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VETERANS ADMINISTRATION MEDICAL CENTER
ANN ARBOR, MICHIGAN

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I. SUMMARY

On April 8, 1986, the National Institute for Occupational Safety and Health (NIOSH) was requested to evaluate exposures to waste anesthetic gases and vapors in the operating rooms of the Veterans Administration (VA) Medical Center, Ann Arbor, Michigan. The requester was concerned with the adequacy of the anesthetic gas scavenging system in the fourth floor Surgery Service of the hospital.

In June 1986, NIOSH investigators conducted an environmental survey at the hospital. Personal and area air sampling was conducted for nitrous oxide (N_2O) and/or halogenated anesthetic agents in the four operating rooms (OR's) where general anesthesia was being administered.

Analysis of five area air samples collected in two operating rooms during the use of nitrous oxide revealed time-weighted average concentrations (TWA) of N_2O ranging from 16 parts per million (ppm) to greater than (>) 138 ppm, with a mean of > 48 ppm. Three of these samples exceeded the NIOSH recommended exposure limit (REL) of 25 ppm for N_2O for the duration of anesthetic administration. A mean concentration of 5 ppm N_2O was also found in seven area samples collected in two OR's in which N_2O was not reportedly used indicating possible high pressure leaks in the gas delivery system. TWA concentrations of isoflurane in ten personal and area air samples collected in three OR's ranged from less than (<) the limit of detection (LOD) of 0.01 milligrams (mg) per sample to 0.77 ppm, with a mean of 0.31 ppm. One sample exceeded the NIOSH REL of 0.5 ppm for halogenated anesthetics when used in combination with nitrous oxide. It should be noted that a malfunction on an anesthetic cart led to the one isoflurane level which exceeded the NIOSH REL, as well as to two of the three N_2O levels which exceeded the NIOSH REL. Under normal conditions, waste anesthetic concentrations in this room would have been expected to be much lower. While the Medical Center had in place engineering controls and work practices which were generally effective in controlling exposures under normal circumstances, the results of this survey indicate a need for sustained efforts in order to maintain waste anesthetic gas and vapor concentrations within acceptable levels.

On the basis of the data obtained during this investigation, it was determined that a potential for overexposure to nitrous oxide and halogenated anesthetic agents existed for employees working in the fourth floor Surgery Service at the Veterans Administration Medical Center. 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.

Key Words: SIC 8062 (General Medical & Surgical Hospitals) nitrous oxide, isoflurane, halogenated anesthetics, scavenging

II. INTRODUCTION

On April 8, 1986, NIOSH received a request from the Veterans Administration (VA) Medical Center, Ann Arbor, Michigan, for a health hazard evaluation. The requester was concerned with the adequacy of the anesthetic gas scavenging system in the fourth floor Surgery Service in the hospital.

On June 18 and 19, 1986, NIOSH investigators conducted an initial/environmental survey at the hospital. During this survey, background information on the nature of the hospital operations was obtained, and environmental monitoring for nitrous oxide and halogenated anesthetics agents was conducted in the operating room area. Results of the survey were provided to the hospital industrial hygienist during the survey and later by phone.

III. BACKGROUND

The main structure of the VA Medical Center, Ann Arbor, Michigan, was completed in 1954. The center currently provides care to approximately 12,000 inpatients and 60,000 outpatients annually. The hospital has 368 beds with a staff of over 900. The medical center is strongly affiliated with a nearby university, and conducts ongoing training programs in the various health professions. The particular area of concern in this evaluation, the "surgery service" area, is located on the buildings fourth floor and encompasses 7 operating rooms, a recovery room, supply rooms, change rooms, and administrative offices. It was estimated that approximately 50 - 60 physicians, nurses, and technicians periodically work in this area.

At the time of the survey, each operating room was equipped with an anesthetic cart with a scavenging line attached directly to one of the rooms' air-conditioning exhaust grilles. The hospital also had available a portable infrared analyzer for monitoring N_2O in the operating rooms; however, it was not being used during this survey.

IV. MATERIALS AND METHODS

On June 19, 1986, NIOSH investigators conducted environmental sampling in the fourth floor Surgery Service in the hospital. Area air samples were collected in order to assess employee exposures to N_2O and halogenated anesthetic gases in use at the time of the survey. This included the collection of samples at the anesthesia cart, as well as area samples collected in the vicinity of the exhaust grilles which previous studies have shown to be generally representative of the airborne concentrations of waste anesthetics in the operating room as a whole.[1] A sample was also collected in an administrative office located at the entrance to the surgery area to determine the possible presence of N_2O outside of the OR's.

Samples for N_2O were obtained using battery-powered portable sampling pumps operating at approximately 0.75 liters of air per minute (Lpm). The exhaust port of each pump was attached via Tygon tubing to an inert Tedlar bag. Samples were collected over periods ranging from 21 - 44 minutes, with clean bags interchanged throughout the duration of the surgical procedures. Bags were immediately analyzed in an area adjacent to the operating rooms using an infrared analyzer (Foxboro Miran 103 Specific Vapor Analyzer) in accordance with NIOSH analytical method 6600.[2]. The analyzer was calibrated prior to use, and periodically recalibrated throughout the day. 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, 5, & 7.

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 using battery-powered sampling pumps operating at approximately 200 cubic centimeters of air per minute (cc/min). The pumps were connected via Tygon tubing to charcoal tube collection media. Samples were later analyzed in accordance with NIOSH analytical method S-286, utilizing a gas chromatograph equipped with an electron capture detector.[3] A listing of information pertinent to sample collection in provided in Tables 2, 4, & 6.

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 pre-existing 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 [Recommended Exposure Limits or REL's], 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) [Threshold Limit Values or TLV's], and 3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) occupational health standards [Permissible Exposure Limits or 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 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 65l, 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 or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

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.[4,5] 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.[6]

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.[7] 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.[8,9]
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 3 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 9 percent of the nonexposed. This difference was statistically significant. 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.[10] 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 a important contributing factor, if not the principal factor".[11] This conclusion is based on a calculation which assumed that as many as 1 in 10 of the dentists using an inhalation anesthetic employed a halogenated agent. If the actual fraction is less than 1 in 10, 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.[8] 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 shall 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 shall be controlled so that no worker shall be 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.[8]

VI. RESULTS

The results of the environmental samples collected for the waste anesthetic gasses and vapors are presented in Tables 1 through 7. Tables 1 and 2 show the results of samples collected during a surgical procedure conducted in OR No. 4 in which both N_2O and isoflurane were being used. As evidenced by this data, the TWA concentration for the duration of the procedure exceeded the NIOSH REL of 25 ppm for N_2O in two of the three area samples collected. In addition, one of three samples collected for isoflurane also exceeded the NIOSH REL of 0.5 ppm for halogenated anesthetics when used in combination with N_2O. It should be noted that a malfunction on the anesthetic cart at the start of the procedure, necessitated a modification in the gas delivery system. As a result, relatively high concentrations of the anesthetic agents escaped into the room during the early portion of the procedure. An close examination of the data in Tables 1 and 2 reveals a pattern of initial high concentrations which occurred during the malfunction, but substantially diminished after the problem was corrected. Therefore, more "normal" exposures in this OR may be better reflected by the individual exposure data provided for the later portions of the procedure.

Tables 3 and 4 show the results of waste anesthetic gas concentrations in OR No. 2 during a surgical procedure involving the use of isoflurane. As evidenced from this data, the concentrations of isoflurane in the three area samples (< LOD, 0.21, and 0.24 ppm) were all maintained below the NIOSH REL of 2 ppm for halogenated anesthetic agents when used alone. While the use of N_2O was anticipated during this procedure, and thus sampled for, it was not in fact used. However, the results of samples collected for N_2O did show background concentrations of the gas averaging 2 ppm, although the levels were well below the NIOSH REL of 25 ppm.

Table 5 shows the results of N_2O concentrations during a surgical procedure conducted in OR 6 during which N_2O was used. One of the two area samples (35 ppm at the anesthetic cart) exceeded the NIOSH REL of 25 ppm as a TWA for the duration of the procedure.

Tables 6 & 7 show the results of waste anesthetic exposure in OR 8 during a surgical procedure involving the use of isoflurane. TWA concentrations in the three area samples (0.24, 0.29, and 0.37 ppm) and the one personal sample collected (0.33 ppm) did not exceed the NIOSH recommendation for isoflurane of 2 ppm for halogenated anesthetic agents when used alone. Although the use of N_2O was anticipated, and thus monitored for, it was not reportedly used during the procedure. However, background levels of approximately 5 ppm N_2O were detected throughout the duration of the procedure. In addition, an excursion to 53 ppm N_2O was detected in one 30 minute sample at the exhaust vent to which the anesthetic cart was scavenged. In light of the fact that, reportedly, nitrous oxide was not used during the procedure, the cause of this excursion is not readily explainable.

Other samples collected for waste anesthetics included a personal sample on a recovery room nurse who was responsible for assisting the patient after the surgical procedure which was monitored in OR 2. A TWA exposure of 0.17 ppm isoflurane was detected in a 43 minute sample for this individual, which was below the NIOSH REL of 2 ppm. In addition, a sample for N_2O was collected in the administrative office which adjoined the OR's, but no N_2O was detected in this sample.

VII. DISCUSSION AND CONCLUSIONS

Of the four surgical procedures monitored, two of the procedures generated airborne waste anesthetic gases and vapors in excess of the NIOSH REL's. However, as previously explained, an equipment malfunction occurred during one of the procedures which caused the levels to be higher than they normally would have been. The other instance in which the NIOSH REL for N_2O was exceeded involved a procedure which was monitored for a relatively short duration (23 minutes). A significant portion of this exposure could have occurred during the initial period of anesthesia induction (i.e., patient masking) during which somewhat higher levels of the anesthetic agent would be expected to be generated. Such initial high exposures would presumably tend to average toward a lower cumulative TWA during a procedure which would last a longer time.

Although under normal circumstances airborne concentrations of waste anesthetics were effectively controlled in the operating rooms which were monitored, the information obtained during the survey pinpoints some areas where ongoing attention would help to further minimize the chance of employee exposure. A discussion of each of these key areas is provided below.

Equipment Maintenance

Of primary importance in maintaining waste anesthetic concentrations within acceptable levels is the regular maintenance of 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.[13] During this survey, background concentrations in the vicinity of 5 ppm N_2O were noted in two of the OR's during procedures in which N_2O was not used. Background N_2O levels of 5 ppm and greater generally are 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.[13] While concentrations of 5 ppm are well below the evaluation criteria, they do add to the cumulative exposure which an employee would receive throughout the course of a workday, even when working at procedures not involving the use of N_2O. In addition, the presence of background levels of N_2O would increase the possibility that the evaluation criteria would be exceeded in a procedure involving the use of N_2O.

During anesthetic administration, low pressure leaks occurring between the flowmeters and breathing hoses (including the flowmeter, vaporizer, reservoir bag, popoff valve, endotracheal tube, automatic ventilator, and CO_2 absorber) can be a significant source of exposure. While the exact magnitude of the contribution of these leaks to the levels of waste anesthetics found in this survey can not be determined, these have been shown to be a major factor in several other surveys.

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 this survey, disposal of the scavenged gas was accomplished by the use of a tubing connection to the nonrecirculating air-conditioning system, where the sweeping effect of the air flowing into the grille was used to carry away the waste gasses. While this type of disposal system has been shown to be both inexpensive and effective, it does totally depend on the proper operation of the rooms air-conditioning system.[8] Resulting failure of this system or the lack of sufficient air flow rates into the grille could cause a buildup of excessive gas concentrations in the room. Furthermore, devices which connect to the exhaust grille and discharge the gas at right angles to the air flow have been shown to cause leakage into the OR at lower air-conditioning flow rates.[1] 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. Such balancing should include the consideration of such occurrences as the accidental occlusion of the tubing which connects the collection device to the exhaust grille.

While overall, the scavenging system at the VA Medical Center appeared to be effective, a review of the environmental data does indicate that in one instance, noticeably higher concentrations of the waste anesthetics were found in the samples collected near the exhaust grilles where the scavenging system was vented (Tables 1 and 2). The possibility therefore exists that the air flow into this grille was not sufficient to carry all of the waste gasses outside of the OR. However, it is also possible that these higher levels may have resulted from the positioning of the operating table and anesthetic equipment in the room and the resulting airflow patterns which may have directed the escaping waste gasses from the area of anesthetic administration to the exhaust grille in closest proximity (which was also the grille to which the scavenging system was vented). Additional in-room monitoring using direct reading instrumentation is necessary to clarify this issue.

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. Proper functioning of the general air-conditioning system is of the utmost importance when the scavenging system disposes waste gasses directly into the air-conditioning system such as was present at the VA Medical Center. Additional reasons for maintaining good general ventilation exchange rates include the rapid removal of waste gasses generated by an unforeseen equipment malfunction (such as that which occurred in OR 4), as well as the removal of waste gases generated as a result of anesthesia induction, poorly fitting face masks, improperly inflated endotracheal tubes, or low or high pressure leaks which may occasionally develop in the system. As evidenced by the detectable level of isoflurane in the personal sample on the recovery room nurse, this is also an area in which maintaining good general ventilation is important. Since scavenging systems are not present in these areas, general ventilation is 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.[14]

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.[1] Improper work practices include the use of poorly fitting face masks, insufficient inflation of endotracheal tubes, and spillage of volatile anesthetic agents while filling vaporizers. The anesthesiology staff at the Medical Center appeared very aware and concerned with minimizing exposures to anesthetic agents. Due to the VA Medial Center's position as a teaching hospital, an opportunity is available to transfer this awareness and concern through training which emphasizes proper anesthetic techniques aimed at reducing waste gas exposure.

Exposure Monitoring

Periodic monitoring of employee exposures is necessary to measure the effectiveness of the steps taken to reduce exposures. Since the Medical Center has a portable direct reading instrument capable of measuring N_2O, as well as an on-staff industrial hygienist to conduct the monitoring, this activity can be easily accomplished. In addition, several references are available which provide a detail discussion of monitoring strategies, encompassing both routine exposure monitoring as well as leak detection.[1,8,13]

VIII. RECOMMENDATIONS

While the Medical Center had in place engineering controls and work practices which were generally effective in controlling waste anesthetic gases and vapors within the evaluation criteria under normal circumstances, sustained efforts should be made to assure that safe exposure levels are maintained in the future. While some of the key areas critical to controlling employee exposures were addressed in the previous section of the report, detailed recommendations regarding specific control procedures, work practices, monitoring procedures, and medical surveillance are included in the NIOSH criteria for a recommended standard....occupational exposure to waste anesthetic gases and vapors.[8] 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 VA Medical Center. 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.

IX. REFERENCES

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X. AUTHORSHIP AND ACKNOWLEDGEMENTS

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XI. 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. Veterans Administration Medical Center, Ann Arbor, Michigan
B. U. S. Department of Labor, OSHA - Region V
C. NIOSH Regional Offices/Divisions

TABLE 1
RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR NITROUS OXIDE

V A Medical Center - Operating Room No. 4, June 19, 1986

Anesthetic Agents in use: Nitrous Oxide & Isoflurane

Sample Type/ Location	Time Start	Time Stop	Sample Time	TWA Concentration of Nitrous Oxide (ppm)
Area/ On anesthetic cart	1151	1222	31	53
	1222	1253	31	57
	1253	1337	44	37
			106*	48**
Area/ Exhaust Vent in Left Corner of OR (Scavenging Vent)	1100	1135	35	228
	1135	1202	27	>250
	1202	1242	40	53
	1242	1307	25	47
	1307	1333	26	21
			153*	>138**
Area/ Exhaust Vent in Right Corner of OR	1103	1137	34	36
	1137	1203	26	21
	1203	1243	40	15
	1243	1308	25	20
	1308	1335	27	12
			152*	21**

NIOSH REL: Nitrous Oxide 25 ppm as a TWA for the period of administration

Refer to Table 7 for Complete Key to Notations and Abbreviations

TABLE 2
RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR HALOGENATED ANESTHETICS

VA Medical Center - Operating Room No. 4, June 19, 1986

Anesthetic Agents in use: Nitrous Oxide & Isoflurane

Sample Type/ Location	Time Start	Time Stop	Sample Time	TWA Concentration of Isoflurane (ppm)
Area/ On anesthetic cart	1115	1245	90	0.48
	1245	1335	50	0.44
			140*	0.47**
Area/ Exhaust Vent in Left Corner (Scavenging Vent)	1113	1213	60	1.26
	1213	1335	82	0.41
			142*	0.77**
Area/ Exhaust Vent in Right Corner	1113	1214	61	0.22
	1214	1335	81	0.16
			142*	0.19**

NIOSH REL: Isoflurane - 0.5 ppm as a TWA for the period of administration when used in combination with nitrous oxide.

Refer to Table 7 for Complete Key to Notations and Abbreviations

TABLE 3
RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR NITROUS OXIDE

VA Medical Center - Operating Room No. 2, June 19, 1986
Anesthetic Agent in use: Isoflurane

Sample Type/ Location	Time Start	Time Stop	Sample Time	TWA Concentration Nitrous Oxide (ppm)
Area/ On Anesthetic	1315	1344	29	1
Cart	1344	1415	31	3
			60*	2**
Area/ Exhaust Vent in Right Rear Corner	1346	1415	29*	2**
Area/ At Main Entrance Door to OR	1347	1415	28*	2**

NIOSH REL: Nitrous Oxide - 25 ppm as a TWA during period of administration

Refer to Table 7 for Complete Key to Notations and Abbreviations

TABLE 4
RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR HALOGENATED ANESTHETICS

VA Medical Center - Operating Room No. 2, June 19, 1986
Anesthetic Agent in use: Isoflurane

Sample Type/ Location	Time Start	Time Stop	Sample Time	TWA Concentration of Isoflurane (ppm)
Area/ On Anesthetic Cart	1316	1425	69*	0.24**
Area/ Exhaust Vent in Right Rear Corner	1353	1425	32*	<LOD**
Area/ At Main Entrance Door to OR	1353	1425	32*	0.21**

NIOSH REL: Isoflurane - 2 ppm as a TWA for the period of administration when used by itself.

Refer to Table 7 for Complete Key to Notations and Abbreviations

TABLE 5
RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR NITROUS OXIDE

VA Medical Center - Operating Room No. 6, June 19, 1986
Anesthetic Agent in use: Nitrous Oxide

Sample Type/ Location	Time Start	Time Stop	Sample Time	TWA Concentration Nitrous Oxide (ppm)
Area/ Anesthetic Cart	1444	1507	23*	35**
Area/ Exhaust Vent Right Corner of Room	1444	1506	22*	16**

NIOSH REL: Nitrous Oxide - 25 ppm as a TWA during period of administration

Refer to Table 7 for Complete Key to Notations and Abbreviations

TABLE 6
RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR HALOGENATED ANESTHETICS

VA Medical Center - Operating Room No. 8, June 19, 1986
Anesthetic Agent in use: Isoflurane

Sample Type/ Location	Time Start	Time Stop	Sample Time	TWA Concentration of Isoflurane (ppm)
Personal/ Circulating	0901	0958	57	0.51
Nurse	0958	1114	76	0.19
			133*	0.33**
Area/ Anesthetic	0935	1035	60	0.28
Cart	1035	1142	67	0.25
	1142	1231	49	0.36
			176*	0.29**
Area/ Exhaust Vent	0935	1037	62	0.44
on East Wall	1037	1107	30	0.22
			92*	0.37**
Area/ Exhaust Vent	1005	1118	73	0.19
on North Wall	1118	1230	72	0.29
(Scavenging Vent)			145*	0.24**

NIOSH REL: Isoflurane - 2 ppm as a TWA for the period of administration when used by itself.

Refer to Table 7 for Complete Key to Notations Abbreviations

TABLE 7
RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR NITROUS OXIDE

VA Medical Center - Operating Room No. 8, June 19, 1986
Anesthetic Agent in use: Isoflurane

Sample Type/ Location	Time Start	Time Stop	Sample Time	TWA Concentration Nitrous Oxide (ppm)
Area/ Anesthetic	0927	0948	21	5
Cart	0948	1020	32	5
	1020	1050	30	5
	1050	1122	32	5
	1122	1155	33	5
	1155	1228	33	5
			181*	5**
Area/ Exhaust Vent	0918	0947	29	5
on East Wall	0947	1018	31	5
	1018	1048	30	5
	1048	1125	37	5
			127*	5**
Area/ Exhaust Vent	0950	1021	31	53
on North Wall	1021	1051	30	5
(Scavenging Vent)	1051	1123	32	5
	1123	1156	33	5
	1156	1229	33	5
			159*	14**
Area/ Exhaust Vent	0918	0946	28	5
on West Wall	0946	1019	33	5
	1019	1049	30	5
	1049	1125	36	5
			127*	5**

NIOSH REL: Nitrous Oxide - 25 ppm as a TWA during period of administration

KEY:
ppm - Parts of contaminant per million parts of air
TWA - Time-weighted average
REL - Recommended exposure limit
* - Indicates the total sampling time for the entire procedure
** - Indicates a cumulative TWA for the duration of the procedure
> - Greater than (exact concentration could not be determined due to an off scale meter deflection on the measuring instrument).
<LOD - Less than the limit of detection of 0.01 milligram per sample