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SAINT JAMES HOSPITAL
BUTTE, MONTANA

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I. SUMMARY

On January l0, l989, the National Institute for Occupational Safety and Health (NIOSH) was requested to evaluate exposures to waste anesthetic gases (wag) in the hospital operating rooms and ethylene oxide (EtO) in central processing at St. James Community Hospital, Inc., in Butte, Montana. The requestor was concerned with possible leakage from the anesthetic equipment used in the operating rooms and leakage from the EtO sterilizers during the sterilization process and during the unloading of the sterilizer.

On March l5, l989, NIOSH investigators conducted an environmental survey at the hospital. Personal breathing zone and area air sampling and leak detection testing was conducted for nitrous oxide (N_2O) and halogenated anesthetic agents in the three operating rooms (ORs) where general anesthesia was administered.

Analyses of twenty-one personal breathing zone and general area air samples collected in the three operating rooms and recovery room showed concentrations of N_2O ranging from 2 to 200 parts per million (ppm), with a mean of 23 ppm. Three of the samples (15%) exceeded the NIOSH recommended exposure limit (REL) of 25 ppm for N_2O during the period of administration.

Time weighted average (TWA) concentrations of isoflurane in five personal and 2 area air samples ranged from 0.04 to 4.50 ppm, with a mean of l.02 ppm. Three of the samples (43%) exceeded the NIOSH REL of 0.50 ppm for halogenated anesthetic agents when used with nitrous oxide. Isoflurane was the only halogenated anesthetic agent used during this evaluation.

Time weighted average (TWA) concentrations of ethylene oxide (EtO) on three area samples were l3.7, 4.3 and 0.2 ppm. The personal breathing zone sample was 0.7 ppm. All samples exceeded the lowest feasible limit of 0.l ppm recommended by NIOSH.

On the basis of the data obtained during this evaluation, it was determined that a potential for overexposure to nitrous oxide and isoflurane existed for employees working in St. James Hospital's surgical suites at the time of this survey. Ethylene oxide was a health hazard to workers in Central Processing. Recommendations are included in this report that may assist the hospital in controlling employee exposure to waste anesthetic gases and ethylene oxide.

KEYWORDS: SIC 8062 (General Medical & Surgical Hospital) nitrous oxide, isoflurane, ethrane, halothane, waste anesthetics, scavenging ethylene oxide, sterilization, xylene, laboratory safety

II. INTRODUCTION

On January 10, l989, NIOSH received a request from St. James Hospital in Butte, Montana, for a health hazard evaluation. The requestor was concerned with possible exposure to waste anesthetic gases and vapors in the hospital's surgical operating rooms, and exposures to ethylene oxide in central processing. There were no employee complaints. Management was interested in checking the results of their inhouse monitoring and that performed by consultants.

On March l5, l989, NIOSH investigators conducted an environmental survey at the hospital. During this evaluation, background information on the nature of the hospital operations was obtained, and personal breathing zone and area air sampling was conducted for nitrous oxide, isoflurane, and ethylene oxide. The results of these analyses were provided to the requestor by phone in April of l989.

III. BACKGROUND

St. James Hospital, located in Butte, Montana, provides a variety of health care services, including inpatient and outpatient surgical services. The surgery department consists of four operating rooms, a recovery room and several supply and storage rooms. Personnel involved in surgery include a scrub nurse, circulating nurse, anesthesiologist, and a surgeon. Other individuals may be involved depending on the complexity of the procedure. The rooms either have a vacuum connection for attachment of the scavenging system, or the scavenging hose is attached to the exhaust general room ventilation grille. General ventilation is supplied through vents located in the hallways, in the ceilings of the operating rooms and open windows in the areas removed from the surgical rooms.

A gas sterilizer which uses ethylene oxide is located in central processing. The sterilizer is recessed into a mechanical access hallway. This area is equipped with exhaust vents and kept under negative pressure with respect to the main central supply room area. The sterilizer is also equipped with local exhaust ventilation. At the completion of the sterilization cycle, the sterilizer door is cracked slightly (l5 degrees) for fifteen minutes. During this time personnel leave the negative pressure area. Following this interval the sterilizer is emptied into a ventilated and exhausted aeration chamber. Only one employee worked in the sterilizer area at the time of this survey.

IV. MATERIALS AND METHODS

NIOSH investigators conducted an environmental evaluation at this facility on March l5, l989. The operating room survey was designed to assess employee exposures to nitrous oxide and isoflurane used during surgery. All patients were intubated during this evaluation. Personal air samples were either collected in the worker's breathing zone or as area samples in the vicinity of the worker's breathing zone. The samples for nitrous oxide were collected using vacuum pumps operating at 200-500 cubic centimeters per minute (cc/min). The exhaust port of each pump was attached with Tygon tubing to an inert Tedlar 40 liter bag. Most samples (if feasible) were collected for the duration of the surgical procedure, with bags changed as necessary for the longer procedures. The 40 liter bag lasts for surgical procedures that do not exceed two hours. Bags were immediately analyzed at a location outside of the operating room area using an infrared analyzer (Foxboro Miran 1A Organic Vapor Analyzer) in accordance with NIOSH analytical method 6600.[1]

To assess employee exposures to isoflurane used during surgery, personal breathing zone and area samples were collected on the same personnel wearing the nitrous oxide collection bags. Sampling pumps were operated at approximately 200 cc/min, and connected with Tygon tubing to organic vapor charcoal

collection tubes. Samples were analyzed in accordance with NIOSH analytical method l003 using a gas chromatograph with flame ionization.[1]

All three of the operating rooms were evaluated for equipment leakage during surgical procedures. The infrared analyzer was taken into the operating rooms and, using a flexible sampling probe, all high and low pressure connections were checked, as well as face mask, tubing, slip connections, male and female nitrous oxide connections, and all parts of the anesthetic cart.

To assess employee exposures to ethylene oxide, personal samples were collected near the breathing zone of the one employee who operated the sterilizer during the operating cycle and during the unloading of the sterilizer and loading of the aerator. Area samples were collected in all areas where leakage was most likely to occur. Samples were collected using vacuum pumps operated at 100 cc/min. The pumps were connected with Tygon tubing to a sampling train containing a hydrogen bromide activated charcoal sampling tube. The samples were analyzed in accordance with NIOSH analytical method l614 for ethylene oxide.[1]

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 RELs], 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) [Threshold Limit Values or TLVs], and 3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) occupational health standards [Permissible Exposure Limits or 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 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.

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 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.[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_2O 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_2O exposure must be a important contributing factor, if not the principal factor".[10] 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.[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 TLVs of 75 ppm for ethrane, and 50 ppm for halothane.[11]

Ethylene Oxide (EtO)

The acute toxic effects of EtO in humans and animals include acute skin, respiratory, and eye irritation; skin sensitization; nausea, vomiting, diarrhea; and nervous system effects. Nonmalignant chronic effects in humans include anemia and respiratory irritation. Further, occupational exposures to EtO 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 leukemia. Experiments indicate that EtO 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 EtO suggest an increased risk of leukemia and other cancers.[17,18] Recent information also suggest that EtO 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 EtO be regarded in the workplace as a potential occupational carcinogen, and that exposure be reduced to the lowest feasible level.[20] An 8-hour TWA below 0.1 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 EtO is 1 ppm as a 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 (53 CFR 1724, 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]

VI. RESULTS

A. Waste Anesthetic Gases

1. Nitrous Oxide

All nitrous oxide personal breathing zone and general room air samples are presented in Table 1. During the procedures monitored, concentrations of nitrous oxide monitored ranged from 2 to 200 ppm. The average concentration was 23 ppm and 15% of the samples exceeded the NIOSH PEL of 25 ppm per procedure.

2. Isoflurane (Halogenated Anesthetic)

Table 2 presents results of the environmental samples collected for isoflurane used along with nitrous oxide during the surgical procedures. Concentrations of isoflurane ranged from 0.04 to 4.5 ppm with an average concentration of 1.02 ppm, and 43% exceeded the NIOSH REL of 0.5 ppm. Isoflurane was the only halogenated anesthetic agent used during this evaluation.

3. Leak Testing

All operating rooms were spot checked for leaks in the high and low pressure connections on the anesthetic cart and all the various tubes going to and from the cart. Small leaks were observed in the popoff valve area, around the face mask, some of the slip connections, and the nitrous oxide gas connections. None of these leaks were serious and most were corrected when they were found.

B. Gas Sterilizer Area

The results of the air samples taken for ethylene oxide during the operation of the gas sterilizer are presented in Table 3. The one personal sample of 0.7 ppm exceeds the NIOSH REL of less than 0.1 ppm as an 8-hour TWA; it does not exceed the OSHA PEL and the ACGIH TLV of 1 ppm as an 8-hour TWA. Two of the area samples did show leakage behind the sterilizer and around the front door seal. The highest concentration of 13.7 ppm, was found behind the sterilizers in the confined maintenance alley. The sterilizer is ventilated into the floor drain behind the sterilizer. The drain pipe on the sterilizer should be extended further into the floor drain to prevent the leakage of EtO during the purge cycle. Until this situation is corrected, maintenance should not be performed during the use of the sterilizer. The other high reading of 4.3 ppm was found at the front door of the sterilizer and was probably caused by some of the offgassing when the sterilizer door was cracked. Employee exposures from this source are probably not substantial, because the ventilation above the door captures most of this gas. This sample was taken to illustrate there is still EtO in the sterilizer and precautions should be taken to eliminate employee exposure during the opening and emptying of the sterilizer. The other area sample (0.2 ppm) was collected at the EtO supply cylinder. This does not indicate leakage of the cylinder but probably illustrates that the general background level behind the sterilizer to be about 0.2 ppm. This is probably due to the drain pipe on the sterilizer emitting some EtO into the general air during the purge cycle.

VII. DISCUSSION AND CONCLUSIONS

A. Waste Anesthetic Gases and Vapors

As indicated by the results of the environmental sampling, concentrations of waste anesthetic gases and vapors were usually maintained below the NIOSH RELs. Two of the three overexposures were personal breathing zone samples. Factors which can influence personal exposures in this area can change over time. Therefore, it is necessary to regularly examine all areas of exposure control to identify any shortcomings. To assist in the identification of problem areas, a brief discussion of some of the key areas necessary for controlling employee exposures is presented below.

l. Equipment Maintenance

Regular maintenance of the anesthetic cart and all the high and low pressure connections will assist in eliminating leakage. Recent data indicate that leaks from the high and low pressure delivery systems resulting from poor maintenance of the anesthetic unit are a primary source of employee exposure in the OR.[23] 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 control valve from the flowmeter.[23] During anesthetic administration, low pressure leaks may occur between the flowmeters and breathing hoses (including the flowmeter, vaporizer, reservoir bag, popoff valve, endotrachial tube, automatic ventilator, and CO_2 absorber) and can be a significant source of exposure.

2. Scavenging

A scavenging system consists of a collection device (usually connected to the popoff, valve which is the major source of anesthetic gas pollution), a means of disposal, and a pressure-balancing device if needed. 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. Scavenging may be necessary at other locations such as the exit port of the CO_2 meter, which is often a source of waste anesthetic gas exposure in the OR.

3. General Ventilation

While local exhaust ventilation (scavenging) is the preferred method of eliminating waste gases, general room ventilation 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 gases 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 clean air changes does not eliminate the source of the anesthetic gases, it does lead to the more effective removal of the waste gases and vapors, thereby reducing the magnitude of employee exposure. As a minimum, operating rooms should be provided with at least 20 air changes per hour.[24]

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. General ventilation should be capable of removing the waste anesthetic gases expired by

the patient. The recovery room should be provided 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 ORs equipped with properly-designed scavenging components may be the result of poor work practices by the anesthetist.[25] 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. 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 exposure control programs within the hospital, it is necessary to periodically monitor employee exposures as well as monitor 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

The results of the environmental samples collected during the operation of the gas sterilizer showed excessive levels of EtO. Since NIOSH considers ethylene oxide to be a potential carcinogen, efforts should be started immediately to lower these concentrations to the lowest possible level. Securing the exhaust vent to the floor drain behind the EtO sterilizer may assist in eliminating most of the EtO expelled into the work space during the purge cycle. If this doesn't eliminate the excessive exposures, more dilution ventilation should be installed. The manufacturer representative that services this machine should make sure that all connections and the door gaskets are well tightened.

VIII. RECOMMENDATIONS

A. Waste Anesthetic Gases and Vapors

This report identifies number of areas that should be examined to continue to ensure that waste anesthetic gases are properly controlled in the ORs. More recommendations and valuable information is provided in the NIOSH Criteria for a Recommended Standard....Occupational Exposure to Waste Anesthetic Gases and Vapors.[6] A copy of this document was given to the hospital.

B. Ethylene Oxide

The hospital should continue its efforts to reduce EtO exposures 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, 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 a safe level.[20, 22, 30]

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XI. DISTRIBUTION AND AVAILABILITY OF 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 Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from the NIOSH Publications Office at the Cincinnati, Ohio address. Copies of this report have been sent to the following:

1. Saint James Hospital, Butte, Montana
2. U. S. Department of Labor, OSHA - Region VIII
3. NIOSH Regional Offices/Divisions

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1
Breathing Zone and General Room Air Concentrations of
Nitrous Oxide (N_20)
Saint James Hospital in
Butte, Montana
March 15, 1989

Bag	Location Sample #	Job	Sampling Time	N_20 (ppm)
G	OR 4	OR Tech	7:45 - 8:48	16
M	OR 4	OR Tech	9:00 - 10:35	9
M	OR 4	OR Tech	11:20 - 12:39	11
K	OR 4	Circ. Nurse	7:57 - 9:45	20
K	OR 4	Circ. Nurse	9:54 - 11:09	200
K	OR 4	Circ. Nurse	11:23 - 12:47	14
D	OR 4	Anes cart/area	9:48 - 9:21	22
G	OR 4	Anes cart/area	9:30 - 11:04	35
G	OR 4	Anes cart/area	11:10 - 1:00	15
G	OR 4	Anes cart/area	1:04 - 1:35	15
Y	OR 1	Scrub tech.	9:25 - 10:38	15
Y	OR 1	Scrub tech.	12:08 - 1:26	28
Y	OR 4	Scrub tech.	9:48 - 10:57	18
D	OR 2	Scrub tech	9:45 - 10:35	2
D	OR 2	Scrub tech.	10:39 - 12:03	5
D	OR 2	Scrub tech.	12:05 - 1:27	5
K	OR 2	anes cart/area	10:28 - 12:18	6
K	OR 2	anes cart/area	12:22 - 1:23	*
R	Recovery	area	10:43 - 11:08	11
R	Recovery	area	11:15 - 11:40	9
R	Recovery	area	11:42 - 12:22	11
Evaluation Criteria				25
Instrument limit of detection				1

*Sample read 1800 ppm
(Discussed with technician - he admitted that he had introduced pure N_20 into bag.)

Table 2

Breathing Zone and General Room Air Concentrations of
Isoflurane in the Hospital Operatory Rooms at
Saint James Hospital in
Butte, Montana

March 15, 1989

Sample #	Job/Location	Sampling Time	Isoflurane (ppm)
A-1	OR Technician/Room 4	7:44 - 12:47	0.18
A-2	Area/Room 4/OR anest. cart	7:48 - l:07	1.24
A-3	Circulating Nurses/Room 4	7:57 - 12:47	4.50
A-4	Scrub Tech./Room 1	9:25 - l:28	0.27
A-5	Scrub Nurse/Room 2	9:25 - 1:27	0.04
A-6	Scrub Tech./Room 4	9:48 - 1:39	0.26
A-7	Area/Recovery Room	ll:06 - 12:53	0.62
Evaluation Criteria			0.50
Laboratory Limit of Detection 0.01 mg/sample			

Table 3

Breathing Zone and General Room Air Concentrations of
Ethylene Oxide (ETO) in Central Processing at
Saint James Hospital in
Butte, Montana
March 15, 1989

Sample #	Job/Location	Sampling Time	PPM EtO
100	Area/behind Sterilizer	2:01 - 5:10	13.7
101	Technician	2:03 - 4:50	0.7
102	Area/on outside door of sterilizer	2:00 - 5:10	4.3
103	Area/on ETO Cylinders	2:02 - 5:10	0.2

Evaluation Criteria LFL
Laboratory Limit of Detection 0.0004 Mg/Sample

LFL= Lowest Feasible Limit