CDC Workplace Safety and Health

Assessment of Nitrous Oxide Exposure in a Pediatric Dentistry

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The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].

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Acknowledgments

Abbreviations

ACGIH®	American Conference of Governmental Industrial Hygienists
ACH	Air changes per hour
AIA	American Institute of Architects
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
ft^3	Cubic feet
GM	Geometric mean
HHE	Health hazard evaluation
HVAC	Heating, ventilating, and air conditioning
Lpm	Liters per minute
MDC	Minimum detectable concentration
mL/min	Milliliters per minute
min	Minutes
n	Number of samples
NAICS	North American Industry Classification System
ND	Not detected
NIOSH	National Institute for Occupational Safety and Health
N_2O	Nitrous oxide
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PBZ	Personal breathing zone
PEL	Permissible exposure limit
ppm	Parts per million
REL	Recommended exposure limit
STEL	Short term exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
WEEL	Workplace environmental exposure level

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation at Children's Dentistry at Hamilton Mill in Dacula, Georgia. Management submitted the request because employees were concerned that nitrous oxide (N_2O) exposure may result in infertility and spontaneous abortions.

What NIOSH Did

- We evaluated the dental clinic in March 2005.
- We took short- and long-term air samples for N_2O.
- We talked to employees about health concerns due to possible N_2O exposure.
- We looked at drawings of the building's ventilation system to see if the treatment rooms were getting enough outdoor air.

What NIOSH Found

- Some air samples had N_2O concentrations above the NIOSH recommended exposure limit.
- Employees reported no health problems.
- The treatment rooms did not get enough outdoor air.

What Managers Can Do

- Improve the clinic's ventilation system.
- Use and maintain scavenging systems properly to prevent overexposures to N_2O.
- Check the scavenging system for leaks, particularly after an N_2O cylinder is changed. Fix any leak points as soon as possible.
- Monitor for N_2O in the air of the treatment rooms yearly.
- Train employees on proper work practices, controls, and hazards associated with N_2O exposure.

What Employees Can Do

- Use as little N_2O as possible.
- Stay as far as possible from the mouth of a child treated with N_2O.
- Encourage patients to minimize talking and mouth breathing when N_2O is used in a procedure.

Summary

On March 2, 2005, NIOSH received a management request for an HHE at Children's Dentistry at Hamilton Mill in Dacula, Georgia. The request was submitted in response to employee concerns that continued exposure to N_2O may result in infertility and spontaneous abortions.

Seventeen task-based and eighteen full-shift PBZ air samples for N_2O were collected on two dentists and eight dental assistants during the survey. One of the full-shift samples, collected on a dentist, exceeded the NIOSH REL of 25 ppm as a TWA. Several task-based samples also exceeded the NIOSH REL. Additionally, two full-shift PBZ samples were collected on receptionists in the reception area; neither of these samples contained detectable concentrations of N_2O. The sampling was done over 2 days using passive sampling badges.

NIOSH investigators evaluated dentists' and dental assistants' exposure to N_2O. We found levels of N_2O exposure above the NIOSH recommended exposure limit during several short-term task-based samples and one full-shift sample. We recommend improvements in the use of scavenging units and improvements to the building ventilation for the treatment rooms.

NIOSH engineers reviewed drawings of the clinic's ventilation system. The building ventilation system in place during the NIOSH evaluation did not supply adequate outdoor air to the treatment rooms.

NIOSH physicians invited employees to participate in confidential medical interviews. Employee concerns primarily stemmed from the potential for N_2O to cause infertility, rather than from any adverse health effects being experienced when the HHE request was made. Factors that affect exposures include work practices, the amount of N_2O administered to patients, and the effectiveness of engineering controls.

Keywords: NAICS 621210 (Offices of Dentists), pediatric dentistry, N_2O

Introduction

On March 2, 2005, NIOSH received a management request for an HHE at Children's Dentistry at Hamilton Mill in Dacula, Georgia. The request was submitted in response to employee concerns that continued exposure to N_2O may result in infertility and spontaneous abortions.

On March 30–31, 2005, NIOSH representatives visited the facility. An opening conference with management, employee, and NIOSH representatives was held on March 30, 2005. Following the opening conference, NIOSH investigators assessed dental staff exposures to N_2O and conducted confidential medical interviews.

Workplace Description

At the time of the NIOSH evaluation, the dental clinic had six treatment rooms. Treatment rooms 1, 2, and 3 were in the old wing of the clinic, while the new wing (added on to the building in 2003) housed treatment rooms 4, 5, and 6. Most surgeries were conducted in treatment rooms 1, 2, 4, and 5. Rooms 3 and 6 were reserved for complicated surgeries and emergencies. In addition to standard dentistry equipment, each treatment room had the capability to administer N_2O gas piped from tanks in a separate room and to exhaust the gas with a scavenging unit dedicated to that room. N_2O is administered to patients who need to relax prior to a dental procedure. Scavenging systems were used while patients received N_2O. At the time of the NIOSH evaluation, two dentists and 10 dental assistants were working at the clinic. All employees were women. One dentist was assigned to the old wing and another to the new wing. Each dentist moved back and forth between patients; dental assistants remained with patients throughout their time in the treatment rooms.

Information on the health effects and occupational health limits of N_2O and the appropriate ventilation criteria are presented in Appendix A.

Assessment

Task-based and full-shift PBZ air samples for N_2O were collected on two dentists, eight dental assistants, and two receptionists over 2 days with passive badges containing activated molecular sieves from Assay Technology (Irvine, California). The task-based sampling was conducted during short-term tasks in which dentists or dental assistants attended to patients to whom N_2O was administered. The badges used for sampling collected N_2O gas via diffusion at a rate of 0.75 mL/min. The badges were clipped on the collars of the employees' attire to sample their PBZ air. The badges were returned to Assay Technology for analysis by gas chromatography with electron capture detection. When feasible, multiple task-based, short-term samples were collected on employees who were also being monitored for full-shift exposures. NIOSH engineers reviewed drawings of the clinic's ventilation system. Employees were also invited to participate in confidential medical interviews with NIOSH medical officers.

Results and Discussion

Seventeen task-based and 20 full-shift PBZ air samples were collected during the evaluation. The MDC for the samples was 0.3 ppm, based on a sample collection time of 480 minutes at a rate of 0.75 mL/min. One of the full-shift PBZ samples collected on a dentist exceeded the NIOSH REL of 25 ppm. Several of the task-based samples exceeded this limit. Table 1 summarizes the full-shift and task-based exposures to employees directly exposed to N_2O. The table also shows that the average N_2O exposures of dentists were higher than those of dental assistants. This may be because the dentists' PBZs are closer to the patients' mouths than the dental assistants' PBZs. Tables 2 and 3 compare task-based, short-term samples to full-shift samples on the same employee. In most instances, the task-based samples registered a higher concentration of N_2O than full-shift samples because the task-based samples were specifically collected during periods when the employees were using N_2O on patients. The full-shift samples include periods when N_2O was not used on patients.

Table 1. Summary data on employee exposure to N_2O during dental procedures

Job Title	Full-shift samples			Task-based samples		
	n	GM	Range (ppm)	n	GM	Range (ppm)
Dentists	4	5.96	1.7 – 47	7	72.5	ND – 460
Dental assistants	14	1.68	ND – 25	10	21.1	ND – 200
Receptionists	2	—	ND	0	—	—

Table 2. Full-shift and task-based concentrations of N_2O for dentists and dental assistants, March 30, 2005

Study Participant	Job Title	Treatment Room	Sample Type	Sampling Time (min)	Concentration (ppm)
Employee 1	Dental assistant	4	Full-shift	431	1.5
Employee 2	Dental assistant	6	Full-shift	424	11
Employee 3	Dental assistant	5	Full-shift Task-based	422 19	12 69
Employee 4	Dental assistant	1	Full-shift	436	18
Employee 5	Dental assistant	2	Full-shift	418	25
Employee 6	Dentist	1, 2, 3	Full-shift Task-based	413 7	47 240
Employee 7	Dentist	4, 5, 6	Full-shift Task-based	404 12	1.7 70
Employee 8	Dental assistant	Several	Full-shift	312	4.4
Employee 9	Dental assistant	3	Full-shift	300	ND

Table 3. Full-shift and task-based concentrations of N_2O on dentists, dental assistants and receptionists, March 31, 2005

Study Participant	Job Title	Treatment Room	Sample Type	Sampling Time (min)	Concentration (ppm)
Employee 2	Dental assistant	4	Full-shift	545	ND
			Task-based	31	ND
			Task-based	28	61
Employee 3	Dental assistant	5	Full-shift	484	ND
			Task-based	29	ND
			Task-based	16	65
			Task-based	106	14
Employee 4	Dental assistant	1	Full-shift	361	4.9
			Task-based	27	110
Employee 5	Dental assistant	2	Full-shift	422	ND
			Task-based	47	2.8
			Task-based	45	200
			Task-based	19	ND
Employee 6	Dentist	1, 2, 3	Full-shift	401	2.6
			Task-based	19	ND
			Task-based	30	220
Employee 7	Dentist	4, 5, 6	Full-shift	474	6.0
			Task-based	8	ND
			Task-based	54	460
			Task-based	110	76
Employee 8	Dental assistant	Several	Full-shift	414	ND
Employee 9	Dental assistant	5	Full-shift	451	ND
Employee 10	Dental assistant	1, 2, 3	Full-shift	240	6.5
Employee 11	Receptionist	—	Full-shift	478	ND
Employee 12	Receptionist	—	Full-shift	337	ND

Because of the limited exposure data collected on the dentists, we were not able to discern any meaningful exposure differences between the two dentists. However, we noticed that the dentists had different work practices that may affect their individual exposure to N_2O: (1) one dentist set the flow of N_2O to 30%, while the other started at 20% and increased it as needed; (2) one dentist performed dental procedures with the door open for better ventilation and closed the door if a patient became agitated, while the other almost always closed the door; and (3) one dentist used a magnifying eyepiece to maintain a distance from the patients' mouths, while the other did not.

Review of Ventilation Diagrams

A complete set of "as-built" drawings, supporting documentation, and sequence of operations for the design and operation of the HVAC system were requested to support the design review. We received only a partial set of drawings (dated November 26, 2001); these drawings contained no supporting documentation or sequence of operations. Because of the limited information available, ventilation calculations were performed for two treatment rooms on the older wing of the clinic to provide basic estimates and to determine whether the treatment rooms had adequate ventilation and adequate supply of outdoor air. Based on the drawing notes, the design intent was to mechanically supply 20 cfm of outdoor air per person. Ideally, this design intent should be evaluated with information on the occupancy level for each room in the facility; however, in this case, occupancy information was not available and had to be assumed for the review. If we assume maximum design occupancy of three persons (patient, dentist, assistant), each room would require a minimum of 60 cfm of outdoor air to meet the 20 cfm of outdoor air per person design intent stated on page M-1 of the drawings. The actual design fails to meet this requirement as the 12.4 cfm of outdoor air delivered to each room is less than that required for even one person (Appendix B).

For each room, the calculated ACHs were 0.8 ACH of outdoor air and 6.7 ACH of total ventilation. These ACH rates failed to meet either AIA or ASHRAE requirements for operating rooms, and they failed to meet ASHRAE's 2 ACH outdoor air requirements for treatment rooms (Appendix B) [AIA 2006; ASHRAE 2007].

NIOSH [1994] recommends using scavenging and/or local exhaust equipment and a negative pressure air balance (i.e., more air is exhausted from the room than is supplied to the room) within rooms where N_2O is used. Because no documentation was provided on the scavenging or auxiliary exhaust systems used at this facility, we are unable to comment on their selection or operation. We were provided no information regarding the exhaust volumes from each room, so we cannot assess room pressurization from the ventilation drawings. Clearly, however, air from these rooms was recirculated to other areas of the building, potentially exposing others (patients, staff, and children) to anesthetic gas.

Employee Interviews

While all staff members were offered an interview with the NIOSH medical officer to discuss health concerns related to potential N_2O exposures, a limited number accepted. No fertility or other diagnosed medical problems were reported. Three employees reported symptoms. One had an occasional episode of temporary paresthesia in the hands that resolved. Two others reported an occasional headache, but did not know if the headaches were caused by N_2O or the routine work stress of dealing with pediatric patients. None of the three sought medical evaluation.

CONCLUSIONS

Based on sampling conducted, N_2O exposures exceeded the NIOSH REL of 25 ppm, particularly during short-term sampling. Factors that affect exposures include work practices, use of engineering controls, and the amount of N_2O administered to patients. The ventilation systems in place at the time of the evaluation were inadequate in supplying outdoor air to the treatment rooms. Employee concerns primarily stemmed from the potential for N_2O to cause infertility, and not from any adverse health effects employees experienced.

RECOMMENDATIONS

Based on our findings, we recommend the actions listed below to create a more healthful workplace. We encourage Children's Dentistry at Hamilton Mill to use a labor-management health and safety committee or working group to discuss the recommendations in this report and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at Children's Dentistry at Hamilton Mill. Our recommendations are based on the hierarchy of controls approach (Appendix A: Occupational Exposure Limits and Health Effects). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and/or personal protective equipment may be needed.

Elimination and Substitution

Elimination or substitution of a toxic/hazardous process or material is a highly effective means for reducing hazards. Incorporating this strategy into the design or development phase of a project, commonly referred to as "prevention through design," is most effective because it reduces the need for additional controls in the future. Eliminating N_2O use is not feasible as a control method because of its requirement as an anesthetic gas, so the use of engineering controls as discussed below is the preferred primary recommendation for controlling such exposures.

Engineering Controls

Engineering controls reduce exposures to employees by removing the hazard from the process or placing a barrier between the hazard and the employee. Engineering controls are effective at protecting employees without placing primary responsibility of implementation on the employee.

1. Use and maintain the N_2O scavenging units as recommended by NIOSH. In the 1994 hazard alert "Controlling Exposures to Nitrous Oxide During Anesthetic Administration" [NIOSH 1994 a] and 1994 technical report "Control of Nitrous Oxide in Dental Operatories" [NIOSH 1994 b], NIOSH recommends a variety of specific actions to be implemented in conjunction with the use of scavenging units to control exposures to N_2O, including the following:

    a. Conduct a comprehensive leak check of the N_2O delivery system and repair all leak points. Implement a preventive maintenance program that includes reviewing the N_2O delivery system and conducting periodic leak checks. Every time a cylinder is changed, the connections should be checked for leaks. Visually inspect all N_2O equipment for worn parts, cracks, holes, or tears. Following visual inspection, leak test the equipment and connections. This is best performed with an infrared spectrophotometer, but can also be accomplished by applying a soap solution to the fittings and observing for bubbles, which indicate the presence of a leak.

    b. Monitor ambient N_2O levels annually. Monitoring data should also be obtained whenever the N_2O delivery system is modified to ensure exposures are maintained below the NIOSH REL.

c. Ensure the scavenging system exhaust rates are approximately 45 Lpm. A flow meter connected to the scavenging system vacuum line and visible to dental personnel would allow them to monitor the flow rate.

d. Ensure the scavenging system is always on when N_2O is used. All exhaust air from the scavenging units should be vented directly outside.

2. Hire a ventilation engineer familiar with healthcare facilities to configure the HVAC system so that the treatment rooms have adequate ventilation and that potentially contaminated air from the treatment rooms is not recirculated to other portions of the facility. Specific ventilation recommendations include:

   a. Use supply register louvers in the ceilings that are designed so that outdoor supply air is directed toward the dental chair. This will maximize the ability to provide mixing and dilution of the air in the operatory. Exhaust air vents ideally should be at or near the floor.

   b. Increase room airflow if the concentration of N_2O is above 25 ppm for dental personnel for further mixing and dilution of the room air.

   c. Exhaust contaminated air directly outdoors away from windows, doors, and HVAC air intakes. The recirculation of operatory air is not recommended.

   d. Maintain a negative pressure differential between the operatory room and surrounding areas. In such a situation, more air is exhausted than supplied in the operatory rooms, prohibiting the flow of N_2O-containing air from circulating into surrounding rooms.

Administrative Controls

Administrative controls are management-dictated work practices and policies to reduce or prevent exposures to workplace hazards. The effectiveness of administrative changes in work practices for controlling workplace hazards is dependent on management commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that control policies and procedures are not circumvented in the name of convenience or production.

1. Encourage dentists to adopt work practices that lower their exposure to N_2O. These practices include limiting the use

Recommendations (continued)

of N_2O as much as possible, using the lowest level of N_2O possible, and maintaining the furthest distance possible from the patient's mouth. The magnifying eyepiece used by one of the dentists in this evaluation may be a means to achieve this. Encouraging patients to minimize talking and mouth-breathing during dental surgery also helps to minimize potential exposures.

2. Management should ensure that all staff members who administer N_2O are trained on potential hazards. Such training includes recognizing the health effects associated with exposures to N_2O and training on proper work practices and use of engineering controls to reduce N_2O concentrations.

References

AIA Academy of Architecture for Health, Facility Guidelines Institute, and United States Department of Health and Human Services [2006]. Guidelines for design and construction of health care facilities. 2006 ed. Washington, DC: American Institute of Architects Press.

ASHRAE [2007]. Health care facilities. In: 2007 ASHRAE handbook: heating, ventilating, and air-conditioning applications. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

NIOSH [1994 a]. NIOSH alert: Controlling exposures to nitrous oxide during anesthetic administration. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 1994–100.

NIOSH [1994 b]. NIOSH Technical report: control of nitrous oxide in dental operatories. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 1994–129.

Appendix A: Occupational Health Limits and Health Effects

In evaluating the hazards posed by workplace exposures, NIOSH investigators use both mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents as a guide for making recommendations. OELs have been developed by federal agencies and safety and health organizations to prevent the occurrence of adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. However, not all employees will be protected from adverse health effects even 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 employee to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Also, some substances can be absorbed by direct contact with the skin and mucous membranes in addition to being inhaled, which contributes to the individual's overall exposure.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended STEL or ceiling values where health effects are caused by exposures over a short period. Unless otherwise noted, the STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday, and the ceiling limit is an exposure that should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits, while others are recommendations. The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits enforceable in workplaces covered under the Occupational Safety and Health Act. NIOSH RELs are recommendations based on a critical review of the scientific and technical information available on a given hazard and the adequacy of methods to identify and control the hazard. NIOSH RELs can be found in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2005]. NIOSH also recommends different types of risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects from these hazards. Other OELs that are commonly used and cited in the United States include the TLVs recommended by ACGIH, a professional organization, and the WEELs recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed by committee members of these associations from a review of the published, peer-reviewed literature. They are not consensus standards. ACGIH TLVs are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2009]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2009].

Outside the United States, OELs have been established by various agencies and organizations and include both legal and recommended limits. Since 2006, the Berufsgenossenschaftliches Institut für Arbeitsschutz (German Institute for Occupational Safety and Health) has maintained a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States available at http://www.dguv.de/bgia/en/gestis/limit_values/index.jsp. The database contains international limits for over 1250 hazardous substances and is updated annually.

Employers should understand that not all hazardous chemicals have specific OSHA PELs, and for some agents the legally enforceable and recommended limits may not reflect current health-based information. However, an employer is still required by OSHA to protect its employees from hazards even in the absence of a specific OSHA PEL. OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. Thus, NIOSH investigators encourage employers to make use of other OELs when making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminate or minimize identified workplace hazards. This includes, in order of preference, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health that focuses resources on exposure controls by describing how a risk needs to be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement the OELs, when available.

Nitrous Oxide

N_2O has been used as an anesthetic agent since 1844 and is often used in conjunction with other anesthetic gases [ACGIH 2009]. However, with the development of more effective local anesthetics, N_2O is now used primarily to relieve anxiety in patients [Frost 1985]. For many years, the only adverse health effects associated with exposure to N_2O have been those of asphyxiation when N_2O physically displaces oxygen, creating an oxygen insufficiency [Hathaway and Proctor 2004; ACGIH 2009]. However, some laboratory studies have also shown adverse reproductive effects (smaller litter, increased incidence of fetal resorption and skeletal anomalies) among rats exposed to high (e.g., 1000 ppm or greater) N_2O concentrations during the early stages of pregnancy [Viera et al. 1980]. Human studies have reported a higher than expected incidence of spontaneous abortions among female workers directly exposed to N_2O and other anesthetic gases [Cohen et al. 1975]. Other studies suggest the incidence of congenital abnormalities and spontaneous abortion is slightly higher in the offspring of wives of exposed dentists, as well as reduced fertility in women occupationally exposed [Cohen et al. 1980; Rowland et al. 1992]. It has also been suggested that mood factors (sleepiness, mental tiredness, etc.) may increase following exposures to as low as 50 ppm [Venables et al. 1983]. In many of these human studies, exposure concentrations are poorly defined and dose-response relationships are difficult to identify.

OSHA has not established a PEL for N_2O. The NIOSH REL is 25 ppm averaged over the duration of anesthetic administration. The NIOSH REL is based on a report of decrements in audiovisual tasks following exposure at 50 ppm and is intended to prevent decreases in mental performance, audiovisual ability, and manual dexterity during exposures to N_2O [NIOSH 1977; NIOSH 1994]. Additionally, concern for reproductive effects such as reduced fertility; spontaneous abortion; and neurological, renal, and liver disease has led NIOSH to recommend minimizing worker exposures [NIOSH 1994]. ACGIH has recommended an 8-hour TLV-TWA of 50 ppm [ACGIH 2009]. The ACGIH TLV-TWA is based on prevention of embryo-fetal toxicity (spontaneous abortion) in humans and significant decrements in human cognitive functions.

Measures for controlling exposures to N_2O in dental operatories include effective scavenging devices, proper equipment, maintenance and routine leak checks of the N_2O delivery system, and good work practices on the part of the dentist and assistants. Scavenging systems to control N_2O at the point of use is the preferred method. A common scavenging system design is the "mask within a mask" unit, with tubes supplying oxygen and N_2O to the inside of the interior mask, and two tubes ventilating the space between the two masks (where the patient exhales). The recommended flow rate for this type of system, shown in figure A1, is 45 Lpm [NIOSH 1977].

These types of scavenging systems, while shown effective in reducing anesthetic gas exposure, do not consistently reduce N_2O to concentrations below the NIOSH REL of 25 ppm [NIOSH 1990]. Additional auxiliary ventilation has shown mixed results [Micklesen 1993]. Once ventilated, the collected anesthetic gas must be properly vented to a point away from personnel. Nonrecirculating air-conditioning systems, the central office suction system, and a separate duct system have successfully been used to accomplish this [NIOSH 1977]. Complete descriptions of scavenging systems, proper maintenance protocols, and work practices are detailed in the NIOSH *Criteria Document on Waste Anesthetic Gases* [NIOSH 1977].

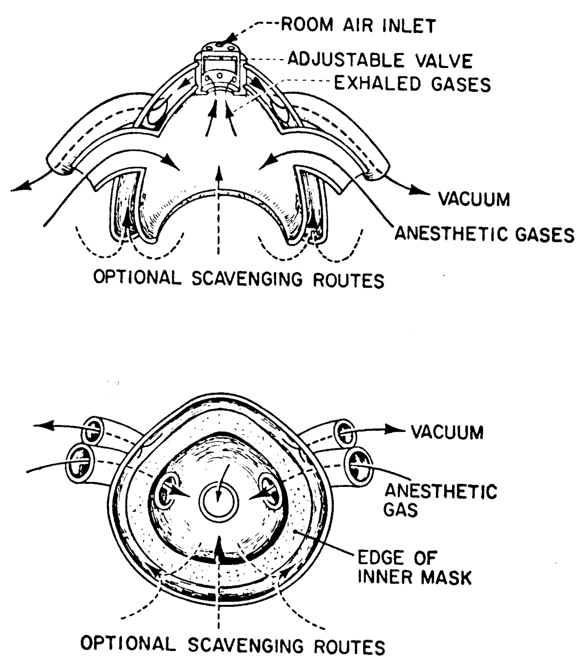

Figure A1. Scavenging system mask airflow

Design and Operational Criteria of the Ventilation System

Proper ventilation of dental operatory rooms is important because of the types of surgical procedures performed and the anesthetic gases used in them. Therefore, appropriate ventilation design criteria should be considered. These criteria include the *Guidelines for Design and Construction of Health Care Facilities* published by the AIA and the Health Care Facilities chapter of the *ASHRAE Handbook: HVAC Applications* [AIA 2006; ASHRAE 2007]. When anesthetic gases are used and surgical procedures occur, the most appropriate ventilation criteria in these guidelines are those identified for "operating rooms." For less invasive procedures performed without anesthetic gases, the criteria identified for "treatment rooms" are most appropriate. In the AIA Guidelines, Table 2.1-2 shows a minimum ventilation requirement of 6 ACH of total ventilation (outdoor air plus recirculated air) for treatment rooms and a minimum ventilation requirement of 15 ACH for "operating/surgical cystoscopic rooms" with a minimum of 3 ACH of outdoor air [AIA 2006]. (2001 AIA guidelines published at the time of the development of the ventilation system drawings included identical requirements.) ASHRAE's *HVAC Applications Handbook* includes a similar table (Table 3) of ventilation requirements. The ASHRAE recommendation in this table for treatment rooms is also 6 ACH of total ventilation. However, ASHRAE also stipulates a minimum of 2 air changes of outdoor air per hour. The ASHRAE recommendations for operating rooms (recirculating HVAC design) are a minimum of 20 ACH of total ventilation with a minimum of 4 ACH of outdoor air [ASHRAE 2007]. Both the AIA and ASHRAE design criteria state that a separate air exhaust system or a scavenging system is required when anesthetic gases are used [AIA 2006; ASHRAE 2007].

ANSI/ASHRAE also publishes *Standard 62: Ventilation for Acceptable Indoor Air Quality*, which provides guidelines on suitable outdoor air requirements for ventilation rates in healthcare facilities. Current and past versions of this standard indicate requirements of 15 cfm of outdoor air per person for medical procedure rooms of healthcare facilities and 30 cfm of outdoor air per person for operating rooms [ASHRAE 1999; ANSI/ASHRAE 2007].

References

ACGIH [2009]. 2009 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

AIHA [2009]. AIHA 2009 Emergency response planning guidelines (ERPG) & workplace environmental exposure levels (WEEL) handbook. Fairfax, VA: American Industrial Hygiene Association.

AIA Academy of Architecture for Health, Facility Guidelines Institute, and United States Department of Health and Human Services [2006]. Guidelines for design and construction of health care facilities. 2006 ed. Washington, DC: American Institute of Architects Press.

ASHRAE [1999]. Ventilation for acceptable indoor air quality. American Society of Heating, Refrigerating and Air-Conditioning Engineers standard 62–1999. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

ASHRAE [2007]. Health care facilities. In: 2007 ASHRAE handbook : heating, ventilating, and air-conditioning applications. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ANSI/ASHRAE [2007]. Ventilation for acceptable indoor air quality. American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers standard 62.1–2007. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

CFR. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Cohen E, Brown B, Bruce D, Cascorbi H, Corbett T, Jones T, Whitcher C [1975]. A survey of anesthetic health hazards among dentists. J Am Dent Assoc *90*(6):1291–1296.

Cohen E, Brown B, Wu J, Whitcher C, Brodsky J, Gift H, Greenfield W, Jones T, Driscoll E [1980]. Occupational disease in dentistry and chronic exposure to trace anesthetic gases. J Am Dent Assoc *101*(1):21–31.

Frost A [1985]. A history of nitrous oxide. In: Eger E II, ed. Nitrous oxide. New York: Elsevier, pp. 1–22.

Hathaway GJ, Proctor NH [2004]. Chemical hazards of the workplace, 5th ed. Hoboken, NJ: John Wiley & Sons, Inc.

Micklesen R, Jacobs D, Jensen P, Middendorf P, O'Brien D, Fischbach T, Beasley A [1993]. Auxiliary ventilation for the control of nitrous oxide in a dental clinic. Appl Occup Environ Hyg *8*(6):564–570.

NIOSH [1977]. Criteria for a recommended standard: occupational exposure to waste anesthetic gases and vapors. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77–140.

NIOSH [1990]. In-depth survey report: control of anesthetic gases in dental operators at University of California at San Francisco, Oral Surgical Dental Clinic. U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Physical Science and Engineering, Engineering Control Technology Branch. NIOSH Report ECTB 166–12b.

NIOSH [1994]. NIOSH Alert: Controlling exposures to nitrous oxide during anesthetic administration. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 1994–100.

NIOSH [2005]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005–149. [http://www.cdc.gov/niosh/npg/]. Date accessed: December 2009.

Rowland A, Baird D, Weinberg C, Shore D, Shy C, Wilcox A [1992]. Reduced fertility among women employed as dental assistants exposed to high levels of nitrous oxide. New Engl J Med *327*(14):993–997.

Venables H, Cherry N, Waldron H, Buck L, Edling C, Wilson H [1983]. Effects of trace levels of nitrous oxide on psychomotor performance. Scand J Work Environ Health *9*(5):391–396.

Vieira E, Cleaton-Jones P, Austin J, Moyes D, Shaw R [1980]. Effects of low concentrations of nitrous oxide on rat fetuses. Anesth Anal *59*(3):175–177.

Appendix B: Ventilation Assessment of Dental Clinic

On page M-1 of the drawings dated November 26, 2001, two 4-ton rooftop units are identified to supply conditioned air for 14 rooms plus ancillary areas (hallways, closets, entryways). The two rooftop units are labeled rooftop unit A (RTU-A) and rooftop unit B (RTU-B). The total ventilation capacity and the percentage of outdoor air for each unit are summarized below.

RTU-A:

- Total cfm provided from the unit = 1610 cfm
- From bullet # 2 under Mechanical Equipment description: "Existing rooftop units (RTU-A) shall have coils cleaned and new filters provided before and after construction. Set outside air to 200 cfm."
- Total outdoor air for unit A expressed in percentage:

% Outdoor Air = 200 cfm / 1610 cfm = 0.1242 or 12.42%

RTU-B:

- Total cfm provided from the unit = 1600 cfm
- From bullet # 2 under Mechanical Equipment description: "Existing rooftop units (RTU-A) shall have coils cleaned and new filters provided before and after construction. Set outside air to 200 cfm."
- Total outdoor air for unit B expressed in percentage:

% Outdoor Air = 200 cfm / 1600 cfm = 0.125 or 12.5%

For summary discussion purposes, a more detailed analysis is provided below for rooms identified as Treatment Room 3 and Treatment Room 4 (Analysis B-1). Ventilation is supplied to these rooms by RTU-A.

Analysis B-1: Analysis of Air Changes per Hour in Treatment Rooms 3 and 4

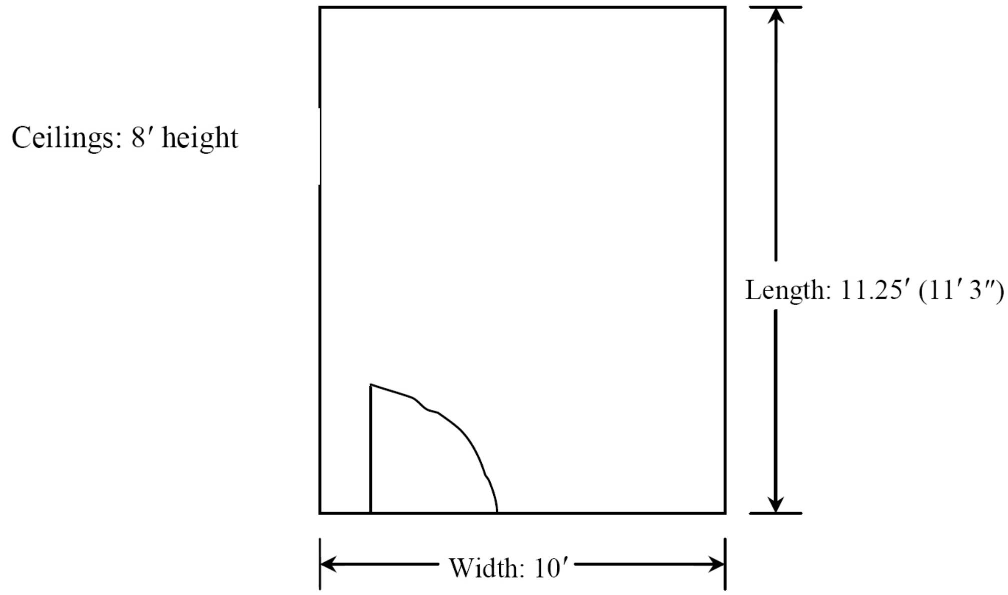

Figure B-1. Dimensions of Treatment Rooms 3 and 4

- Volume of each room = $11.25\text{ ft} \times 10\text{ ft} \times 8\text{ ft} = 900\text{ ft}^3$
- Supply Air for Treatment Room 3 and Treatment Room 4 = 100 cfm each
- Air changes per hour (ACH):

$$\text{ACH} = {}^{100\text{ ft}^3}/_{\text{min}} \times {}^{60\text{ min}}/_{\text{hour}} \times {}^{1\text{ air change}}/_{900\text{ ft}^3} = 6.666\text{ ACH}$$

- From previous calculations, the total outdoor air for RTU-A is 12.42%

$$0.1242 \times 100\text{ cfm} = 12.42\text{ cfm (total outdoor air)}$$

- Air changes per hour of outdoor air ($\text{ACH}_{outdoor}$):

$$\text{ACH}_{outdoor} = {}^{12.42\text{ ft}^3}/_{\text{min}} \times {}^{60\text{ min}}/_{\text{hour}} \times {}^{1\text{ air change}}/_{900\text{ ft}^3} = 0.828\text{ ACH}_{outdoor}$$

Acknowledgments and Availability of Report

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