenever working in the laboratory. The procedures developed for the use of chemicals such as these should include information on the appropriate engineering controls (e.g., fume hoods), personal protective equipment (e.g., respirator, gloves), and work practices to be used as needed.

D. Formaldehyde

As evidenced by the environmental data, concentrations of formaldehyde were above the environmental criteria. Although this procedure is only carried out approximately once per month, the potential carcinogenicity of this substance would indicate a need for further steps to be taken to control exposure to the lowest feasible level. During the survey, and again following receipt of the environmental results, recommendations were made to install local exhaust ventilation in the area where this procedure is conducted. The hospital management indicated that such a system would be installed.

VIII. RECOMMENDATIONS

A. Waste Anesthetic Gases and Vapors

The previous section of this report identified a number of areas that should be examined to continue to ensure that waste anesthetic gases are properly controlled in the ORs. More detailed recommendations regarding specific control procedures, work practices, and monitoring procedures are included in the NIOSH criteria for a recommended standard....occupational exposure to waste anesthetic gases and vapors.[6] In order to effectively control employee exposures in the operating room, a comprehensive program which addresses all of these areas is necessary. Due to the length of these recommendations they are not repeated in this section. In lieu of this, copies of this document have been provided separately to the hospital. Adherence to the recommendations specified in this document should help to maintain exposures within acceptable levels and protect the health of the employees in this area.

B. Ethylene Oxide

Following installation of the new gas sterilizer unit, the hospital should conduct environmental monitoring to ensure that exposures are maintained as low as possible. Continued adherence to the provisions of the OSHA standard for ethylene oxide should help to ensure that employee exposures are maintained within safe levels.[22]

C. Histology Laboratory

While no overexposures to organic solvents were found in the histology laboratory, the Occupational Safety and Health

Administration has proposed a laboratory safety standard which would require laboratories to develop a "Chemical Hygiene Plan" for laboratories.[32] While this is presently only a proposal, the concepts presented in its text would be of value in strengthening the current laboratory safety program. Another resource, which might also prove useful, is the publication entitled Prudent Practices for Handling Hazardous Chemicals in Laboratories, by the Committee on Hazardous Substances in the Laboratory/National Research Council.[33] This document helps form the basis for, and is cited frequently in, the OSHA proposed lab standard. A systematic implementation of the key concepts provided in these documents should help to continue to further reduce the risk of exposure to organic solvents and other materials used in the histology lab.

D. Formaldehyde

Local exhaust ventilation should be installed at the operation where the formaldehyde is dumped to help reduce exposure to this substance to the lowest feasible level. The particular type of ventilation used would depend on the location where the operation is to be placed. However, the system should enclose the process as much as possible and maintain sufficient capture velocity to keep the formaldehyde from entering the work atmosphere. A complete discussion of specific details regarding ventilation system design, construction, and operation is contained in the ACGIH Industrial Ventilation, A Manual of Recommended Practice.[34]

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X. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared By:	William J. Daniels, CIH, CSP Industrial Hygienist NIOSH - Region VIII Denver, Colorado
Environmental Evaluation Assistance:	Bobby Gunter, PhD., CIH Regional Consultant NIOSH - Region VIII Denver, Colorado
Originating Office:	Division of Surveillance, Hazard Evaluations & Field Studies Hazard Evaluation and Technical Assistance Branch Cincinnati, Ohio
Laboratory Analysis:	Utah Biomedical Test Laboratory Salt Lake City, Utah
	Measurement Support Branch DPSE/NIOSH Cincinnati, Ohio

IX. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Services (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from the NIOSH publications office at the Cincinnati, address. Copies of this report have been sent to:

A. St. Thomas More Hospital, Canyon City, Colorado
B. U. S. Department of Labor, OSHA - Region VIII
C. NIOSH Regional Offices/Divisions

For the purposes of informing the affected employees, copies of the report should be posted in a prominent place accessible to the employees, for a period of 30 calendar days.

Table 1
Breathing Zone Air Concentrations of Nitrous Oxide
Saint Thomas Moore Hospital, Canyon City, Colorado
January 31, 1989

LOCATION (OR No.)	SAMPLE DESCRIPTION	SAMPLING PERIOD	TWA CONCENTRATION NITROUS OXIDE (PPM)
2	Circulating Nurse	7:49 - 8:45	85
2	Scrub Nurse	7:51 - 8:45	70
2	Anesthesiologist*	8:15 - 9:00	35
1	Circulating Nurse	7:58 - 9:10	15
1	Anesthesiologist*	8:10 - 9:15	5
1	Circulating Nurse	9:10 - 10:20	2
1	Anesthesiologist*	9:15 - 10:30	5
1	Scrub Nurse	9:12 - 10:25	5
2	Circulating Nurse	10:02 - 11:31	35
2	Anesthesiologist*	10:30 - 11:40	45
1	Scrub Nurse	10:50 - 13:02	7
1	Circulating Nurse	12:00 - 13:10	5
1	Anesthesiologist*	12:00 - 13:10	5
Recovery	Recovery Room Nurse	7:47 - 8:50	< LOD
Recovery	Recovery Room Nurse	8:50 - 10:40	5
Recovery	Recovery Room Nurse	10:40 - 1:00	< LOD

Evaluation Criterion - NIOSH REL: 25 ppm TWA for the period of administration
Abbreviations and Key
ppm - parts of contaminant per million parts of air
* These samples were collected on the anesthetic cart to approximate the breathing zone concentration of the anesthesiologist
< LOD - Less than the limit of detection estimated at 1 part per million (ppm)

Table 2
Concentrations of Isoflurane and Halothane
Saint Thomas Moore Hospital, Canyon City, Colorado
January 31, 1989

LOCATION (OR No.)	SAMPLE DESCRIPTION	SAMPLING PERIOD	TWA CONCENTRATION (ppm) ISOFLURANE	HALOTHANE
1	Scrub Nurse	7:47 - 12:02	< LOQ (0.05)	< LOQ (0.03)
2	Circulating Nurse	7:49 - 13:05	0.40	0.35
1 & 2	Scrub Nurse	7:51 - 13:08	0.17	0.38
1 & 2	Scrub Nurse	7:54 - 12:37	0.38	0.11
1	Circulating Nurse	8:09 - 13:10	< LOQ (0.06)	< LOQ (0.02)
1	Anesthetic Cart	8:10 - 13:10	< LOQ (0.07)	< LOQ (0.02)
2	Anesthetic Cart	8:15 - 11:31	0.60	0.28
Recovery	Recovery Nurse	8:32 - 13:19	0.10	< LOQ (0.02)
Evaluation Criteria - NIOSH REL:			0.5	0.5

Abbreviations
ppm - parts of contaminant per million parts of air
TWA - Time-weighted average
< LOQ - Contaminant was detected on the sample at a level less than the laboratory limit of quantitation of 0.03 mg/sample. The numbers appearing in ( ) should only be considered estimates of the actual concentration.

Table 3
Breathing Zone and General Room Air Concentrations of Ethylene Oxide
Saint Thomas Moore Hospital, Canyon City, Colorado
January 31, 1989

SAMPLE TYPE	SAMPLE DESCRIPTION	SAMPLE TIME (Minutes)	SAMPLE VOLUME (Liters)	TWA CONCENTRATION* ETHYLENE OXIDE (PPM)
Personal	Sterilizer Operator	229	SI**	SI**
Area	Work Table 8-10 ft. away	229	22.2	0.017
Area	On top of Sterilizer	229	22.2	0.067
Personal	Door Cracking Sterilizer Operator	15	2.8	0.58

Evaluation Criteria - Ethylene Oxide
NIOSH REL: Lowest Feasible Level (< 0.1 ppm 8-hr TWA, 5 ppm 10 min ceiling)
OSHA PEL: 1 ppm 8-hr TWA, Action Level of 0.5 ppm 8-hr TWA
ACGIH TLV: 1 ppm 8-hr TWA

* - Time-weighted average concentrations are calculated for the sampling time.
** - Sample invalid due to sampling pump malfunction

Table 4
Breathing Zone and General Room Air Concentrations of Formaldehyde
Saint Thomas Moore Hospital, Canyon City, Colorado
January 31, 1989

SAMPLE TYPE	SAMPLE DESCRIPTION	SAMPLE TIME (Minutes)	SAMPLE VOLUME (Liters)	TWA CONCENTRATION* FORMALDEHYDE (PPM)
Personal	Histologist	63	4.9	4.8
Area	Lab Bench	70	5.6	1.8
Area	Lab Table	70	5.2	1.8

Evaluation Criteria - Formaldehyde
NIOSH REL: Lowest Feasible Level (0.1 ppm 8-hr TWA, 5 ppm 10-min ceiling)
OSHA PEL: 1 ppm 8-hr TWA, 5 ppm 15-min ceiling, Action Level 0.5 ppm 8-hr TWA
ACGIH TLV: 1 ppm 8-hr TWA, STEL 2 ppm

* - Time-weighted average concentrations are calculated for the sampling time.