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

HEALTH HAZARD EVALUATION DETERMINATION
REPORT HE 79-5-564

CHILDREN'S HOSPITAL DENTAL DEPARTMENT
CINCINNATI, OHIO

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I. TOXICITY DETERMINATION

An environmental survey was conducted December 14 and 15, 1978 in the Dental Clinic of the Children's Hospital to determine airborne concentrations of waste anesthetic gas (nitrous oxide) to which dental residents and assistants were being exposed. The potential toxicity of waste anesthetic gases, including nitrous oxide, (N_2O), has been demonstrated in animal experiments and epidemiological studies. Present technology does not allow anesthetic gases to be completely eliminated from operating room air without compromising safe anesthetic administrative practices. However, the potential health hazard can be minimized by insuring that specific work practices be followed to reduce leakage of gases, and by establishing scavenging techniques to collect and dispose of waste anesthetic gases. Research has demonstrated that concentration of 50 parts per million (ppm) N_2O can be achieved during routine use. Nitrous oxide concentrations measured at the Children's Dental Clinic ranged from 75 to 3500 ppm during dental procedures.

Recommendations are presented in this report to reduce anesthetic gas concentration to 50 ppm, the level recognized by NIOSH as attainable in dental operatories.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Division of Technical Services, Information Resources 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, Publication Office at the Cincinnati address.

Copies of this report have been sent to:

A) Director, Children's Hospital Dental Department
B) U.S. Department of Labor, Region V
C) NIOSH Region V

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 a dental resident on October 5, 1978. The recognition of the potential health hazard associated with chronic exposure to anesthetic gases was primarily responsible for the health hazard evaluation (HHE) request. It should be noted that no specific health problems were alleged as a result of the anesthetic gas exposures prior to the industrial hygiene survey.

IV. HEALTH HAZARD EVALUATION

A. Process Description

The Children's Dental Clinic occupies approximately one quarter of the third floor of the Children's Hospital Pavilion Building. This clinic consists of nine operatories, one preparation room, a prothesis laboratory, X-ray developing room, library-conference room, a central bay area, a reception office, waiting room, three staff dentist offices and an administration office. Heating and cooling of the area is provided by a central ventilation system. Current staffing of the clinic provides for three staff doctors, nine resident dentists, eight dental assistants, one dental hygienist, three receptionists and one administrator.

Nitrous oxide and oxygen are piped to the operatories from cylinders located in operatory 3-98. The anesthesia machines used by the dentist are supplied with gas by connecting them to outlets located in the walls and counters. Located on the anesthesia machine is a flow meter used for controlling the in-coming nitrous oxide and oxygen. These gases are administered to the patient(s) through flexible tubing terminating in a non-scavenging nosepiece. The major source of N_2O being admitted into the work environment is the non-scavenged nosepiece, although

each fitting in the system as well as cracks in the tubing are a potential for leaks.

B. Evaluation Design

Both breathing zone (BZ) and general area (GA) samples for nitrous oxide were collected using 20 liter mylar bags and MSA Model G* personal sampling pumps. The flow rates on the pumps were adjusted to collect a representative sample during the scheduled operations. The samples were subsequently analyzed on site by infrared spectroscopy. Direct measurements were collected by placing the inlet of the infrared analyzer at a desired point and drawing air via pump into the analyzer. Using this method, short term exposures could be measured and leak sources for N_2O could be detected. Quantitative N_2O measurements were conducted using an analytical wavelength of 4.47 µm and a pathlength of 5.25 meters. Response time for the instrument was 15 to 30 seconds. The lower limit of detection using this mode of operation was ten parts per million (10 ppm). Calibration of the instrument was performed each morning prior to use.

C. Evaluation Criteria

1. Environmental

Presently, NIOSH recommends that no worker be exposed to levels greater than 50 ppm nitrous oxide based on a time weighted average (TWA) for eight hours a day over a 40 hour work week.[1] This recommendation is based primarily on the technology available designed for reducing waste anesthetic gases.

2. Medical Criteria[2]

Until recently, nitrous oxide (N_2O) was considered to be a simple asphyxiant without other significant physiologic effects. However, animal experiments and epidemiologic studies are now providing evidence that show chronic exposure to low concentration of inhalation anesthetics to be a potential health hazard.

The teratogenic effects of N_2O have been demonstrated in developing chicks and rats when pregnant animals were exposed to N_2O in anesthetic concentrations.[3,4] Other animal experiments have shown the embryotoxicity in the rat of chronic exposure to low concentrations of N_2O.[5] Nitrous oxide has also been associated with hematopietic effect, including leucopenia and bone marrow depression.[6]

* Mention of commerical names does not constitute a NIOSH endorsement.

Reports by Vaisman[7], and Askrog and Harvald[8] 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. 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).[9] 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!"

In a study published by NIOSH[10], "nitrous oxide and halothane in respective concentrations as low as 50 parts per million (ppm) and 1.0 ppm, cause 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.[7,11]

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

In an epidemiological study among dentists[12], Cohen et. al. compared exposed persons in that profession who used inhalation anesthetics more than three hours per week with a control group in the same profession who used no inhalation anesthetics in their practice. 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 for the unexposed. These data are statistically significant. This study did not identify the specific anesthetic being used by the dentists surveyed, that is, whether they used N_2O alone or if a halogenated agent was used. However, in a review of that study, NIOSH[13] concludes that "the halogenated anesthetics alone do not explain the positive findings of the survey and that N_2O exposure must be an important contributing factor, if not the principal factor." This conclusion is based on a calculation assuming

that as many as one in ten of the dentists using an inhalation anesthetic employs a halogenated agent. If the actual fraction is less than one in ten, then this conclusion would be even more significant.

D. Evaluation Results and Discussion

The results of both bag samples and direct measurements taken for nitrous oxide at the Children's Dental Hospital are presented in Table I. Levels ranging from < 10 ppm to 15 parts per million were found in the operatories and the receptionist's office area prior to N_2O use. However, concentrations greatly increased in all areas as N_2O use increased. During the application of N_2O, levels ranged from 40 to 3500 ppm. Only 5 of 36 measurements, after application of N_2O, were below the 50 ppm recognized by NIOSH as achievable during dental procedures. The highest levels were recorded in the BZ of the dentists and assistants during the application of N_2O and while the N_2O:O_2 ratio was in excess of 2:4 liters per minute (l/m). Concentrations exceeding 3000 ppm were recorded in operatories where cracked, or loose N_2O breathing hoses were being used. It should be noted that only during the morning hours prior to dental procedures were N_2O levels below the limits of detection (10 ppm). Levels were also significantly lower during the end of the workshift which succeeded N_2O utilization.

Since there was no individual exhaust system in the dental clinic for anesthetic gas removal, the low concentrations measured during the morning and late afternoon were contributed to removal by natural flow of the building's general ventilation system.

E. Summary[13]

The sources of N_2O in the operatory air include leakage from the anesthesia machine, from the nasal mask, and the patient's mouth. Nitrous oxide may also enter the operatory from adjacent rooms via the window, door, air conditioning inlet or from the dental suction machine when the exhaust is not vented to a safe disposal site outside the building.

In the absence of scavenging, the most important source of environmental N_2O is the normal gas flow from the anesthesia machine escaping into the room air via the relief valve and around the perimeter of the nasal mask. A secondary source is the patient himself. At the end of the anesthetic, when the gas is turned off, the approximately 30 liters of N_2O which have been absorbed by the patient are rapidly exhaled. Leakage from the patient also occurs constantly during mouth breathing, conversation, and laughter.

Another important and variable source of N_2O is leakage from the anesthetic machine, both in the high-pressure and low-pressure systems. The high-pressure system includes components located between the high-pressure N_2O source and the flowmeters where leakage occurs in worn wall connectors, loose high-pressure hose connections, and in deformed compression fittings. The low-pressure system includes all parts located between the flowmeters and the patient. Leakage occurs here in loose, defective, or missing gaskets and seals; worn or defective bags and breathing hoses; loosely assembled or deformed slip joints and threaded connections; and in loose flowmeter tubes.

V. RECOMMENDATIONS:

It is assumed that the presence of inhalation anesthetics in the Dental Clinic, even in trace concentrations, are potentially toxic. No "safe" concentration can be defined, but the adverse effects appear dose-related. The most reasonable course, therefore, is to limit personnel exposure. Control measures include informing operatory personnel as to the sources of leakage and instituting programs for anesthetic gas scavenging equipment, maintenance, and air monitoring. Control measures to reduce N_2O levels to the lowest reasonably achievable concentrations should be implemented as follows:

1. Use scavenging equipment such as the nasal mask as described in DHEW (NIOSH) Publication No. 77-140.[1]

2. The venting suction mechanism should be maintained properly outside the building. As it is set up an exhaust suction pump for all dental procedures is located in a storage closet and it is assumed that this suction is exhausted into the wall and directly into a space above the ceiling rather than outdoors.

3. Conversation with the patient should be minimized while administering N_2O.

4. Anesthesia equipment such as hoses, tubing, breathing bags, fittings, etc. should be inspected and tested for leakage on a monthly basis.

5. Where acceptable concentrations of N_2O are not achieved, an air sweep method of removing the gas should be considered. Such a method, as described in Publication DHEW No. 77-171[13], can be designed to carry concentrated anesthetics away from the breathing zone of the operatory personnel by means of a properly located fan.

6. Air monitoring program should be designed and implemented to prove the effectiveness of the control measures.

VI. REFERENCES

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TABLE 1

RESULTS OF AIR SAMPLING FOR NITROUS OXIDE

DATE	SAMPLE TYPE & NUMBER	SAMPLE TIME	LOCATION & DESCRIPTION	NITROUS OXIDE CONCENTRATIONS IN PARTS PER MILLION (PPM)	
12/14/78	BZ-Direct	2:05	RM 3-7 Dentist II N_2O 3 l/m	140 to 900 ppm	
" "	GA-Direct	2:30	RM 3-99 Ambient	80 to 90 ppm	
" "	GA-B,#B-1	13:14-14:15	Reception Office Area	85 ppm	
" "	BZ-B,#A-3	13:15-14:05	Bay Area A Dentist II N_2O 3.5 l/m	410 ppm	
" "	BZ-B,#5	13:35-14:00	RM 3-7 Dentist II N_2O 3 l/m	895 ppm	
" "	GA-B,#E	15:15-15:35	Receptionist Office	75 ppm	
" "	BZ-B,+B-1	14:05-15:05	Bay Area A Dentist II N_2O 2 l/m	>110 ppm	
" "	BZ-Direct	15:00-15:10	RM 3-7 Anest. Outlet 2-3 l/m	750 to 900 ppm	Anest. outlet
" "	GA-Direct	3:40	RM 3-99 Ambient N_2O 2 l/m	50 ppm	
12/15/78	GA-Direct	9:45	Bay Area, before N_2O use	Below limits of detection	
" "	GA-Direct	9:50	RM 3-7, before N_2O use	Below limits of detection	
" "	GA-Direct	9:55	RM 3-93, before N_2O use	Below limits of detection	
" "	GA-Direct	10:00	RM 3-99, before N_2O use	Below limits of detection	
" "	GA-Direct	10:05	RM 3-3, Doorway using 3.5 lpm N_2O	100 to 300 ppm	
" "	BZ-Direct	10:06	RM 3-3, Using 3.5 lpm N_2O Dentist II	850 to 1050 ppm	
" "	BZ-direct	10:25	RM 3-3, Using 2.5 lpm N_2O Dentist II	1000 to 1250 ppm	Loose hoses on equip-ment
" "	BZ-Direct	10:30	RM 3-3, Using 2.3 lpm N_2O Dental Assistant	750 to 1150 ppm	
" "	BZ-Direct	10:40	RM 3-3, Using 2.5 l/m N_2O Dentist II	1100 to 1300 ppm	

TABLE 1 (CONTINUED)

RESULTS OF AIR SAMPLING FOR NITROUS OXIDE

DATE	SAMPLE TYPE & NUMBER	SAMPLE TIME	LOCATION & DESCRIPTION	NITROUS OXIDE CONCENTRATIONS IN PARTS PER MILLION (PPM)	
12/15/78	GA-Direct	10:35	RM 3-3 Doorway using 2 l/m N_2O	250 to 900 ppm	
" "	GA-Direct	10:45	RM 3-9 Receptionist N_2O 2 l/m	80 ppm	
" "	GA-Direct	10:46	RM 3-3, N_2O shut off	10 to 100	
" "	GA-Direct	11:15	RM 3-3, N_2O shut off	15 ppm	
" "	BZ-Direct	11:20	RM 3-8, 1.0 l/m N_2O Dental Assistant	770 ppm	hole in breathing bag
" "	GA-Direct	11:22	RM 3-8, Top of breathing bag	3000 ppm	
" "	BZ-Direct	11:40	Bay Area - B Section	100 to 600 ppm	
" "	BZ-B#A-3	10:10-10:55	RM 3-3, 2 l/m N_2O	>90 ppm	
" "	BZ-B,#H	10:05-10:25	RM 3-3, 2 l/m N_2O	>400 ppm	
" "	GA-Direct	12:00	RM 3-93, Confer. No. N_2O being used	10 ppm	
" "	BZ-B,#Bl	10:35-12:00	Area B using 2 l/m N_2O	>200 ppm	
" "	GA-Direct	12:05	Equipment RM 3-98	10 ppm	
" "	GA-Direct	12:10	RM 3-99 (lunch period)	60 ppm	N_2O not being used
" "	GA-Direct	1:20	RM 3-99 (after lunch)	10 ppm	
" "	BZ-Direct	1:25	RM 3-7 Assistant	1100 to 1300	
" "	BZ-Direct	1:30	RM 3-7 Dentist II	>3500 ppm	Loose hoses
" "	GA-Direct	1:35	RM 3-7 N_2O shut off	550 ppm	

TABLE 1 (CONTINUED)

RESULTS OF AIR SAMPLING FOR NITROUS OXIDE

DATE	SAMPLE TYPE & NUMBER*	SAMPLE TIME	LOCATION & DESCRIPTION	NITROUS OXIDE CONCENTRATIONS IN PARTS PER MILLION (PPM)
12/15/78	GA-B,#B-1	13:35-13:46	RM 3-9 Receptionist Office	90 ppm
" "	BZ-B#E	13:20-13:45	RM 3-7 Dentist II	>950 ppm, Loose hoses on circuit
" "	BZ-Direct	1:40	RM 3-4 Assistant, using 2 l/m N_2O	1050 - 1250
" "	BZ-Direct	1:45	RM 3-4 Dentist I, using 2 l/m N_2O	up to 3500 ppm
" "	GA-Direct	13:55-14:05	RM 3-99 Ambient	40 ppm

* BZ-Direct Breathing Zone sample measured with direct reading instrument.

GA-Direct General Area sample measured with direct reading instrument.