HETA 87-243, 292-1876
FEBRUARY 1988
SANTA BARBARA COTTAGE HOSPITAL
SANTA BARBARA, CALIFORNIA

NIOSH INVESTIGATORS:
William Daniels, CIH
Bobby Gunter, PhD., CIH
Stan Salisbury, CIH

I. SUMMARY

On April 15, 1987, the National Institute for Occupational Safety and Health (NIOSH) was requested to evaluate exposures to waste anesthetic gases and vapors in the Outpatient Surgery Center and the main operating rooms of the Santa Barbara Cottage Hospital, Santa Barbara, California. A subsequent request was received on May 19, 1987 to evaluate exposures to ethylene oxide from a gas sterilizer used in the hospital.

In May 1987, NIOSH investigators conducted an environmental survey at the hospital. During this survey, personal and area air samples were collected for nitrous oxide (N_2O), halogenated anesthetic agents, and methyl methacrylate. Leak testing on anesthetic equipment was conducted, and general ventilation measurements were taken. Personal and area air samples for ethylene oxide (EtO) were collected during operation of the gas sterilizer.

Time-weighted average (TWA) concentrations of N_2O ranged from less than (<) the limit of detection (LOD) of 1 part per million (ppm) to 50 ppm in the 32 personnel and area samples collected. Only two samples exceeded the NIOSH recommended exposure limit (REL) of 25 ppm for N_2O as a TWA during the period of anesthetic administration. TWA concentrations of forane ranged from < LOD of 0.01 milligrams (mg) per sample to 1.68 ppm in the 34 personal and area air samples collected. Eight of these samples (six of which were from one operating room in the Outpatient Surgery Center) exceeded the NIOSH REL of 0.5 ppm for halogenated anesthetics used in combination with nitrous oxide. No ethrane or halothane were detected above the limit of quantitation (LOQ) of 0.03 mg/sample. TWA concentrations of 0.12 and 0.17 ppm methyl methacrylate were found in two personal samples collected during the use of a surgical cement. Both samples were below the Occupational Safety and Health Administrations (OSHA) Permissible Exposure Limit (PEL) of 100 ppm as an 8-hour TWA.

An 8-hour TWA concentration of 0.009 ppm EtO was found in a long-term personal sample, and a concentration of 0.4 ppm was found in a short-term personal sample during sterilizer operation. These results are below the NIOSH REL's of < 0.1 ppm 8-hour TWA, and 5 ppm 10-minute ceiling, and the OSHA PEL of 1 ppm as an 8-hour TWA.

As evidenced by the results of the environmental survey, concentrations of waste anesthetic gases and vapors were generally maintained within the NIOSH recommended exposure limits in the majority of the procedures monitored. The only consistent exception was OR 1 in the Outpatient Surgery Center where concentrations of forane exceeded the NIOSH REL in both of the procedures monitored. This OR also was noted to have

approximately half of the recommended number of air changes per hour for its general ventilation system. While it is possible that the lack of general ventilation may have played an important role in allowing the buildup of waste anesthetic vapors, other factors such as leakage from anesthetic cart fittings and components, and work practices, may also have contributed to the exposures. Since the exact magnitude which these and other factors may have influenced employee exposures can not be accurately determined, it is necessary that all areas of exposure control be regularly examined to identify where improvements can be made.

Although contaminant concentrations were maintained below the environmental criteria in the majority of the samples collected, a potential for overexposure to nitrous oxide and forane existed in a few instances. Recommendations are included in the full body of this report designed to strengthen the hospital's existing program for controlling employee exposures to waste anesthetic gases and vapors and ethylene oxide.

Key Words: SIC 8062 (General Medical & Surgical Hospitals) nitrous oxide, isoflurane, ethrane, halothane, waste anesthetics, scavenging ethylene oxide, sterilization, methyl methacrylate

II. INTRODUCTION

On April 15, 1987, NIOSH received a request from the Santa Barbara Cottage Hospital, Santa Barbara, California, for a health hazard evaluation. The requestor was concerned with possible exposure to waste anesthetic gases and vapors in the hospital's main operating rooms and Outpatient Surgery Center. A subsequent request was received from the hospital on May 19, 1987, to evaluate exposures to ethylene oxide resulting from the use of a gas sterilizer.

On May 19 through 22, NIOSH investigators conducted an environmental survey at the hospital. During this survey, background information on the nature of the hospital operations was obtained, and personal and area air sampling was conducted for nitrous oxide (N_2O), halogenated anesthetic agents, and methyl methacrylate. In addition, personal and area air samples for ethylene oxide (EtO) were collected in the hospital's Central Supply Department during operation of a gas sterilizer. The results of these surveys were provided to the requestor by letter in November 1987.

III. BACKGROUND

Santa Barbara Cottage Hospital, located in Santa Barbara, California, provides a variety of health care services, including inpatient and outpatient surgical services. The Surgery Department is located on the hospital's second floor, and consists of ten operating rooms, a recovery room, and miscellaneous storage and supply rooms. Adjacent to the main hospital structure is the Outpatient Surgery Center, which has two operating rooms and a recovery room. This center is designed to provide service to those individuals whose surgery does not require overnight stays.

The personnel involved in surgical procedures generally include a surgeon, an anesthesiologist, a scrub nurse, and a circulating nurse. Often, additional personnel may be involved, depending on the complexity of the procedure. Each anesthesiologist has an anesthetic cart which is moved into the room where they will be working that day. The rooms contain vacuum connections for attachment to the scavenging system of the anesthetic carts. General ventilation is also supplied through vents located near the ceilings of each OR.

A gas sterilizer, which uses ethylene oxide, is located in the hospital's Central Supply Department. The sterilizer is recessed into a mechanical access room. This room is equipped with exhaust vents and kept under a negative pressure with respect to the main supply room area. The gas sterilizer also is equipped with local exhaust ventilation and has a large exhaust hood which is located directly above the sterilizer. At the completion of the gas sterilization cycle, the sterilizer door is cracked for fifteen minutes, during which time the personnel leave the immediate area. Following this interval, the sterilized equipment is transferred to the aeration chamber. Two employees worked in the sterilizer area at the time of the survey.

IV. MATERIALS AND METHODS

NIOSH investigators conducted an environmental survey on May 19, 1987, in the Outpatient Surgery Center, and on May 20 and 21, 1987, in the hospitals main operating rooms. The survey was designed to assess employee

exposures to N_2O and the halogenated anesthetic agents used during the course of the surgical procedures, as well as to identify potential sources of waste anesthetic gas exposure through leak detection using direct reading instrumentation. In addition to the evaluation of the waste anesthetic gases, personal and area samples were collected for methyl methacrylate, a component of an adhesive material used during bone surgery.

Air samples collected for the assessment of employee exposures in the operating rooms included both personal (collected in the vicinity of the employees breathing zone) and area (collected on the anesthetic cart in order to estimate the anesthesiologists' exposure) air samples. 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 OR's in which the use of N_2O was anticipated. Additional information pertinent to sample collection is provided in Tables 1, 3, and 4.

In order to assess employee exposures to the halogenated anesthetics 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 ethrane, 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 Tables 2, 5, and 6.

Samples for methyl methacrylate also were collected in the manner previously described using charcoal tubes as the collection media. These samples were desorbed with carbon disulfide and analyzed by gas chromatography using a fused silica capillary column and a flame ionization detector. A listing of information pertinent to the collection of these samples is provided in Table 7.

Where possible, leak detection for N_2O was conducted in the ORs. High pressure hose connections were checked at the wall and anesthetic cart. Low pressure connections were checked by measurements taken directly at the various anesthetic cart and scavenging system components during anesthetic gas administration. These measurements were made using a flexible sampling probe attached to the portable infrared analyzer.

In addition to the collection of environmental samples, ventilation measurements were taken in the OR's and recovery room in the Outpatient Surgery Center using a Flow Hood (Shortridge Instruments). Calculations of the number of air changes per hour (ACH) were made in order to determine the adequacy of the general ventilation system in the OR's. Due to the location of the air supply vents in the main OR's, accurate readings to permit the calculation of the number of ACH for these rooms could not be obtained.

In order to assess employee exposures to the ethylene oxide, personal samples were collected near the breathing zones of the two central supply technicians 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, aerator, and in the mechanical access room, in order to identify areas where leakage from the system might occur. Samples were collected using

battery-powered sampling pumps operating at 100 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 8.

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, potentially 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 (TLV's), and 3) the U.S. Department of Labor/Occupational Safety and Health Administration (OSHA) occupational health standards [Permissible Exposure Limits (PEL's)]. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's 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 (REL's), 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 (STEL's) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high, short-term exposures.

A brief discussion of the toxicity and evaluation criteria for the substances evaluated during this survey is provided as follows.

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 the female was found.[4]

In a study published by NIOSH in 1976, "N_2O and halothane in respective concentrations as low as 50 parts per million (ppm) and 1.0 ppm 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. 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.[8] 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.[9] 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. However, in it's "Notice of Intended Changes" for 1986-87, ACGIH has proposed TLV's of 75 ppm for ethrane, and 50 ppm for halothane.[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 Criteria 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 the 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] 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. Methyl Methacrylate

Short-term overexposures to methyl methacrylate may cause irritation of the nose, throat, skin, and eyes. At very high levels it can cause drowsiness, and possible unconsciousness. Long-term exposure to the substance may cause a skin rash.[23] The current OSHA standard and ACGIH TLV for for methyl methacrylate are 100 ppm as an 8-hour TWA.[11,23] The vapor of methyl methacrylate can be detected by the nose at levels far below the standard, with the odor threshold reported to be approximately 0.21 ppm.[23]

VI. RESULTS

A. Outpatient Surgery Center

1. Nitrous Oxide

The results of the environmental samples collected for N_2O during the surgical procedures conducted in the Outpatient Surgery Center are presented in Table 1. During the two procedures conducted in OR 1 during which N_2O was used, TWA concentrations ranged from 3 to 15 ppm N_2O, with a mean of 7.5 ppm. TWA concentrations of N_2O in two personal samples collected on recovery room nurses attending to the patients following these procedures were 10 and 50 ppm. One of these samples exceeded the NIOSH REL of 25 ppm for N_2O. No N_2O was used in OR 2 during the survey period.

2. Halogenated Anesthetic Gases

Table 2 shows the results of the environmental samples collected for halogenated anesthetics used during the surgical procedures. In the two surgical procedures monitored in OR 1, TWA concentrations of forane were found to range from below the limit of detection of 0.01 milligram (mg)/sample to 1.68 ppm, with a mean of 1.22 ppm. In the two procedures monitored in OR2, forane was detected in only one of six samples at a TWA concentration of 0.39 ppm. Of three samples collected on recovery room personnel, forane was detected in only one sample at a TWA concentration of 1.17 ppm. This sample from the recovery room, as well as all six samples collected in OR1, exceeded the NIOSH REL 0.5 ppm for halogenated anesthetic agents when used in combination with N_2O. Ethrane and halothane were not found above the limit of quantitation of 0.03 mg/sample in any of the samples collected.

3. Leak Testing

Prior to the surgical procedures, both ORs were checked for N_2O leakage from the high pressure gas supply lines. Leakage of approximately 200 ppm N_2O was found at the point of the ceiling connection in OR 1, and leakage in excess of 250 ppm (full scale deflection) was found at the point of the wall connections in both ORs 1 and 2. Following the procedures, maintenance employees placed teflon tape on the fitting threads and tightened them. Subsequent testing did not reveal detectable concentrations of N_2O.

Low pressure leak testing was also conducted during a surgical procedure being performed in OR 1. Concentrations of N_2O ranged from non-detectable to 7 ppm at locations throughout the breathing circuit and scavenging connections.

4. General Ventilation

The results of the general ventilation measurements which were taken in the Outpatient Surgery Center were as follows; 10 air changes per hour (ACH) in OR 1, 12 ACH in OR 2, and 7 ACH in the Recovery Room. While there are no NIOSH criteria for general ventilation, the Department of Health and Human Services "Guidelines for Construction and Equipment of Hospital and Medical Facilities" currently recommends a minimum of 20 total ACH for operating rooms, and 6 ACH for Recovery Rooms.[24]

B. Main Operating Rooms

1. Nitrous Oxide

The results of the environmental samples collected for N_2O during the surgical procedures conducted in the main ORs are presented in Tables 3 and 4. Cumulative TWA concentrations of N_2O in twenty samples collected in six different operating rooms ranged from below the limit of detection of 1 ppm to 32 ppm, with a mean of 6 ppm. Only one of these samples (32 ppm in OR 6) exceeded the NIOSH REL of 25 ppm for N_2O. TWA concentrations of N_2O in three personal samples collected on recovery room personnel ranged from 1 to 23 ppm, with a mean of 13 ppm. Additional samples collected for an operating room attendant and a supply room technician were both below the limit of detection.

2. Halogenated Anesthetic Gases

Tables 5 and 6 show the results of the environmental samples collected for the halogenated anesthetics used during the surgical procedures. Of 17 samples collected in eight different OR's, forane was detected in eight samples at TWA concentrations ranging from 0.15 to 0.78 ppm, with a mean of 0.29 ppm. Only one sample (0.78 ppm in OR 4) exceeded the NIOSH REL 0.5 ppm for halogenated anesthetic agents when used in combination with N_2O. In addition, no forane was detected in samples collected for the supply room technician and OR attendant. Ethrane and halothane were not found above the limit of quantitation of 0.03 mg/sample in any of the samples collected.

3. Methyl Methacrylate

The results of the environmental samples collected for methyl methacrylate are presented in Table 7. A TWA of 0.12 ppm was found in the personal sample collected for the scrub nurse, and a TWA of 0.17 ppm was found in the area sample collected inside the enclosure tent where the procedure was taking place. Both of these concentrations are below the OSHA PEL and ACGIH TLV of 100 ppm as an 8-hour TWA.

4. Leak Testing

Due to the large number of personal samples being collected and analyzed, only a limited amount of leak testing was conducted in the main ORs. In OR 4, leak testing of high pressure connections revealed 100 ppm N_2O at the gas supply connection. During leak testing on the anesthetic cart, a concentration in excess of 250 ppm was detected directly above the scavenger bypass valve. In leak testing performed in OR 3, N_2O concentrations in excess of 250 ppm were found at the point where a hose attached to the ventilator and at the exhaust port of an unscavenged CO_2 monitor. A concentration of 50 ppm N_2O was detected directly above the popoff valve.

5. General Ventilation

As previously discussed, due to the location of the supply vents in the main ORs, accurate measurements of the air supply to these ORs could not be made with the available equipment.

C. Gas Sterilizer Area

The results of the air samples collected for ethylene oxide during the operation of the gas sterilizer are presented in Table 8. Of the two personal samples which were collected for a 145-minute period during the operation of the gas sterilizer, one sample was below the limit of quantitation of 0.6 micrograms, while the second sample showed a TWA concentration of 0.03 ppm. Assuming no additional exposure to EtO during the work-shift, the 8-hour TWA

exposure for this employee would be 0.009 ppm. This would be below the NIOSH REL of 0.1 ppm as an 8-hour TWA, and the OSHA PEL and ACGIH TLV of 1 ppm as an 8-hour TWA. A concentration of 0.4 ppm was found in a short-term personal sample collected while an employee was unloading the gas sterilizer. This concentration is below the NIOSH REL of 5 ppm as a 10 minute ceiling. In addition to the personal samples, two area samples were collected to assess the EtO concentrations in the immediate vicinity of the sterilizer. A sample collected above the sterilizer drain in the access room showed a TWA concentration of 1.6 ppm, while no EtO was detected in a sample collected directly above the sterilizer door.

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 generally maintained within the NIOSH recommended exposure limits in the majority of the procedures monitored. The only consistent exception was OR 1 in the Outpatient Surgery Center where concentrations of forane exceeded the NIOSH REL in both of the procedures monitored. This OR also was noted to have approximately half of the recommended number of air changes per hour for its general ventilation system. While it is possible that the lack of general ventilation may have played an important role in allowing the buildup of waste anesthetic vapors, other factors such as leakage from anesthetic cart fittings and components, and work practices, may also have contributed to the exposures. Since the exact magnitude which these and other factors may have influenced employee exposures can not be accurately determined, it is necessary that all areas of exposure control be regularly examined to identify where improvements can be made. 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 indicates that leaks from the high and low pressure anesthetic delivery system resulting from poor maintenance of the anesthetic unit is a primary source of employee exposures in the OR.[25] 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.[25] 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.

During this survey, leakage from high pressure N_2O hose connections was found in both the Outpatient Surgery Center and main hospital OR's. Immediate steps were taken by the hospital maintenance staff to correct the leaks by applying a teflon tape to the connection threads and re-tightening the connectors. Subsequent testing showed that the leakage was eliminated by these corrective actions.

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, non-breathing valve, T-tube, and ventilator. In addition, as noted in the survey, scavenging may also be necessary at locations such as the exit port of the CO_2 meter, which was also shown to 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 gasses 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, or low or high pressure leaks which may occasionally develop in the system. During the survey, the highest concentrations of forane were found in an OR which had only one-half of the recommended number of air changes per hour. While increasing the number of air changes would not eliminate the source of the anesthetic gases, it would lead to the more effective removal of the waste gases and vapors, thereby reducing the magnitude of employee exposures.

During the survey, the highest concentration of nitrous oxide was found in a personal sample collected for a recovery room nurse. This illustrates the need for good general ventilation in these areas. Since scavenging systems are not present in recovery rooms, general ventilation is solely relied on to remove the waste gases expired by the patient. As a minimum, OR's should be supplied with at least 20 total air changes per hour, and recovery rooms with at least 6 air changes per hour.[24]

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 OR's equipped with properly designed scavenging components may be the result of poor work practices of the anesthetist.[26] 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.

In general, the anesthesiologists appeared very aware of the hazards of waste anesthetic gasses and vapors, and took appropriate actions to control them. During the survey, one anesthesiologists expressed a concern over the difficulty in filling a certain type of vaporizer with the halogenated anesthetic agents. Due to the design of the anesthetic container, filling the vaporizer without some spillage was difficult. In order to minimize exposures in situations such as this, vaporizers should be filled either prior to or following the scheduled procedures, when the room is not occupied.

5. Exposure Monitoring

In order to determine the effectiveness of the overall exposure control program within the hospital, it is necessary to periodically monitor employee exposures as well as monitor equipment for leakage. This could be easily accomplished since the hospital had available a direct reading infrared spectrophotometer similar to the one used by the NIOSH investigators. It was however noted, that although this instrument had undergone recent calibration, it was not functioning properly. Subsequent investigation indicated that a damaged filter was responsible for the malfunction. It was recommended at the time of the survey that the hospital obtain a calibration loop to permit them to accurately check the calibration of the instrument, thereby validating the monitoring data which they might collect. Sampling and analytical procedures, such as those provided in NIOSH method 6600, should be referenced for further guidance.[1]

B. Methyl Methacrylate

As evidenced by the results of the environmental samples, the concentrations of methyl methacrylate from the surgical adhesive were well below the evaluation criteria. In order to minimize possible irritant effects from brief exposure periods during adhesive mixing and application, sufficient amounts of general ventilation should be supplied to the work area.

C. Ethylene Oxide

The results of the environmental samples collected during the operation of the gas sterilizer showed that ethylene oxide levels were kept below the current evaluation criteria. However, since NIOSH considers ethylene oxide to be potentially carcinogenic, continued efforts should be taken to ensure that exposures are reduced to the lowest feasible level. Periodic testing of the local exhaust ventilation should be conducted to ensure that it continues to function effectively. Periodic environmental monitoring should also be conducted to help ensure that sterilizer equipment does not leak or malfunction. Manufactures recommendations for work procedures and equipment maintenance should be closely followed.

VIII. RECOMMENDATIONS

The previous section of the report touched on a number of areas where improvements could be made related to the control of anesthetic gases in the OR's. 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.

The hospital should also continue in its efforts to reduce ethylene oxide exposure to the lowest possible level. Adherence to the guidelines contained in the NIOSH Special Occupational Hazard Review with Control Recommendations: Use of Ethylene Oxide as a Sterilant in Medical Facilities, the NIOSH Current Intelligence Bulletin 35: Ethylene Oxide, and the provisions of the OSHA standard for ethylene oxide, should help to ensure that employee

exposures are maintained at safe levels.[27,20,22] Particular attention should be given to continued periodic exposure monitoring and leak detection to ensure the effectiveness of existing engineering controls. Additionally, the source of ethylene oxide exposure in the mechanical access room (presumable the drain area) should be identified. Although personnel would not normally be present in this

area during sterilizer and aerator operation, it would still be advisable to control the EtO emissions at this point of generation in order to prevent migration of the gas into adjacent work areas.

IX. REFERENCES

1. National Institute for Occupational Safety and Health. NIOSH manual of analytical methods, Third Ed., Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1984. (DHHS publication no. (NIOSH) 84-100).

2. Vaisman AI. Working conditions in surgery and their effect on the health of anesthesiologists. Eksp Khir Anesteziol 1967;3:44-9.

3. Askrog V, Harvald B. Teratogen effeckt of inhalations-anestetika. Nord Med 1970:83:498-504.

4. Cohen EN, Brown BW, Bruce DL, Cascorbi HF, Corbett TH, Jones TW, Whitcher C. Occupational disease among operating room personnel: a national study. Anesthesiology 1974:41:321-40.

5. National Institute for Occupational Safety and Health. Effects of trace concentrations of anesthetic gases on behavioral performance of operating room personnel. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1976. (DHEW publication no. (NIOSH) 76-179).

6. National Institute for Occupational Safety and Health. Criteria for a recommended standard–occupational exposure to waste anesthetic gases and vapors. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1977. (DHEW publication no. (NIOSH) 77-140).

7. Uhlirova A, Pokorny J. Results of questionnaire survey of health damage to anesthesiologists. Rozhl Chir 1976:53:761-70 (Cze).

8. Bond M. Statement of the american college of obstetricians and gynecologists on video display terminals and reproductive health to the house subcommittee on health and safety, committee on education and labor. Washington, DC, May 8, 1984.

9. Cohen EN, Brown BW, Bruce DL, Cascorbi HF, Corbett TH, Jones TW, Whitcher C. A survey of anesthetic health hazards among dentists: report of an american society of anesthesiologists ad hoc committee on the effect of trace anesthetics on the health of operating room personnel. JADA 1975;90:1291.

10. National Institute for Occupational Safety and Health. Control of occupational exposure to N_2O in the dental operatory. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1977. (DHEW publication no. (NIOSH) 77-171).

11. American Conference of Governmental Industrial Hygienists. Threshold limit values and biological exposure indices for 1986 - 1987. Cincinnati, Ohio, American Conference of Governmental Industrial Hygienists, 1986.

12. National Institute for Occupational Safety and Health. Special occupational hazard review with control recommendations for the use of ethylene oxide as a sterilent in medical facilities. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1977. (DHEW publication No. (NIOSH) 77-200).

13. Gross, JA., Hass ML, Swift TR. Ethylene oxide neurotoxicity: Report of four cases and review of the literature. Neurology 1979;29: 978-983.

14. Snelling, W.M., C.S. Weil and R.R. Maronport: Final report on ethylene oxide two-year inhalation study on rats, Project report 44-20, Bushy run research center (formerly Carnegie-Mellon Institute of Research), January 28, 1981. Submitted by Union Carbide Corporation to the U.S. Environmental Protection Agency under Section 8(e) of the Toxic Substances Control Act, on behalf of co-sponsors of the study (February 1981).

15. Written communication. Final report on ethylene oxide one-generation reproduction inhalation study, Project report 42-7, Carnegie-Mellon Institute of Research, May 1, 1979. Submitted by Union Carbide Corporation to the U.S. Environmental Protection Agency under Section 8(e) of the Toxic Substances Control Act, on behalf of the co-sponsors the study (June 1979).

16. LaBorde, J.B. and C.A. Kimmel: The teratogenicity of ethylene oxide administered intravenously to mice. Toxicol. Appl. Pharmacol. 56: 16-22 (1980).

17. Hogstedt, C. O. Rohlen, B.S. Berndtsson, O. Axelson and L. Ehrenberg: A cohort study of mortality and cancer incidence in ethylene oxide production workers. Br. J. Ind. Med. 36:276-280 (1979).

18. Hogstedt, C., N. Malmqvist, and B. Wadman: Leukemia in workers exposed to ethylene oxide. JAMA 24l-1132-1133 (1979).

19. Abrahams, R.H.: Recent studies with workers exposed to ethylene oxide, in the Safe use of ethylene oxide: Proceedings of the educational seminar, J.F. Jorkasky, ed. Health Industry Manufacturers Association, Washington, D.C., HIMA Report No. 80-4, pp. 27-38, 211-220 (1980).

20. National Institute for Occupational Safety and Health. Current Intelligence Bulletin 35, Ethylene oxide. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1981. (DHHS publication no. (NIOSH) 81-130).

21. Millar JD. Testimony to DOL, Occupational Safety and Health Administration, Proposed Rule: Occupational exposure to ethylene oxide, July 20, 1983.

22. Occupational Safety and Health Administration. Ethylene oxide, U.S. Dept. of Labor, Occupational Safety and Health Administration. Section 1910.1047 added by 49 FR 32031, June 19, 1981.

23. National Institute for Occupational Safety and Health. Occupational Health Guidelines for Chemical Hazards. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1981. (DHHS publication no. (NIOSH) 81-123).

24. Health Resources and Services Administration. Guidelines for Construction and Equipment of Hospitals and Medical Facilities. Health Resources and Services Administration, U.S. Dept. of Health and Human Services, 1984. DHHS Publication No. (HRS-M-HF) 84-1.

25. Gendreua L, Roberge, B. Monitoring of nitrous oxide in operating rooms: Paper presented at the american industrial hygiene conference. Institute de recherche en sante et en secutite du travail du Quebec. May 1985.

26. National Institute for Occupational Safety and Health. Development and evaluation of methods for the elimination of waste anesthetic gases and vapors in hospitals Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1984. (DHHS publication no. (NIOSH) 75-137).

27. National Institute for Occupational Safety and Health. Special occupational hazard review with control recommendations for the use of ethylene oxide as a sterilant in medical facilities. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1977. (DHEW publication No. (NIOSH) 77-200).

X. AUTHORSHIP AND ACKNOWLEDGMENTS

Report Prepared By:	William Daniels, CIH, CSP Industrial Hygienist NIOSH - Region VIII Denver, Colorado
	Bobby Gunter, PhD., CIH Regional Consultant NIOSH - Region VIII Denver, Colorado
Environmental Evaluation Assistance:	Stan Salisbury, CIH Regional Industrial Hygienist NIOSH - Region IV Atlanta, Georgia
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 Research Branch NIOSH/DPSE Cincinnati, Ohio

IX. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Services (NTIS), Springfield, Virginia. 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 the following:

A. Santa Barbara Cottage Hospital, Santa Barbara, California
B. U. S. Department of Labor, OSHA - Region IX
C. NIOSH Regional Offices/Divisions

Table 1

Breathing Zone and General Room Air Concentrations of Nitrous Oxide

Santa Barbara Cottage Hospital, Santa Barbara, California

Outpatient Surgery Center

May 19, 1987

SAMPLE TYPE	LOCATION (OR No.)	SAMPLE DESCRIPTION	SAMPLING PERIOD	TWA CONCENTRATION NITROUS OXIDE (PPM)
Personal	1	Anesthesiologist	0740 - 0910	5
Personal	1	Anesthesiologist	0910 - 1000	8
		Cumulative TWA for Procedure:		6
Personal	1	Circulating Nurse	0740 - 0909	4
Personal	1	Circulating Nurse	0909 - 0945	6
		Cumulative TWA for Procedure:		5
Personal	1	Scrub Nurse	0740 - 0909	3
Personal	1	Scrub Nurse	0909 - 0945	3
		Cumulative TWA for Procedure:		3
Personal	1	Anesthesiologist	1216 - 1319	8
Personal	1	Circulating Nurse	1240 - 1320	8
Personal	1	Scrub Nurse	1216 - 1319	15
Personal	RR	Recovery Room Nurse	0947 - 1049	50
Personal	RR	Recovery Room Nurse	1320 - 1402	10

Evaluation Criteria - NIOSH REL: 25 ppm during the period of administration.

Table 2

Breathing Zone and General Room Air Concentrations of Forane

Santa Barbara Cottage Hospital, Santa Barbara, California

Outpatient Surgery Clinic

May 19, 1987

SAMPLE TYPE	LOCATION (OR No.)	SAMPLE DESCRIPTION	SAMPLING PERIOD	TWA CONCENTRATION FORANE (PPM)
Area	1	Anesthetic Cart	07:33 - 10:10	1.36*
Personal	1	Circulating Nurse	07:40 - 09:45	0.69*
Personal	1	Scrub Nurse	07:45 - 09:45	1.68*
Area	1	Anesthetic Cart	12:16 - 13:16	1.16*
Personal	1	Circulating Nurse	12:40 - 13:16	1.34*
Personal	1	Scrub Nurse	12:16 - 13:16	1.10*
Area	2	Anesthetic Cart	07:30 - 09:06	< LOD
Personal	2	Circulating Nurse	07:49 - 08:58	0.39
Personal	2	Scrub Nurse	07:52 - 09:02	< LOD
Area	2	Anesthetic Cart	09:06 - 10:37	< LOD
Personal	2	Circulating Nurse	09:02 - 10:14	< LOD
Personal	2	Scrub Nurse	09:03 - 10:31	< LOD
Personal	RR	Recovery Room Nurse	09:47 - 10:49	1.17*
Personal	RR	Recovery Room Nurse	10:09 - 10:50	< LOD*
Personal	RR	Recovery Room Nurse	13:20 - 14:02	< LOD

Evaluation Criteria:

NIOSH REL - Halogenated Anesthetics: 2.0 ppm when used by themselves,
0.5 ppm when used with N_20.

* Indicates that N_2O was in use during the procedure.

Abbreviations and Key:

< LOD - Less than the limit of detection of 0.01 mg/tube for forane.

< LOQ - Sample was above the limit of detection, but less than the limit of quantification of 0.03 mg/sample for forane, ethrane, and halothane.

No quantifiable levels of halothane or ethrane were found in these samples.

Table 3

Breathing Zone and General Room Air Concentrations of Nitrous Oxide

Santa Barbara Cottage Hospital, Santa Barbara, California

Surgery Department

May 20, 1987

SAMPLE TYPE	LOCATION (OR No.)	SAMPLE DESCRIPTION	SAMPLING PERIOD	TWA CONCENTRATION NITROUS OXIDE (PPM)
Personal	1	Circulating Nurse	0842 - 1006	1
Personal	3	Scrub Nurse	0840 - 1003	< LOD
Personal	3	Scrub Nurse	1250 - 1430	3
Personal	3	Scrub Nurse #2	1305 - 1430	5
Personal	4	Circulating Nurse	0822 - 0950	50
Personal	4	Circulating Nurse	0950 - 1056	4
Personal	4	Circulating Nurse	1056 - 1145	6
		Cumulative TWA for Procedure:		24
Personal	4	Scrub Nurse	0837 - 1010	8
Personal	4	Scrub Nurse	1010 - 1106	4
Personal	4	Scrub Nurse	1106 - 1204	< LOD
Personal	4	Scrub Nurse	1204 - 1347	2
		Cumulative TWA for Procedure:		4
Area	4	Anesthetic Cart	1218 - 1345	7
Personal	5	Scrub Nurse	0814 - 0955	< LOD
Personal	5	Scrub Nurse	0955 - 1128	2
Personal	5	Scrub Nurse	1152 - 1324	< LOD
		Cumulative TWA for Procedure:		2
Personal	5	Scrub Nurse #2	0815 - 0941	< LOD
Personal	5	Scrub Nurse #2	0941 - 1055	3
Personal	5	Scrub Nurse #2	1055 - 1217	4
Personal	5	Scrub Nurse #2	1217 - 1312	3
		Cumulative TWA for Procedure:		3
Personal	5	Circulating Nurse	0818 - 1100	3
Personal	5	Circulating Nurse	1100 - 1313	< LOD
		Cumulative TWA for Procedure:		2
Area	5	Anesthetic Cart	1155 - 1328	< LOD

Evaluation Criteria - NIOSH REL: 25 ppm as a TWA for the period of administration (procedure).

< LOD - Less than the limit of detection estimated at 1 part per million (ppm)

Table 3 (continued)
Breathing Zone and General Room Air Concentrations of Nitrous Oxide
Santa Barbara Cottage Hospital, Santa Barbara, California
May 20, 1987

SAMPLE TYPE	LOCATION (OR No.)	SAMPLE DESCRIPTION	SAMPLING PERIOD	TWA CONCENTRATION NITROUS OXIDE (PPM)
Personal	6	Anesthesiologist	0838 - 0958	21
Personal	6	Anesthesiologist	0958 - 1200	53
Personal	6	Anesthesiologist	1200 - 1305	5
		Cumulative TWA for Procedure:		32
Personal	6	Circulating Nurse	0821 - 0945	7
Personal	6	Circulating Nurse	0945 - 1121	8
Personal	6	Circulating Nurse	1121 - 1225	5
Personal	6	Circulating Nurse	1225 - 1345	7
		Cumulative TWA for Procedure:		7
Personal	6	Scrub Nurse	0832 - 1017	7
Personal	6	Scrub Nurse	1017 - 1120	6
Personal	6	Scrub Nurse	1120 - 1146	5
		Cumulative TWA for Procedure:		6
Personal	7	Scrub Nurse	0844 - 1000	1
Personal	7	Scrub Nurse	1000 - 1119	< LOD
		Cumulative TWA for Procedure:		1
Personal	7	Circulating Nurse	0835 - 0959	30
Personal	7	Circulating Nurse	0959 - 1206	< LOD
		Cumulative TWA for Procedure:		13
Personal	RR	Recovery Room Nurse	1107 - 1223	21
Personal	RR	Recovery Room Nurse	1223 - 1350	24
		Cumulative TWA for Procedure:		23
Personal	RR	Recovery Room Nurse	1123 - 1223	14
Personal	RR	Recovery Room Nurse	1223 - 1350	15
		Cumulative TWA for Procedure:		15
Personal	RR	Recovery Room Nurse	1402 - 1420	1

Evaluation Criteria - NIOSH REL: 25 ppm as a TWA for the period of administration (Procedure).
< LOD - Less than the limit of detection estimated at 1 part per million (ppm)

Table 4

Breathing Zone and General Room Air Concentrations of Nitrous Oxide

Santa Barbara Cottage Hospital, Santa Barbara, California

Surgery Department

May 21, 1987

SAMPLE TYPE	LOCATION (OR No.)	SAMPLE DESCRIPTION	SAMPLING PERIOD	TWA CONCENTRATION NITROUS OXIDE (PPM)
Personal	3	Circulating Nurse	0726 - 0847	< LOD
Personal	3	Circulating Nurse	0847 - 1007	< LOD
		Cumulative TWA for Procedure:		< LOD
Personal	3	Scrub Nurse	0739 - 0858	< LOD
Personal	3	Scrub Nurse	0858 - 1012	< LOD
		Cumulative TWA for Procedure:		< LOD
Area	3	Anesthetic Cart	0735 - 0900	< LOD
Area	3	Anesthetic Cart	0900 - 1010	< LOD
		Cumulative TWA for Procedure:		< LOD
Area	4	Anesthetic Cart	0753 - 0905	8
Area	4	Anesthetic Cart	0905 - 1011	5
		Cumulative TWA for Procedure:		7
Personal	All	OR Attendant	0835 - 0923	< LOD
Personal	All	OR Attendant	0923 - 1043	< LOD
		Cumulative TWA for Procedure:		< LOD
Personal	Inst. Room	Instrument Tech.	0715 - 0845	< LOD
Personal	Inst. Room	Instrument Tech.	0909 - 1015	< LOD
		Cumulative TWA for Procedure:		< LOD

Evaluation Criteria - NIOSH REL: 25 ppm as a TWA for the period of administration (Procedure).

< LOD - Less than the limit of detection estimated at 1 part per million (ppm)

Table 5

Breathing Zone and General Room Air Concentrations of Forane

Santa Barbara Cottage Hospital, Santa Barbara, California

Surgery Department

May 20, 1987

SAMPLE TYPE	LOCATION (OR No.)	SAMPLE DESCRIPTION	SAMPLING PERIOD	TWA CONCENTRATION FORANE (PPM)
Personal	1	Circulating Nurse	12:45 - 13:55	< LOD
Personal	2	Scrub Nurse	08:20 - 12:30	0.22
Personal	2	Scrub Nurse	08:20 - 15:28	0.25
Personal	2	Scrub Nurse	13:10 - 15:28	0.39
Personal	3	Scrub Nurse	12:50 - 14:30	< LOD*
Personal	4	Circulating Nurse	08:22 - 10:56	0.78*
Personal	5	Scrub Nurse	08:14 - 11:28	< LOD*
Personal	5	Scrub Nurse	08:15 - 13:12	< LOD*
Personal	5	Circulating Nurse	08:18 - 11:47	< LOD*
Personal	6	Circulating Nurse	08:21 - 14:10	0.15*
Personal	6	Scrub Nurse	08:32 - 11:46	< LOD*
Personal	7	Circulating Nurse	08:06 - 12:13	< LOD*
Personal	8	Scrub Nurse	08:22 - 11:00	< LOD
Personal	8	Circulating Nurse	08:25 - 15:20	< LOD

Table 6

Breathing Zone and General Room Air Concentrations of Forane

Santa Barbara Cottage Hospital, Santa Barbara, California

Surgery Department

May 21, 1987

SAMPLE TYPE	LOCATION (OR No.)	SAMPLE DESCRIPTION	SAMPLING PERIOD	TWA CONCENTRATION FORANE (PPM)
Personal	8	Scrub Nurse	07:25 - 10:20	0.16
Personal	8	Anesthetic Cart	07:35 - 11:00	0.24
Personal	8	Scrub Nurse	07:20 - 10:20	0.15
Personal	Inst. Room	Instrument Tech.	07:15 - 10:15	< LOD
Personal	All OR's	OR Attendant	07:09 - 10:43	< LOD

Evaluation Criteria:

NIOSH REL - Halogenated Anesthetics: 2.0 ppm when used by themselves,
0.5 ppm when used with N_20.

* Indicates that N_2O was in use during the procedure.

Abbreviations and Key:

< LOD - Less than the limit of detection of 0.01 mg/tube for forane

< LOQ - Sample was above the limit of detection, but less than the limit of quantification of 0.03 mg/sample for forane, ethrane, and halothane.

No quantifiable levels of halothane or ethrane were found in these samples.

Table 7

Breathing Zone and General Room Air Concentrations of Methyl Methacrylate

Santa Barbara Cottage Hospital, Santa Barbara, California

Surgery Department

May 21, 1987

SAMPLE TYPE	SAMPLE DESCRIPTION	MINUTES SAMPLED	LITERS SAMPLED	TWA CONCENTRATION* METHYL METHACRYLATE (PPM)
Personal	Scrub Nurse	187	35.4	0.12
Area	On Light Support Next to OR Table	182	37.6	0.17

Evaluation Criteria - Methyl Methacrylate
OSHA PEL: 100 ppm 8-hr TWA
ACGIH TLV: 100 ppm 8-hr TWA

Table 8
Breathing Zone and General Area Air Concentrations of Ethylene Oxide
Santa Barbara Cottage Hospital, Santa Barbara, California
Central Supply Department
May 20, 1987

SAMPLE TYPE	SAMPLE DESCRIPTION	MINUTES SAMPLED	LITERS SAMPLED	TWA CONCENTRATION* ETHYLENE OXIDE (PPM)
Personal	Supply Technician #1	145	15.1	< LOQ
Personal	Supply Technician #2	145	14.9	0.03
Personal	Supply Technician #2 Unloading Sterilizer	9	2.1	0.40**
Area	Above Sterilizer	144	15.4	< LOQ
Area	Above Sterilizer Drain in Access Room	148	14.6	1.64

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

*All results are shown as TWA's for the duration of sample collection. Since no additional exposure would be expected to occur, the eight-hour TWA's would be significantly lower.
**This sample should be compared to ceiling criteria

< LOQ - Less than the limit of quantitation. A trace amount was detected, but it was less than the limit of quantitation of of 0.6 micrograms per sample.