U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45226

HEALTH HAZARD EVALUATION DETERMINATION
REPORT NO. 77-85-445

MESA VETERINARY HOSPITAL
GOLDEN, COLORADO

NOVEMBER 1977

I. TOXICITY DETERMINATION

A Health Hazard Evaluation was conducted by the National Institute for Occupational Safety and Health (NIOSH) in the Mesa Veterinary Hospital, Golden, Colorado. On August 22 & 24, 1977, environmental samples were collected to determine concentrations of waste anesthetic gases.

Findings on the days of this evaluation indicate that the mean 8-hour time weighted average exposure to nitrous oxide was 34 ppm for the veterinarian and 45 ppm for the anesthesia technicians. Average exposure to halogenated anesthetic was 0.8 and 2.2 ppm for the same two groups. These concentrations were slightly above the NIOSH Recommended Limit of 25 ppm nitrous oxide and 0.5 ppm halogenated anesthetic. Since information on adverse health effects due to exposure to waste anesthetic gases is not completely definitive and many unknown factors still exist, recommended permissible levels of exposure are not defined as safe levels but rather as levels which are attainable with current technology. These levels should prevent the effects caused by acute exposure and significantly reduce the risk associated with long term, low level exposure. Recommendations to further reduce concentrations are included in this report.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Division of Technical Services, Information and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from NIOSH, Publications Office at the Cincinnati address.

Copies of this report have been sent to:

a. Mesa Veterinary Hospital
b. U.S. Department of Labor, Region VIII
c. NIOSH, Region VIII

For the purpose of informing the approximately ten "affected employees", the employer shall promptly "Post" for a period of 30 calendar days the determination report in a prominent place near where exposed employees work.

III. INTRODUCTION

Section 20 (a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669 (a)(6), authorizes the Secretary of Health, Education, and Welfare following a written request by an employer or authorized representative of employees to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The National Institute for Occupational Safety and Health received such a request from the management of Mesa Veterinary Hospital.

There were no specific alleged health problems at the time the request was generated. The recognition of the potential health hazard associated with chronic exposure to anesthetic gases was primarily responsible for the health hazard evaluation request.

IV. HEALTH HAZARD EVALUATION

A. Process Description

The areas of Mesa Veterinary Hospital of interest to this study are those areas involved in surgical procedures on animals, primarily dogs and cats. Anesthetic gases were used in three areas on the days of the evaluation. These are 1) the surgical preparation area, where most animals are initially anesthetized either by intravenous or inhalation techniques before being carried into the operating rooms, and where some minor procedures are performed; 2) the small operating room where dental and minor surgical procedures are performed; and 3) the large operating room which is equipped to handle two procedures simultaneously and in which major surgeries are performed.

A halogenated anesthetic, either halothane or methoxyflurane, is used alone or in combination with nitrous oxide.

The anesthetic circuit is composed of the anesthesia machine and the breathing system. The anesthesia machine vaporizes the halogenated anesthetic and combines it with nitrous oxide and oxygen, which are supplied to the machine from cylinders. The breathing system consists of a soda lime canister (to absorb exhaled carbon dioxide), breathing bag or ventilator, valves for assuring unidirectional gas flow, flexible hoses, and "Y" piece terminating in an endotracheal tube or face mask.

The anesthetic gas mixture is delivered at a rate higher than the patient's metabolic needs. When a breathing bag is used, excess gases are vented out of the breathing system through the pop-off valve. The volume of gases and vapors escaping through the pop-off valve are highly variable since it depends on the patient's breathing pattern and metabolic rate. When a ventilator is in use the pop-off valve on the anesthetic machine is closed and the ventilator assumes the function of the pop-off valve. As the system is now designed, the pop-off valve and the ventilator are the major sources of waste anesthetic gas. Local exhaust ventilation was available and in use to remove waste anesthetic gas from around the pop-off valve.

Other sources of waste anesthetic gas are the face mask or endotracheal tube, cracks or holes in the hoses, tube fittings or seals, or from spilled liquid anesthetic.

Two people are generally involved directly in surgery: 1) the anesthetic technician who prepares the animal by administering an initial anesthetic, either intravenous or inhalation, and then shaves and scrubs the animal in preparation for surgery; and 2) the veterinarian/surgeon who performs the surgery and in many cases simultaneously administers anesthetic.

Other employees who spend a portion of their time in or near areas where anesthetic gas is used include veterinarians other than the one performing surgery, technicians and other animal care personnel, and office staff. During the time of this study there were also people in the area observing both the veterinary and industrial hygiene techniques, and in two instances these people served as sampling subjects although their exposure was limited to only a few days at most, as compared with the regular employees who are exposed almost daily for the tenure of their employment.

B. Evaluation Design

On August 22 & 24, 1977, breathing zone and general area air samples were obtained for halothane, methoxyflurane and nitrous oxide. The breathing zone samples were obtained by attaching sampling equipment to operating room personnel. The equipment consisted of a charcoal tube sampler for the halogenated agent, and a bag sampler for nitrous oxide. Identical sampling equipment was also placed in the areas where anesthetic gas was used, as well as reception, treatment and other peripheral locations. The charcoal tubes were shipped to a laboratory for analysis by gas chromatography and bag samples were analyzed on site by infrared spectrophotometry. A more detailed description of the sampling and analytical methods can be found in Health Hazard Evaluation Determination Reports 75-22-228(23) and 75-76-234(24).

C. Evaluation Criteria

In a criteria document for a recommended standard for occupational exposure to anesthetic gases (1), NIOSH states: "Current scientific evidence obtained from human and animal studies suggests that chronic exposure to anesthetic gases increases the risk of both spontaneous abortion among female workers and congenital abnormalities in the offspring of female workers and the wives of male workers. Risks of hepatic and renal diseases are also increased among exposed personnel. In addition, physiological function may be impaired. A few studies have suggested increased risk of cancer. Effects on the central nervous system due to acute exposures of anesthetic gases have been associated with headaches, nausea, fatique, irritability, etc." Control procedures and work practices presented in that document, however, should prevent the effects caused by acute exposure and significantly reduce the risk associated with long term, low level exposure. A dose response relationship for halogenated anesthetic toxicity has not been defined.

That same NIOSH publication recommends maximum exposures of 25 ppm nitrous oxide (eight-hour time weighted average); and 2 ppm halogenated anesthetic when used alone, or 0.5 ppm when used with nitrous oxide. These recommendations are based upon available technology in reducing waste anesthetic gas levels.

Reports by Vaisman (8) and Askrog and Harvald (9) were among the first to identify increased incidence of spontaneous abortion in women exposed to anesthetic gases and in wives of men exposed to anesthetic gases. Results of a more recent and comprehensive nationwide survey of occupational disease among operating personnel were published in 1974 by American Society of Anesthesiologists (ASA) (2). The results of this study indicate "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 increased risk of congenital abnormalities was also present among the unexposed wives 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."

While several investigators have reported increased rates of resorption in animals, particularly rats, most of these studies involved concentrations of anesthetic gases well above the levels found in occupational exposure. One investigator (19), however, showed increased fetal death rates in two groups of rats following exposure of 1,000 and 100 ppm of nitrous oxide. Doenicke et al (18) concluded from their study of anesthetized pregnant rats that halothane demonstrates an abortive effect directly proportional to the concentration inhaled, again referring to anesthetic concentrations, but nitrous oxide does not produce an abortive effect. Bruce (20) reports no significant difference, including implantations and resorptions per pregnancy, in his exposure of rats to 16 ppm halothane.

Several epidemiological studies that indicate increased spontaneous abortions also indicate an increased rate of congenital abnormalities. The ASA study (2), as well as surveys by Knill-Jones et al (10) and Corbett et al (11) indicated an increased rate of congenital abnormalities in children of women with occupational exposures to anesthetic gases, and to wives of men with similar exposures. While most animal exposures studies have been conducted at anesthetic levels, one study (15,16,17) indicated liver, kidney, and brain tissues changes in pups born to rats exposed to sub-anesthetic concentrations of halothane during pregnancy.

The same epidemiological and toxicological studies that indicated an increase in spontaneous abortion and congenital abnormalities also indicated an increase in liver and kidney abnormalities. This increase, however, was less pronounced in both rate and severity.

In a study published by NIOSH, (7) "nitrous oxide and halothane in respective concentrations as low as 50 parts per million (ppm) and 1.0 ppm, caused measurable decrements in performance on some psychological tests taken by healthy male graduate students. 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 have also been reported (8,12); and damage to cerebral cortical neurons has been seen in rats after subanesthetic exposure to halothane (14). Quimby et al (13) reported permanent learning deficits in rats exposed to anesthetic concentrations of halothane during early development (from conception).

Mortality and epidemiological studies have raised the questions of possible carcinogenicity of anesthetic gases, but sufficient data are lacking to list nitrous oxide, halothane or enflurane as suspected carcinogens.

Literature reviews regarding halothane (4,5,6,21) indicate the most widely accepted mechanism of bio-transformation is the production of trifluoroacetic acid with resulting urinary excretion of trifluoroacetic acid and bromide. The literature regarding enflurane (3,22) does not indicate any one accepted mechanism, but increased serum and urinary fluoride levels were found in patients receiving enflurane anesthesia. While epidemiological and toxicological studies have indicated several symptoms apparently related to sub-anesthetic exposure to anesthetic gases, no cause and effect relationship has yet been shown.

D. EVALUATION RESULTS

Table 1 shows results of the fourteen samples taken for nitrous oxide. Calculations show one veterinarian was exposed to eight-hour time weighted average concentrations of 34 and 33 ppm on two days of sampling, and an anesthetic technician was exposed to 57 and 32 ppm. These averages assume that these people spent the unsampled portion of their day in areas of very low nitrous oxide concentration, as was observed to be the case.

Direct monitoring of nitrous oxide during two procedures on August 24 indicated varying concentrations. Listed below are segments of a canine hysterectomy performed in the large operating room noting the location sampled, the duration and concentration range of that sample. The entire procedure was from approximately 10:00 to 11:00 a.m.

Location	Sample Duration	Nitrous Oxide Concentrations
approximately 1 foot above anesthesia machine, early in procedure	7 minutes	250-500 ppm
near surgeon, leading up to tie-off of ovaries	7 minutes	300-400
near dogs mouth, 5 minutes after ovaries tied off	3 minutes	550-650
above operating table	4 minutes	350-450
near dogs mouth, 1-4 min. before starting to close	3 minutes	300-700
breathing zone of surgeon during close, dog on its own respiration	2 minutes	200
near dogs mouth, not forced respiration	3 minutes	200-250
breathing zone of anesthetic technician final 3 minutes dog was on table	3 minutes	350-500

During a portion of this procedure a quantity of nitrous oxide was released by a defective endotracheal tube. This exposure was disregarded since it was atypical. However, gas that escaped during this time probably resulted in higher readings throughout the rest of the procedure.

Thirty minutes after the dog had been removed from the operating table, the nitrous oxide concentration in the room dropped from approximately 500 ppm to below 25 ppm, and ten minutes later the concentration was below the limit of detection (approximately 5 ppm).

The second procedure monitored for nitrous oxide was performed on a cat and lasted approximately ten minutes. For this procedure a face mask was used to anesthetize the animal. For a four-minute period during the initial administration of anesthetic the concentration of nitrous oxide near the face of the cat was found to range from 500 to greater than 700 ppm. A six-minute period during the procedure found concentrations 175 to 400 ppm in the breathing zone of the surgeon and technician.

Samples for halothane and methoxyflurane ranged from below the limit of detection of current analytical methods (approximately 0.02 ppm) to a maximum of 3.1 ppm for halothane and 0.9 ppm for methoxyflurane. The combined exposure of halogenated anesthetics ranged up to 3.2 ppm, with 3 of the 24 samples being above the 2 ppm level recommended as an occupational exposure limit. These three samples, all taken in the morning of August 22, were 2.2 ppm, 3.2 ppm, and 2.7 ppm and were located on the veterinarian-surgeon, on the anesthetic technician and at a stationary location in the operating room, respectively. All were primarily halothane exposure. Table 2 shows the results of all samples taken for halogenated anesthetic.

General exhaust ventilation in the areas tested appeared to be adequate both from the measurements taken (a flow greater than 2,000 CFM was measured at the system inlet) and from the dissipation of residual anesthetic gas. No measurements of air flow were taken at the local exhaust system designed as a scavenge for the pop-off valve, but the flow of air could be felt on the hand, and given the design of the system, this would seem adequate.

E. Summary and Conclusions

Findings of this evaluation indicate that the veterinarian/surgeon and the anesthesia technician were exposed to concentrations slightly in excess of the recommended standards for both nitrous oxide and halogenated anesthetic on an 8-hour time weighted average basis on the days of this evaluation. One other person, an observer, had an exposure at the recommended standard for halogenated anesthetic.

No other employees were found to be over-exposed to halothane or methoxyflurane. While full shift sampling was not conducted for nitrous oxide on these other employees, testing was done during the times considered to be the highest exposures, and observations of work practices and operating schedules indicates that exposures to nitrous oxide on a time-weighted average basis would be below the recommended standard for technicians and office personnel.

It can be seen from Table 1, however, that nitrous oxide concentrations ranged up to 340 ppm. The fact that time weighted average exposures are so low is due primarily to the short exposure time. The following recommendations should help reduce peak concentrations and consequently time weighted average exposures. This in turn would permit safer long-term exposures should work loads change so that any individual was exposed for more time than is currently standard practice.

V. RECOMMENDATIONS

Since a scavenging system was available and in use during all procedures when inhalation anesthetic was used, and general room circulation is adequate, the majority of the recommendations aimed at reducing waste anesthetic gas concentrations falls into the category of work practices.

Anesthesia equipment should be checked and maintained on a regular basis. Face masks, tubing, breathing bags and endotrachial tubes should be visually checked for cracks and other leak sources. Both high and low pressure components should be leak tested. The high pressure components, from nitrous oxide and oxygen supply up to flow meter control valves, can be tested by applying soap solution to all connections and observing any bubbles. This should be done quarterly. Low pressure components, including breathing bags and tubing, can be tested using the procedure presented in Appendix I of the NIOSH Criteria Document on Waste Anesthetic Gases (1):

(a) Assemble the anesthesia machine as in the usual manner for clinical anesthesia with breathing tubes, Y-piece, breathing bag, and high-pressure hoses or cylinders connected.

(b) Occlude the Y-piece securely with the thumb or palm of hand.

(c) Pressurize the breathing system to 30 cm water, observed on the absorber pressure gauge. This may be accomplished by using the oxygen flush valve.

(d) Add a sufficient flow of oxygen through the low-range flowmeter to maintain a constant pressure of 30 cm water in the breathing system. The oxygen flow required to maintain the pressure is a measure of the leak rate. This test may be abbreviated by using an oxygen flowrate of 100 ml/minute. If pressure in the system increases, the breathing system is below the maximum allowed leak rate.

(e) Determine the presence of check valves downstream from the flowmeters by consulting the manufacturer or a serviceman. These valves must be tested differently. With oxygen flowing as indicated in (d), briefly turn off in turn each flowmeter which is equipped with a check valve until there is a rise in pressure on the absorber gauge. An increase in pressure indicates absence of leakage in the circuit tested. The low pressure leak rate should be below 100 ml per minute.

Small components such as breathing bags and hoses can be leak tested separately by pressurization, immersion in water and observation of any bubbles. In situations where this is not practical, it is recommended that fittings and seals be checked periodically to make sure gaskets and o-rings are in place properly, that connections are tight and not worn, and that moisture or chemical action has not caused corrosion or degradation of materials. Typical places to check, and where leaks have been found in other studies, include the seals at the domed unidirectional valves, seals at the top, bottom and center of the CO_2 absorber, and fittings where the breathing tubes connect to the machine and to the "Y" piece.

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Table I

Nitrous Oxide Concentrations
Mesa Veterinary Hospital
August 22 & 24, 1977
RHE 77-85

Location	Time	Concentration
August 22		
Reception Area	9:20 - 11:00	<5 ppm
Surgical Preparation Area	9:20 - 11:00	50
Veterinarian/Surgeon	9:25 - 10:55	160
Anesthetic Technician	9:20 - 11:00	260
Small Surgery Room	10:15 - 11:00	180
Veterinarian/Surgeon	11:00 - 11:30	60
Anesthetic Technician	11:00 - 11:30	50
Surgical Preparation Area (1-3 hours after procedures)	1:30 - 2:30	<5
August 24		
Anesthetic Technician	9:50 - 11:00	180
Large Surgery Room	10:50 - 11:20	110
Veterinarian/Surgeon	10:00 - 10:40	190
Large Surgery Room	9:55 - 11:35	340
Anesthetic Technician	11:05 - 11:25	130
Veterinarian/Surgeon	10:40 - 11:20	200

Table 2

Halogenated Anesthetic Concentrations

Mesa Veterinary Hospital
August 22 & 24, 1977

Date	Location	Time	Type*	Concentration (ppm) Halothane	Methoxyflurane	Total
8/22	Surgical Prep. Area	10:10-11:30	A	0.9	0.08	1.0
	Small Operating Room	10:15-11:30	A	2.7	<0.08	2.7
	Reception Room Desk	10:10-11:30	A	0.3	<0.05	0.3
	Anesthetic Technician	10:10-11:40	P	3.1	0.1	3.2
	Vet/Surgeon	10:10-11:40	P	2.1	0.1	2.2
	Near Surgery	09:40-11:40	A	0.8	0.1	0.9
	Technician	09:40-11:40	P	0.04	<0.05	0.04
	Vet	01:40-04:30	P	0.2	0.1	0.3
	Treatment Room	01:40-04:30	A	<0.04	0.2	0.2
	Large Operating Room	01:40-04:30	A	<0.04	0.4	0.4
	Vet/Surgeon	01:40-04:30	P	<0.04	0.4	0.4
	Technician	01:40-04:30	P	<0.04	0.5	0.5
8/24	Vet/Surgeon	08:40-11:30	P	0.9	0.1	1.0
	Technician	08:55-11:30	P	0.6	0.2	0.8
	Observer	08:40-11:40	P	1.9	0.3	2.2
	Observer	09:05-11:20	P	1.3	0.2	1.5
	Anesthetic Technician	09:00-11:40	P	1.0	0.2	1.2
	Surgical Prep. Area	09:05-11:30	A	0.8	0.1	0.9
	Technician	01:45-03:45	P	<0.05	0.8	0.8
	Vet/Surgeon	02:20-03:45	P	<0.07	0.9	0.9
	Surgical Prep Area	01:45-03:45	A	<0.05	0.3	0.3
	Large Operating Room	02:20-03:45	A	<0.08	0.9	0.9
	Large Operating Room	03:15-03:45	A	<0.02	0.05	0.05
	Vet	02:55-03:45	P	<0.02	<0.02	<0.04

*A = Area sample
P - Personal Breathing Zone sample