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I. SUMMARY

On May l0, l988, the National Institute for Occupational Safety and Health (NIOSH), was requested to evaluate exposure to waste anesthetic gases and vapors in the surgical operating rooms and in the recovery room of the University Hospital, Denver, Colorado.

On August 8, 9, and l0, l988, NIOSH investigators conducted an environmental survey at the hospital. During this survey personal air samples were collected for nitrous oxide (N_2O) and halogenated anesthetic agents.

Time-weighted average (TWA) concentrations of N_2O in 19 personal samples ranged from less than the limit of detection of 1 part per million (ppm) to 77 ppm, with a mean concentration of l7 ppm. Five of the 19 samples exceeded the NIOSH recommended exposure limit (REL) of 25 ppm for N_2O as a TWA for the period of anesthetic administration.

Twenty-four personal samples were collected and analyzed for halothane, ethrane, and isoflurane. Halothane was detected in seven of the samples at TWA concentrations ranging from 0.09 ppm to l.6 ppm, with a mean concentration of 0.52 ppm. Three of these samples exceeded the NIOSH REL of 0.5 ppm for halothane when used in combination with N_2O. Ethrane was detected in five of the samples at TWA concentrations ranging from 0.06 to l.5 ppm, with a mean concentration of 0.65 ppm. Two of the samples exceeded the NIOSH REL of 0.5 ppm for ethrane when used in combination with N_2O. Isoflurane was detected in six samples at TWA concentrations ranging from 0.06 to 0.99 ppm, with a mean concentration of 0.40 ppm. Three of samples exceeded the NIOSH REL of 0.5 ppm for isoflurane when used in combination with N_2O. The limit of detection for each of the halogenated anesthetic agents was 0.01 milligram per sample. There are presently no OSHA standards for nitrous oxide or halogenated anesthetic gases.

Concentrations of waste anesthetic gases and vapors were found to exceed the NIOSH recommended exposure limits during some of the surgical procedures monitored. 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.

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

II. INTRODUCTION

On May l0, l988, NIOSH received a request from the University Hospital, Denver, Colorado, for a health hazard evaluation. The requester was concerned with the possible exposure to waste anesthetic gases and vapors in the surgical operating rooms and in the recovery room.

On August 8, 1988, NIOSH investigators conducted an initial survey at the hospital, and on August 9 and l0, l988, a more indepth environmental survey was conducted. During the indepth survey, personal air sampling was conducted for nitrous oxide (N_2O) and the halogenated anesthetic agents. The results of the survey were discussed with the requester by telephone in October l988.

III. BACKGROUND

University Hospital, located in Denver, Colorado, provides a variety of health care services, including surgical services. During the NIOSH survey, nine of the ten hospital operating rooms were in use. In addition, a recovery room, also located in the operating suite area, was used to stabilize the patients immediately following surgery.

Personnel normally involved in surgical procedures 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. The rooms contain vacuum connections for attachment of the anesthetic carts to the scavenging system. General ventilation is also supplied through vents located near the ceilings of each OR.

IV. MATERIALS AND METHODS

NIOSH investigators conducted an environmental survey in the operating rooms on August 9 and 10, 1988. The survey was designed to assess N_2O and halogenated anesthetic agents used during the course of the surgical procedures, and their effect upon employee exposures in the operating and recovery rooms.

Air samples collected for the assessment of employee exposures in the operating rooms included personal samples which were collected in the vicinity of the employees breathing zone. 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 where N_2O use was anticipated. Additional information pertinent to sample collection is provided in Table 1.

In order to assess employee exposures to the halogenated anesthetic agents used during the surgical procedures, personal samples were collected as 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 Table 2.

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 anesthetic gases is provided as follows.

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 anesthetics 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 are presently no OSHA standards for nitrous oxide or the halogenated anesthetic agents. The ACGIH recommends a TLV of 75 ppm for ethrane, and 50 ppm for halothane. In addition, in it's "Notice of Intended Changes" for 1989-89, ACGIH proposes a TLV of 50 ppm for nitrous oxide.[11]

VI. RESULTS

A. Nitrous Oxide

The results of the environmental samples collected for N_2O during the surgical procedures are presented in Table 1. Time-weighted average concentrations of N_2O in 19 personal samples ranged from less than the limit of detection of 1 part per million (ppm) to 77 ppm, with a mean concentration of l7 ppm. Five of the 19 samples exceeded the NIOSH REL of 25 ppm for N_2O as a TWA for the period of anesthetic administration. All of the samples exceeding the REL were found in ORs 1 and 8. These data represent samples collected in eight of the nine ORs that were in use during the survey period, as well as samples collected in the hallway and recovery room.

B. Halogenated Anesthetic Gases

Table 2 shows the results of the environmental samples collected for halogenated anesthetics used during the surgical procedures. Twenty-four personal samples were collected and analyzed for halothane, ethrane, and isoflurane. Halothane was detected in seven of the samples at TWA concentrations ranging from 0.09 ppm to l.6 ppm, with a mean concentration of 0.52 ppm. Three of these samples exceeded the NIOSH REL of 0.5 ppm for halothane when used in combination with N_2O. Ethrane was detected in five of the samples at TWA concentrations ranging from 0.06 to l.5 ppm, with a mean concentration of 0.65 ppm. Two of the samples exceeded the NIOSH REL of 0.5 ppm for ethrane when used in combination with N_2O. Isoflurane was detected in six samples at TWA concentrations ranging from 0.06 to 0.99 ppm, with a mean concentration of 0.40 ppm. Three of samples exceeded the NIOSH REL of 0.5 ppm for isoflurane when used in combination with N_2O. The limit of detection for each of the halogenated anesthetic agents was 0.01 milligram per sample.

Seven of the eight exposures which exceeded the NIOSH REL for halogenated anesthetic agents were found in ORs 1 and 8. These data represent samples collected in eight of the nine ORs that were in use during the survey period, as well as samples collected in the recovery room.

VII. DISCUSSION AND CONCLUSIONS

As evidenced by the results of the environmental survey, concentrations of waste anesthetic gases and vapors exceeded the NIOSH recommended exposure limits in some of the surgical procedures monitored. However, with one exception, all of the exposures above the NIOSH REL's were limited to operating rooms 1 and 8. In order to determine the cause of these overexposures, several factors which may have played an important role in allowing the buildup of waste anesthetic vapors in these ORs must be examined. These include; leakage from anesthetic cart fittings and components, an ineffective scavenging system, poor work practices, and inadequate exchange rates of the general

ventilation system. Since the exact magnitude which these and other factors may have influenced employee exposures can not be accurately determined by the data collected in this survey, it is necessary that hospital staff regularly examine all areas of exposure control and attempt to identify where further improvements can be made. A brief discussion of some of the key areas necessary for controlling employee exposures is presented below.

A. 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 are a primary source of employee exposures in the OR.[13] 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.[13] 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.

B. 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, scavenging may also be necessary at locations such as the exit port of the CO_2 meter, which may also be a source of waste anesthetic gases in the OR. As with all scavenging systems, it is important to ensure proper pressure balancing so that the gas system does not interfere with the proper operation of the anesthetic delivery system.

C. General Ventilation

While local exhaust ventilation (such as scavenging) is the preferred means of eliminating waste gases at their point of generation, general room ventilation also plays an important role in maintaining acceptable waste gas levels in the OR. Reasons for maintaining good general ventilation exchange rates include the rapid removal of waste gasses generated as a result of anesthesia induction, poorly fitting face masks, improperly inflated endotrachial tubes, and low or high pressure leaks which may occasionally develop in the system. While increasing the number of air changes does not eliminate the source of the anesthetic gases, it does lead to the more effective removal of the waste gases and vapors, thereby reducing the magnitude of employee exposures. As a minimum, operating rooms should be provided with at least 20 air changes per hour.[12]

Although no exposures above the NIOSH REL were found in the recovery room during this survey, it is still important to ensure that adequate amounts of fresh air are being brought into this area. Since scavenging systems are not present in recovery rooms, general ventilation is solely relied on to remove the

waste gases expired by the patient. As a minimum, recovery rooms should be provided with at least 6 air changes per hour.[12]

D. 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.[14] 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.

E. Exposure Monitoring

To determine the effectiveness of the overall exposure control program within the hospital, it is necessary to periodically monitor employee exposures as well as monitor equipment for leakage. This could be easily accomplished since the hospital has two industrial hygienists on staff. Sampling and analytical procedures, such as those provided in NIOSH methods 6600 and 1003, should be referenced for further guidance in the conduct of personal monitoring.[1]

VIII. RECOMMENDATIONS

In order to effectively control employee exposures in the operating room, a comprehensive program which addresses all of the previously discussed areas is necessary. 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] 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. Due to findings of the NIOSH survey, operating rooms 1 and 8 should be immediately evaluated to determine the source of the overexposures.

IX. REFERENCES

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XI. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

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

A. University Hospital, Denver, Colorado
B. U. S. Department of Labor, OSHA - Region VIII
C. NIOSH Regional Offices/Divisions

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

Table 1

Breathing Zone Air Concentrations of Nitrous Oxide

University Hospital, Denver, Colorado

August 9 & 10, 1988

LOCATION (OR No.)	SAMPLE DESCRIPTION	SAMPLING PERIOD	TWA CONCENTRATION NITROUS OXIDE (PPM)
(Samples collected August 9, 1988)			
1	Scrub Nurse	7:18 - 9:08	70
"	" "	9:08 - 10:45	55
"	" "	10:45 - 1:00	*
"	" "	1:00 - 1:47	20
	Cumulative TWA		55
1	Circulating Nurse	7:20 - 9:00	63
"	" "	9:00 - 10:40	60
"	" "	10:40 - 11:52	10
"	" "	11:52 - 1:25	12
	Cumulative TWA		39
1 & 2	Scrub Nurse	7:25 - 9:55	< LOD
"	" "	9:55 - 11:45	2
"	" "	11:45 - 12:15	25
	Cumulative TWA		4
2	Circulating Nurse	7:28 - 8:57	< LOD
"	" "	8:57 - 10:45	< LOD
"	" "	10:45 - 11:30	< LOD
	Cumulative TWA		< LOD
6	Circulating Nurse	7:42 - 9:14	15
"	" "	9:14 - 11:05	5
"	" "	11:05 - 11:35	35
	Cumulative TWA		13
5	Scrub Nurse	7:44 - 9:10	13
"	" "	9:10 - 10:35	7
"	" "	10:35 - 12:05	< LOD
"	" "	12:05 - 1:15	5
	Cumulative TWA		6
5	Scrub & Circ. Nurse	7:46 - 8:52	25
"	" " " "	8:52 - 10:55	5
"	" " " "	10:55 - 12:10	5
	Cumulative TWA	10	
7	Circulating Nurse	7:47 - 8:50	< LOD
"	" "	8:50 - 10:40	< LOD
"	" "	10:40 - 1:00	< LOD
	Cumulative TWA		< LOD
7	Scrub Nurse	7:50 - 1:00	< LOD
	Cumulative TWA		< LOD

Table 1 (continued)
Breathing Zone Air Concentrations of Nitrous Oxide
University Hospital, Denver, Colorado
August 9 & 10, 1988

LOCATION (OR No.)	SAMPLE DESCRIPTION	SAMPLING PERIOD	TWA CONCENTRATION NITROUS OXIDE (PPM)
Hallways	Charge Nurse	7:40 - 9:18	< LOD
"	" "	9:18 - 12:00	< LOD
	Cumulative TWA		< LOD
Recovery	Recovery Nurse	8:00 - 9:16	5
"	" "	9:16 - 10:54	3
"	" "	10:54 - 11:54	5
	Cumulative TWA		4
(Samples collected August 10, 1988)			
1	Circulating Nurse	7:15 - 8:15	75
"	" "	8:15 - 9:15	35
"	" "	9:15 - 10:15	67
"	" "	10:15 - 11:15	40
	Cumulative TWA		54
1	Scrub Nurse	7:17 - 8:17	28
"	" "	8:17 - 9:17	18
	Cumulative TWA		23
10	Scrub Nurse	7:17 - 9:15	< LOD
"	" "	9:15 - 10:10	< LOD
"	" "	10:10 - 11:00	< LOD
	Cumulative TWA		< LOD
4	Circulating Nurse	7:21 - 9:00	< LOD
"	" "	9:00 - 10:30	< LOD
	Cumulative TWA		< LOD
8	Circulating Nurse	7:25 - 9:00	77
"	" "	9:00 - 10:15	78
	Cumulative TWA		77
8	Scrub Nurse	7:36 - 9:00	55
"	" "	9:00 - 11:17	17
	Cumulative TWA		31
Recovery	Recovery Nurse	7:40 - 9:15	< LOD
"	" "	9:15 - 11:30	< LOD
	Cumulative TWA		< LOD
Recovery	Recovery Nurse	7:40 - 9:15	< LOD
"	" "	9:15 - 11:30	< LOD
	Cumulative TWA		< LOD

Evaluation Criteria - NIOSH REL: 25 ppm TWA for the period of administration
< LOD - Less than the limit of detection estimated at 1 part per million (ppm)
* Sample lost due to bag leakage

Table 2

Breathing Zone Air Concentrations of Halothane, Ethrane, & Isoflurane

University Hospital, Denver, Colorado

August 9 & 10, 1988

LOCATION (OR No.)	SAMPLE DESCRIPTION	SAMPLING PERIOD	TWA CONCENTRATION (ppm) HALOTHANE	ETHRANE	ISOFLURANE
(Samples collected on August 9, 1988)					
1	Scrub Nurse	7:18 - 12:28	< LOD	1.5	< LOD
1	Circulating Nurse	7:20 - 11:52	< LOD	1.1	< LOD
2	Scrub Nurse	7:25 - 1:15	< LOD	< LOD	< LOD
2	Circulating Nurse	7:28 - 11:35	< LOD	< LOD	< LOD
Recovery	Recovery Nurse	8:00 - 2:15	< LOD	0.06	< LOD
5	Scrub Nurse	7:44 - 12:05	0.09	< LOD	< LOD
5	Scrub & Circ. Nurse	7:46 - 12:10	0.17	< LOD	< LOD
6	Circulating Nurse	7:42 - 11:05	0.12	< LOD	0.06
7	Circulating Nurse	11:47 - 1:00	< LOD	< LOD	< LOD
7	Scrub Nurse	7:50 - 11:45	< LOD	< LOD	< LOD
1	Scrub Nurse	1:00 - 1:47	< LOD	0.32	< LOD
1	Circulating Nurse	11:25 - 1:25	< LOD	0.26	< LOD
6	Circulating Nurse	11:36 - 1:05	< LOD	< LOD	0.99
5	Scrub Nurse	12:05 - 1:15	< LOD	< LOD	< LOD
(Samples collected August 10, 1988)					
1	Circulating Nurse	7:15 - 11:35	0.80	< LOD	0.53
1	Scrub Nurse	7:15 - 11:35	0.23	< LOD	0.55
4	Circulating Nurse	7:21 - 11:35	< LOD	< LOD	< LOD
6	Circulating Nurse	7:25 - 9:30	< LOD	< LOD	< LOD
6	Scrub Nurse	7:25 - 9:30	< LOD	< LOD	< LOD
8	Circulating Nurse	7:25 - 10:15	1.6	< LOD	< LOD
8	Scrub Nurse	7:36 - 11:17	0.63	< LOD	< LOD
10	Scrub Nurse	7:20 - 11:00	< LOD	< LOD	< LOD
Recovery	Recovery Nurse	7:40 - 11:30	< LOD	< LOD	0.13
Recovery	Recovery Nurse	7:40 - 11:30	< LOD	< LOD	0.11
Evaluation Criteria; NIOSH REL: (with N_2O)			0.5	0.5	0.5
(used alone)			2.0	2.0	2.0
ACGIH TLV:			75		50

Abbreviations

< LOD - Less than the Laboratory Limit of Detection of 0.01 mg/sample

ppm - parts of contaminant per million parts of air

TWA - Time-weighted average