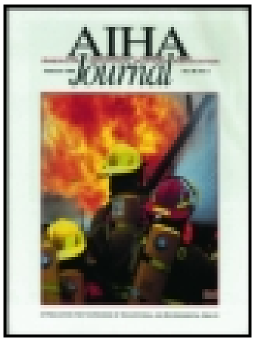

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A Long-Term Study of the Development of N_2O Controls at a Pediatric Dental Facility

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A review is given of National Institute for Occupational Safety and Health (NIOSH) efforts to control N_2O at a pediatric dental operatory from 1978 to the present. Measurements of N_2O concentrations were made on four occasions before and after installation of different controls, using an infrared analyzer. Air velocity and volumetric flow measurements also were taken. Video imaging was done in some cases simultaneously with real-time N_2O measurements to correlate work practices with exposure data. An infrared imaging system was used to identify sources of N_2O. Critical components of resulting recommendations for control include monitoring of N_2O concentrations; use of engineering controls, such as a scavenging mask, an effective dilution ventilation system, and auxiliary exhaust; good work practices; maintenance of the equipment; and worker education. Data presented strongly supports the hypothesis that better implementation of controls leads to reduction of N_2O exposures. N_2O concentrations were reduced by a factor of 61 from their initial levels. The current NIOSH recommended exposure limit of 25 ppm TWA during the time of N_2O administration appears to be achievable.
Keywords: dentist, exposure control, NIOSH, nitrous oxide, pediatric

From 1978 to the present, the National Institute for Occupational Safety and Health (NIOSH) has worked cooperatively with a pediatric dental facility to reduce nitrous oxide (N_2O) exposures to healthy levels.[1–3] The N_2O is administered through a mask that covers only the nose of the child/patient. The pure N_2O is mixed typically with equal parts of oxygen (O_2) to produce a 50–50 mixture of breathing gas for sedative purposes, at the beginning of administration. Later in the operation the dentist usually reduces the percentage N_2O, depending on the patient's needs. The Occupational Safety and Health Administration has not established a permissible exposure limit for N_2O. The American Conference of Governmental Industrial Hygienists (ACGIH®) has established a 50-ppm 8-hour time-weighted average (TWA).[4] NIOSH has a 25-ppm recommended exposure limit (REL).[5] This REL is not an 8-hour TWA, but is determined by measurement of the average concentration of N_2O in the worker's breathing zone, solely during analgesic administration of the N_2O during the dental procedure. Since it takes inhalation of only 12.5 cm^3 of the 50–50 mixture to reach the REL for a typical 25-min operation, very small leaks and very short exposures can lead to overexposure.

To address this problem, NIOSH carried out a health hazard evaluation of N_2O exposures at the dental facility in 1978,[1] followed by three more in-depth studies of the same operation in 1988,[2] 1992,[3] and 1996, after the introduction of new controls. In 1996 the operation had moved to new facilities. (Additional information on control of N_2O in dental facilities and an update on the adverse health effects of N_2O exposure can be found in the NIOSH Technical Report.[6])

In this report, recommendations for control of N_2O exposures in a dental operatory will be presented. The basis for the recommendations was presented in two earlier NIOSH publications, an Alert[7] and a Hazard Control.[8] A comparison will be made of the program of recommendations with actual practices found in the dental operatory during each of the four studies, and the resulting N_2O concentrations will be given. Considerable reduction in N_2O exposures was found as control practices improved, which generally supports the program.

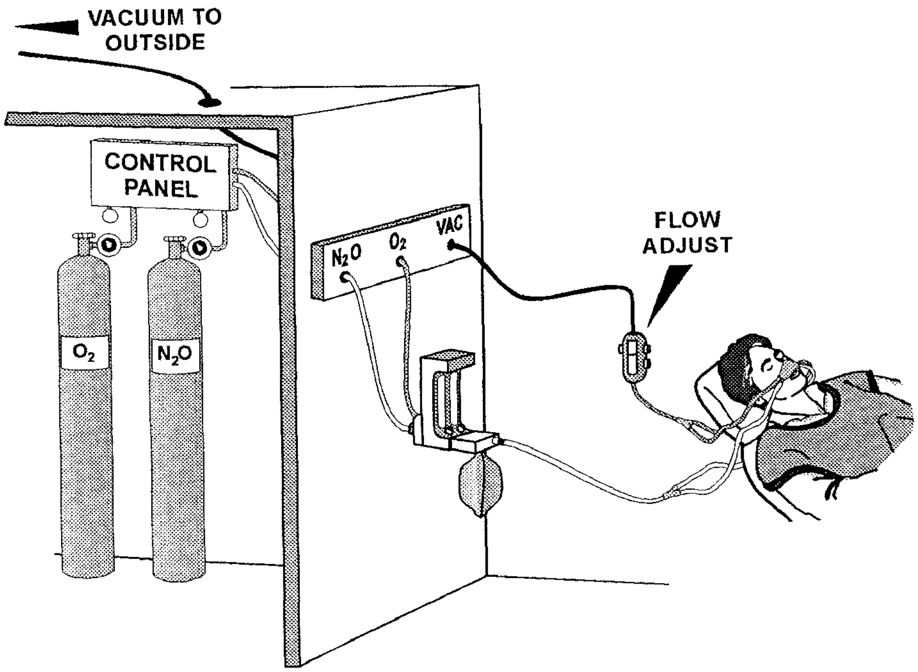

FIGURE 1. Diagram of N_2O delivery and scavenging systems

CONTROL PROGRAM

N_2O Delivery System

N_2O is delivered to the patient in a dental operatory from high-pressure tanks through a series of regulators, tubing, valves, hoses, pressure and flow rate gauges, and finally a mask that fits over the patient's nose (Figure 1). The N_2O is mixed with O_2 in an administration unit, which controls the flow rates of each of these gases. The administration unit includes a reservoir bag, which is filled with the breathing gas and allows the patient to draw this gas on demand, and a relief valve to supply room air to the patient if the flow rate from the unit is too low. Currently, most masks (about 65%) have a built-in local exhaust system for scavenging the waste gas the patient exhales or that escapes from the mask.[9,10]

The exhaust flow is generated by a vacuum pump; a rotameter and valve in the scavenging exhaust line permit the exhaust flow rate to be set.

N_2O Control Program

The following is a summary of key elements that NIOSH has found necessary to achieve acceptably low N_2O exposures. The Alert[7] and Hazard Control[8] contain more specific details.

(1) Monitor airborne concentrations of N_2O.
(2) Use engineering controls: use scavenging masks that fit the patients, maintaining a scavenging flow rate of 45 L/min, and use a flow meter in the scavenging system. Exhaust the air from the operatory's ventilation system outside the building. Use an auxiliary exhaust to improve control of N_2O.
(3) Use good work practices: Inspect the N_2O delivery system thoroughly before each use; check the scavenging flow rate; check the fit of the mask; and encourage nose breathing.
(4) Maintain the equipment: Visually inspect all parts of the N_2O delivery system every day it is used; periodically, leak test the whole system under pressure.
(5) Educate and train the workers.

METHODS

In the four studies described here, the concentration of N_2O was measured using MIRAN® infrared analyzers, models 1A or 1B2 (Foxboro Co., East Bridgewater, Mass.), by method 6600 of the *NIOSH Manual of Analytical Methods.* Typically, the N_2O concentration was measured in the breathing zone of the dentist and dental assistant. For the dentist, real-time N_2O sampling was conducted by drawing air from the dentist's breathing zone through approximately 20 ft of Tygon® tubing into a MIRAN using a diaphragm pump. The breathing zone sample for the dental assistant was obtained similarly, except that it was pumped into a 100 L sample bag at 2 L/min only while N_2O was administered and later analyzed using a MIRAN. The bag sampling technique also was used to take area samples in the operatory, the hallway, and other parts of the facility. Only the breathing zone concentrations are reported here, because they are the most representative of control effectiveness. Also, the breathing zone was the only sampling point repeated consistently through all four studies.

N_2O Control Description and Results

Studies 1–3

The first three studies were conducted at the same location.[1–3] The facility was located on the third floor of one wing of a large hospital. There were two operatories open to the central hallway, one containing three chairs, the other two chairs. Five other operatories with doors contained one chair each. A number of staff offices, a reception/waiting room area, storage, and a laboratory

TABLE I. N_2O Personal Sampling Data, Concentration, ppm

1978		1988		1992		1996	
Dentist	Assistant	Dentist	Assistant	Dentist	Assistant	Dentist	Assistant
165	950	223	120	7.8	14	3	25
410	770	1000	432	59	4.9	17	2
895	1200	904	142	170	22	34	3
110		133	88	33	31	14	5
568		347	44	270	1.4	90	8
1125		290	47	400	50	172	14
1200		160	113	410		42	27
3500						10	3
						22	3
						23	2
							3
Geometric mean							
605	957	331	106	102	12	25	5
Geometric standard deviation*							
3.08	1.25	2.21	2.16	4.41	3.75	3.11	2.63

*Pooled values: 3.17 (28) for dentist, 2.64 (23) for assistant.

made up the rest of the facility. The N_2O was stored in large high-pressure bottles in the back of the facility. Medium-pressure N_2O was piped to each of the operatories, where connection was made to the administration units with quick-connectors. The facility was served by a ventilation system that was shared by all building occupants. The air exhausted from occupied spaces in the building, including the dental facility, was mixed with some fresh air and recirculated throughout the building. The supply and exhaust flow rates were measured during the 1988 survey.

In the first study (1978) there was no provision for scavenging. Excess breathing gas containing N_2O was simply released into the operatory. Although supply and exhaust rates and the amount of fresh air supplied by the building heating, ventilating, and air conditioning (HVAC) system were not measured, it was observed that the N_2O concentration in the operatory rose during administration and remained elevated an hour or more after N_2O use was discontinued, a clear indication of inadequate dilution ventilation. The resulting personal breathing zone (PBZ) concentrations of N_2O, averaged over an operation, were about 605 ppm for the dentist (N=8) and 957 ppm for the dental assistant (N=3), as shown in Table I (geometric means). PBZ concentrations of N_2O exceeding 3000 ppm were recorded in operatories where cracked or loose breathing hoses were being used.

In the second study (1988) a mask with scavenging capability was introduced. However, at the recommended scavenging flow rate the mask made a loud whistling noise, which was irritating to dental personnel and was considered frightening to some of the patients. The flow rate was thus reduced until the whistling became tolerable. As a result, typical scavenging flow rates were around 10 L/min, whereas the recommended rate was 45 L/min. Supply and exhaust flow rates delivered by the HVAC system to the operatories ranged from 0 to 120 ft^3/min, well below the design rates. No other substantive changes were made between the 1978 and the 1988 study. In the 1988 study, PBZ N_2O concentrations averaged 331 ppm for the dentists (N=7) and 105 ppm for the dental assistants (N=7), as shown in Table I.

In the third study (1992), the general ventilation system was the same as described previously, but a new mask was in use that did not whistle at the recommended scavenging flow rate of 45 L/min, and a prototype auxiliary ventilation system was evaluated. The resulting PBZ N_2O concentrations averaged 102 ppm for the dentists (N=7) and 12 ppm for the dental assistants (N=6), as shown in Table I. Turning the auxiliary exhaust system on and off made little or no difference in the dentists' exposure levels. The improvement was attributed to a better-fitting mask and a higher scavenging flow rate. In this study, it was found that the by-pass rotameters, indicating scavenging flow rate, were unreliable in two ways. First, the factory calibration indicated a higher flow than actual. Second, if the flexible tubing that carried the scavenged waste breathing gases was crimped, the rotameter would indicate that the flow had increased when it had actually decreased.

Study 4

In the fourth study (1996) the whole facility was moved to the top floor of a new building. There were no open operatories in the new building. Each operatory had a door and one or two chairs. The general ventilation system was also changed, so that no exhaust air was recirculated, and the supply air was 100% outside air. The supply inlets were located overhead, very close to the dentist's position. Negative pressure relative to the rest of the facility was maintained by exhausting about 20% more air from each operatory than was supplied. The high-pressure supply tanks for

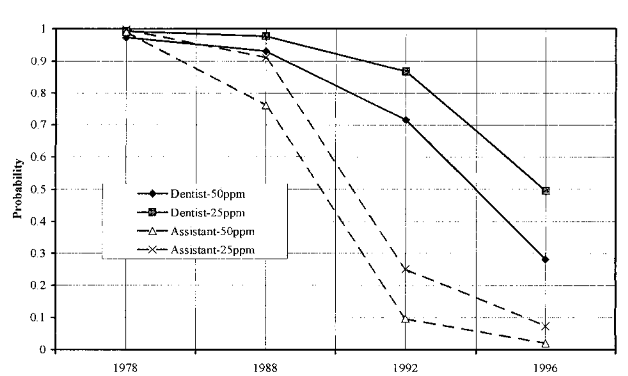

FIGURE 2. Probability of a measurement exceeding limits 25 and 50 ppm

the gases were located in a remote utility area and piped to the operatories at reduced pressure, minimizing exposures caused by high-pressure leakage. The scavenging system was the same as for the third study, but more care was taken to see that it was maintained and used properly. The resulting PBZ N_2O concentrations averaged 25 ppm for the dentists (N=10) and 5 ppm for the dental assistants (N=11), as shown in Table I. Although much improved, 4 of the 11 operations resulted in exposures to the dentist above the NIOSH REL for N_2O of 25 ppm.

DISCUSSION AND CONCLUSIONS

Since 1978, through the application of several control principles, there was a reduction in the dentists' mean exposure to N_2O by a factor of 24 (605 to 25 ppm). The dental assistants' mean exposure was reduced by a factor of 191 (957 to 5 ppm). In 1992 the effect on PBZ concentrations of an auxiliary exhaust system was determined. A relatively small number of runs was made with auxiliary exhaust, and it had no apparent effect. In contrast, it appears that scavenging and general ventilation have a large effect on N_2O exposures. It is possible that the effect of auxiliary exhaust was masked in the 1992 study by the high concentrations resulting from a poor general ventilation system and a spotty implementation of the scavenging system, so that if a similar experiment were conducted in the future, a significant beneficial effect of the auxiliary exhaust might be found.

A statistical analysis of the exposure data for the dentist and the dental assistant (Figure 2) shows that the probability of exceeding a range of N_2O concentrations at or near the NIOSH REL and the ACGIH threshold limit value decreased dramatically over the four studies. This analysis was performed by obtaining pooled estimates for the standard deviation of the dentist and the dental assistant data, each over all four control situations. Means were obtained separately for each control situation and for the dentist and the dental assistant data. The probability that a measurement for either the dentist or dental assistant exceeded a certain threshold can then be calculated using Student's t-distribution.

There were large fluctuations from operation to operation in achieving the final (1996) average value of 25 ppm for the dentists' exposure to N_2O. In a pediatric dental ward, patients are often uncooperative, either because they are too young or afraid or both. Dental personnel can feel pressure just to get the operation done in the most expedient way possible. Thus, the mask frequently is dislodged from its position of best fit for extended periods, leading to leaks during patient exhalation. Also, patient mouth breathing, talking, crying, etc., often cannot be controlled, and N_2O is released into the operatory during these times. In further research an auxiliary local exhaust system is being evaluated that shows promise in controlling these emissions. Also, a prototype mask having a fit less sensitive to position has been under evaluation. At this time, the authors feel very close to an approach capable of consistently controlling N_2O concentrations in the dentist's breathing zone to below the NIOSH REL of 25 ppm. The recommended approach seems already to have accomplished that for dental assistants.

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