HETA 94-0017-2394
FEBRUARY 1994
DR. GAMMUCHIA'S DENTAL OFFICE
APOPKA, FLORIDA

NIOSH INVESTIGATOR:
John Decker, M.S.

Summary

In response to an employee request, the National Institute for Occupational Safety and Health (NIOSH) conducted an evaluation of indoor environmental quality and exposures to nitrous oxide and glutaraldehyde at Dr. Gammuchia's dental office on November 29-30, 1993. The requestors asked NIOSH to determine if symptoms experienced by some employees in the building (sinusitis, headaches, fatigue, dizziness, inability to concentrate, nausea, irritation) were possibly related to their work environment. Concerns mentioned in the request included possible exposures to chemicals used in the dental office and microbiological contaminants from the ventilation system.

Exposures to nitrous oxide exceeded the NIOSH Recommended Exposure Limit (REL) for all activities assessed in the dental office. Although the nitrous oxide administration masks were equipped to scavenge waste nitrous oxide, a vacuum system to activate the scavenging system had not been installed. Real-time exposure monitoring was conducted for five procedures. Personal exposures ranged from 225 to 1730 parts per million (ppm) nitrous oxide, expressed as a time-weighted average (TWA) over the duration of anesthetic administration. The NIOSH REL for nitrous oxide is 25 ppm.

Three area air samples for glutaraldehyde vapor were collected. Two samples collected in the sterilization room had concentrations of 0.01 ppm glutaraldehyde. One sample collected in the reception office had no detectable glutaraldehyde. The results indicated negligible contamination of the building with glutaraldehyde vapor. Exposures in excess of the NIOSH Ceiling limit of 0.2 ppm glutaraldehyde vapor probably do not occur under current usage conditions.

The four heat pump units serving the dental building did not have provision for outside air intake. Additionally, the units had an unpleasant odor, probably the result of water-damaged insulation inside the units.

A potential health hazard from over-exposure to nitrous oxide, but not glutaraldehyde, was determined on the day of the NIOSH evaluation. Other identified problems included no provision for outside air and odors emanating from the heat pumps. To reduce nitrous oxide exposures and improve general indoor environmental quality, the following recommendations are discussed in this report: installation of a vacuum system to remove waste nitrous oxide, improvement of work practices related to nitrous oxide administration, replacement of water-damaged insulation in the heat pumps, and addition of outside air intakes on the heat pumps.

KEYWORDS: SIC 8021 (Offices and Clinics of Dentists) nitrous oxide, waste anesthetic gas, ventilation, scavengers, headaches, fatigue, indoor environmental quality, microbiological contamination

Introduction

On October 15, 1993, NIOSH received an employee request for a health hazard evaluation at Dr. Gammuchia's dental office in Apopka, Florida. The requestors asked NIOSH to determine if symptoms experienced by some employees in the building (sinusitis, headaches, fatigue, dizziness, inability to concentrate, nausea, irritation) were possibly related to their work environment. Concerns mentioned in the request included potential exposures to chemicals used in the dental office and microbiological contaminants from the ventilation system. In response to this request, NIOSH conducted an industrial hygiene evaluation on November 29-30, 1993.

Background

The dental office building is a one-story, brick frame building constructed over a dirt crawl space. The building has approximately 2,500 square feet of floor space and is about 12 years old. In July 1993, the roof was replaced because of water leakage (part of the roof is flat). Most of the building is carpeted. None of the windows can be opened.

Approximately 6-9 employees work in the facility at any given time. The dental office area has four operatories (one room is used almost exclusively by a dental hygienist), a laboratory area, a sterilization area, a dark room, the front office, and supply room. Twenty to 40 patients are seen per day. There are no other tenants in the building (one section is vacant). Smoking is not permitted.

All four operatories are equipped for nitrous oxide administration. Up to 40% of patients receive nitrous oxide. The decision to use nitrous oxide is dependent on the patient and the type of procedure. Although the administration masks have provision for scavenging, the units are not connected to a powered vacuum system or exhaust fan. One operatory is equipped with a Porter/Brown® double mask, while the other three have older Porter® masks (designed to scavenge through the exhalation valve). On three units, the exhaust tubing leads to the crawl space; on one unit, the tubing simply lays on the floor (not connected to crawl space). Dental office personnel believed that the nitrous oxide would diffuse through the exhaust tubing into the crawl space because nitrous oxide is denser than air. According to office personnel, about one tank of nitrous oxide is used per month. The nitrous oxide tanks are located in a separate room equipped with passive outdoor ventilation (louvered vents to outside).

The sterilization area was moved to the building's vacant area (mentioned above) because some chemicals (glutaraldehyde and formaldehyde) reportedly were causing irritant symptoms among employees. The Chemclave 5000® sterilizer, which uses a formaldehyde-containing solution (Harvey Vapo-Steril®, 0.23% formaldehyde), was discontinued recently because of continuing employee complaints. This sterilizer vented directly into the general office air. A steam sterilizer is now used, and use of the formaldehyde product has been discontinued. Additionally, the Cetylcide-G® solution (50% glutaraldehyde) was substituted with Cidex Plus® (3.2% glutaraldehyde). Employees stated that these changes have made a dramatic improvement in air quality.

The building is served by four heat pumps located on the roof. Air is distributed to the building through ductwork with interior fiberglass acoustical lining. The return air system is also ducted.

The heat pumps do not have air filters and have no provision for outside air intake. Residential-type electrostatic air filters are located at the return duct vent inside the building. In July 1993, the heat pumps were visually inspected by dental office personnel and Patriot Air and Engineering, Inc., Altamonte Springs, Florida. According to the service receipt, at least two heat pumps had severe mold growth and plugged coils. Mold growth was also found on wet insulation inside the units. Photographs taken by dental office personal confirmed the poor condition of the units. In July-August 1993 the coils were cleaned and drain pipes were added to reduce the water accumulation problem in the drain pans. Apparently, there were no drain pipes previously.

Evaluation Methods

The NIOSH evaluation consisted of the following: (1) a review of background information regarding the problems experienced and suspected causes; (2) a review of procedures used for nitrous oxide, glutaraldehyde, and other chemicals; (3) a review of information regarding design and previous problems in the building heating, ventilating, and air-conditioning (HVAC) systems; and (4) an on-site evaluation at the facility, including air sampling for nitrous oxide and glutaraldehyde.

Nitrous Oxide

A Brüel & Kjær Type 1302 direct reading multi-gas monitor was used to measure nitrous oxide concentrations during the period of administration. The principle of detection is infrared absorption at a specific wavelength with subsequent analysis via the photoacoustic effect. The monitor, which records nitrous oxide concentrations in parts per million (ppm) approximately every minute. Calibration was last verified at the Brüel & Kjær laboratory in Decatur, Georgia, on September 14, 1993. According to Brüel & Kjær literature, the instrument has a limit of detection of 0.025 ppm when using the #0985 filter.

Personal samples were obtained by attaching the sample tube inlet (13-foot polytetrafluoroethylene tube) of the Brüel & Kjær monitor to the collar of the individual being monitored. Monitoring was conducted through the entire procedure. Personal exposures from three procedures were evaluated (dentist-tooth extraction, assistant-acrylic resin filling, dental hygienist-teeth cleaning). In addition to monitoring in the continuous sampling mode, air sampling bags were also used to collect samples from a dental assistant during an extraction and a dental hygienist during teeth cleaning. These bags were filled using a portable air sampling pump and subsequently analyzed with the Brüel & Kjær monitor. When using the bag sample technique, the inlet tube of the air sampling pump was attached to the collar of the individual being monitored and the outlet of the pump was connected via plastic tubing to the sample collection bag.

Glutaraldehyde

Three area air samples for glutaraldehyde were collected with treated silica gel sorbent tubes (SKC #226-119) using SKC model 223 low-flow sampling pumps. The glutaraldehyde vapor reacts with the dinitrophenylhydrazine to yield glutaraldehyde dinitrophenylhydrazone. This derivative is necessary to provide sample stability and contribute a chromophore for ultraviolet detection during analysis of the samples.

Two samples were collected in the sterilization room at breathing-zone height (5 feet above floor) over the glutaraldehyde solutions. One sample was collected in the front office area. The sampling rate was approximately 100 milliliters per minute (mL/min). The pumps were equipped with a pump stroke counter, and the number of strokes necessary to pull a known volume of air was determined. This information was used to calculate an air volume per pump or stroke "K" factor. The pump stroke count was recorded before and after sampling and the difference used to calculate the total volume of air sampled.

At the time of the NIOSH visit, employees did not attribute their symptoms to activities directly involving the glutaraldehyde solutions. However, some employees thought their symptoms could be related to long-term, low-dose exposures to glutaraldehyde vapor in the building. Therefore, sampling times of approximately 5 hours were used (rather than a 15-minute sample generally used to determine ceiling concentrations). Longer sampling times were chosen to ensure that detectable amounts of glutaraldehyde vapor would be collected. Little worker activity involving the glutaraldehyde solutions occurred during the day, although some workers were in the sterilization room to use other sterilization equipment. Occasionally a worker would add or remove a few instruments from the glutaraldehyde solution, but this activity only took a few seconds or minutes.

The samples were shipped to the analytical laboratory where the glutaraldehyde dinitrophenylhydrazone was desorbed from the silica gel with 3 mL acetonitrile for 2 hours. The acetonitrile solution then was filtered with a 0.45 micron PTFE filter and the samples were injected into a High Performance Liquid Chromatography system also with standard and quality assurance samples. Separation was achieved on an Alltech Altima C18 column with a mobile phase consisting of 65% acetonitrile and 35% water with a flow rate of 1.5 mL/min. The detection wavelength was set at 365 nanometers. These conditions provided baseline separation of the two isomers of glutaraldehyde. The limits of detection and quantification for the method were 0.0004 and 0.0013 ppm, based on a sample volume of 30 liters.

General Indoor Environmental Quality

A visual inspection of the building was conducted to identify additional IEQ issues in the building. Three of the four heat pump units were inspected, consisting of a visual inspection of the cooling coils, drip pans, and filters. Morning and afternoon measurements for temperature, RH, and CO_2 were made in the facility. Informal discussions of IEQ issues in the building were conducted with several employees.

Sampling for comfort-related parameters was as follows:

Carbon Dioxide (CO_2) Instantaneous measurements of CO_2 concentrations were obtained using a Gastech Model RI-411A Portable (direct reading) CO_2 monitor. The principle of detection is non-dispersive infrared absorption. The instrument was zeroed (zero CO_2 gas source) and calibrated prior to use with a known CO_2 source (span gas). The monitor provides CO_2 concentrations in 25 parts per million (ppm) increments with a range of 0 - 4975 ppm. Measurements were obtained at various intervals in the building. Outdoor readings were taken to determine baseline CO_2 levels.

Temperature and Relative Humidity Dry bulb temperature and relative humidity levels throughout the building were determined at various intervals. Outdoor readings were obtained for comparison purposes. Instrumentation consisted of a TSI, Inc. model 8360 VelociCalc® meter with a digital readout. This unit is battery operated and has humidity and temperature sensors on an extendable probe. The temperature range of the meter is 14 to 140°F and the humidity range is 20 - 95%.

Evaluation Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff use established environmental criteria for the assessment of a number of chemical and physical agents. These criteria suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It should be noted, however, that not all workers will be protected from adverse health effects if their exposures are below the applicable limit. A small percentage may experience adverse health effects due to individual susceptibility,
pre-existing medical conditions, and/or hypersensitivity (allergy).

Some hazardous substances or physical agents may act in combination with other workplace exposures or the general environment to produce health effects even if the occupational exposures are controlled at the applicable limit. Due to recognition of these factors, and as new information on toxic effects of an agent becomes available, these evaluation criteria may change.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Criteria Documents and recommendations, (2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and (3) the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) standards.[1,2,3] Often, NIOSH recommendations and ACGIH TLVs may be different than the corresponding OSHA standard. Both NIOSH recommendations and ACGIH TLVs are usually based on more recent information than OSHA standards due to the lengthy process involved with promulgating federal regulations. OSHA standards also may be required to consider the feasibility of controlling exposures in various industries where the hazardous agents are found; the NIOSH Recommended Exposure Limits (RELs), by contrast, are based primarily on concerns relating to the prevention of occupational disease.

The evaluation criteria for indoor environmental quality (IEQ) and bioaerosols can be found in Appendix A.

Evaluation Criteria - Nitrous Oxide

Nitrous oxide has been used as an anesthetic agent since 1844, and is often used in conjunction with other anesthetic gases.[2] However, with the development of more effective local anesthetics, nitrous oxide is now used primarily to relieve anxiety in patients.[4] For many years, the only adverse health affects associated with exposure to nitrous oxide have been those of asphyxiation when there is insufficient oxygen due to physical displacement by nitrous oxide.[2,5] Over the past 30 years, other specific toxic effects have been found in both animal and human studies. An early observation was that nitrous oxide, when clinically used at very high concentrations (50% or 500,000 ppm) caused a generally reversible (within 4 days after discontinuing use) bone marrow depression.[6,7] Carcinogen studies with laboratory animals (mice) have not shown any increases in tumors.[2,5] Cancer studies of humans exposed to nitrous oxide and other anesthetic gases have shown mixed results. Some suggest a small increase in the incidence of cancer in women, while others have reported a negative correlation.[2,5,8] 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) nitrous oxide concentrations during the early stages of pregnancy.[9] Human studies have reported a higher than expected incidence of spontaneous abortions among female workers directly exposed to nitrous oxide and other anesthetic gases.[10] 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.[11,12] Studies have shown that adverse neurologic effects (e.g., numbness, tingling, weakness, audiovisual performance decrements) appear to increase in persons occupationally exposed to nitrous oxide, while other studies have not confirmed these findings.[13-16] It has also been suggested that mood factors (sleepiness, mental tiredness, etc.) may deteriorate following exposures to as low as 50 ppm.[16] In many of these human studies, exposure concentrations are poorly defined and dose-response relationships are difficult to identify.

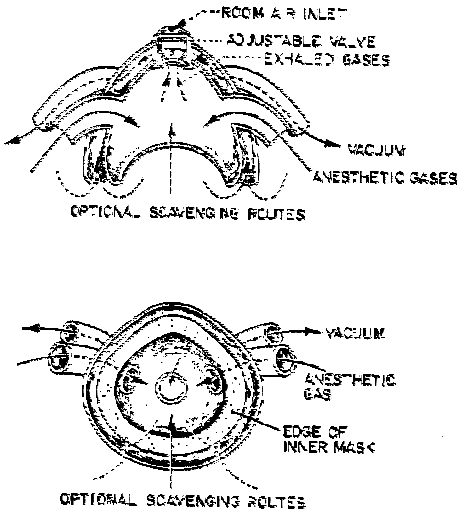
Exposure Standards

The Occupational Safety and Health Administration (OSHA), the agency responsible for enforcing compliance with workplace safety regulations, has not established a standard for nitrous oxide. NIOSH has established a Recommended Exposure Limit (REL) of 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.[8] The American Conference of Governmental Industrial Hygienists (ACGIH), a professional association, has recommended an 8-hour time-weighted average Threshold Limit Value (TLV-TWA) of 50 ppm.[2] The ACGIH TLV-TWA is based on prevention of embryofetal toxicity (spontaneous abortion) in humans and significant decrements in human cognitive functions.

Control Measures

Nitrous oxide is not metabolized, and following absorption, is rapidly eliminated unchanged from the body through the lungs.[17] As such, dental office personnel may be exposed to nitrous oxide that has either escaped from the delivery system or been exhaled by the patient. A wide range of nitrous oxide exposure concentrations in dental operatories have been reported ($\leq$ 25 ppm - 6700 ppm).[8,18-20] Studies in dental operatories conducted by NIOSH and others have generally found that existing control technologies do not consistently control nitrous oxide concentrations to the NIOSH REL.[19,20]

Measures for controlling exposures to nitrous oxide in dental operatories include effective scavenging devices, proper equipment, maintenance and routine leak checks of the nitrous oxide delivery system, and good work practices on the part of the dentist and assistants. Scavenging systems to control nitrous oxide 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 nitrous oxide 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 the following figure, is 45 liters per minute.[8] As noted previously, these types of scavenging systems, while shown to be effective in reducing anesthetic gas exposure, may not consistently reduce nitrous oxide to concentrations to below the NIOSH REL of 25 ppm.[20] Providing additional auxiliary ventilation has shown mixed results.[19] Once ventilated, the collected anesthetic gas must be properly vented to a point away from personnel. Non-recirculating air-conditioning systems, the central office suction system, and a separate duct system have successfully been used to accomplish this.[8] Complete descriptions of scavenging systems, proper maintenance protocols, and work practices are detailed in the NIOSH Criteria Document on Waste Anesthetic Gases.[8]



common nasal mask with scavenger

Evaluation Criteria - Glutaraldehyde

Glutaraldehyde is used as a cold sterilant in hospitals and dental offices. It is used in pulmonary physiology units, at nurses' stations, and research laboratories to clean sputum mouthpieces, suction bottles, tubing, and other equipment.[21] Although glutaraldehyde is available in 50%, 25%, 10%, and 2% solutions, most health care facilities use 2% glutaraldehyde solutions buffered to pH 7.5-8.5. Glutaraldehyde solutions also contain surfactants to promote wetting and rinsing of surfaces, sodium nitrite to inhibit corrosion, peppermint oil as an odorant, and FD&C yellow and blue dyes to indicate activation of the solution.[21] One disadvantage of buffered glutaraldehyde solutions is that they are stable for less than 2 weeks, so solutions must be dated and made as needed.[22] Another disadvantage is that at 20° C (68° F), a 50% solution of glutaraldehyde has a vapor pressure of 0.015 mm Hg[23] and can generate an atmosphere that contains as much as 20 ppm glutaraldehyde. This concentration is well above that shown to cause adverse health effects in animals and humans.

Glutaraldehyde may be absorbed into the body by inhalation, ingestion, and skin contact. Extensive skin contact may cause allergic eczema and may also affect the nervous system. Glutaraldehyde has an odor threshold of about 0.04 ppm, is highly toxic, and is irritating to the skin and mucous membranes at concentrations of 0.3 ppm.[23] A NIOSH investigation determined that airborne glutaraldehyde concentrations of 0.4 ppm were responsible for symptoms of irritation in 9 of 11 (82%) exposed workers. Eye, throat, and lung irritation were reported among 45% of the workers. Other symptoms included cough, chest tightness, headache, skin irritation, and asthma symptoms.[21]

In a study published by the National Toxicology Program (NTP) in 1993, groups of five rats and five mice of each sex were exposed to glutaraldehyde by whole-body inhalation at concentrations of 0, 0.16, 0.5, 1.6, 5, and 16 ppm for 6 hours per day, 5 days per week, for 2 weeks. All rats and mice exposed to 5 or 16 ppm glutaraldehyde died before the end of the studies; all mice exposed to 1.6 ppm also died. Deaths were attributed to severe respiratory distress. Mice appeared to be more sensitive than rats because the small airways of the nasal passage of mice were more easily blocked by cell debris and keratin. Lesions noted in the nasal passage and larynx of rats and mice included necrosis, inflammation, and squamous metaplasia. The no-observed-adverse-effect level (NOAEL) was 0.125 ppm for respiratory lesions in rats. An NOAEL was not reached for mice, as inflammation was found in the anterior nasal passage at concentrations as low as 0.0625 ppm.[24]

Glutaraldehyde exposure has also been associated with fetotoxicity in mice, DNA damage in chickens and hamsters, and mutagenicity in microorganisms.[25]

Exposure Standards

The NIOSH and ACGIH Ceiling limit value for glutaraldehyde is 0.2 ppm. A ceiling limit value is defined as the concentration that should not be exceeded during any part of the working exposure. OSHA does not have an exposure standard for glutaraldehyde.

Results

Nitrous Oxide

Concentrations of nitrous oxide exceeded the NIOSH REL for all activities assessed in the dental office. Exposures for workers performing different procedures differed significantly, probably because of differences in work practices. Figure 1 (end of report) shows exposures measured from the dentist during a tooth extraction. The time-weighted average (TWA) concentration was 225 ppm nitrous oxide, which exceeded the NIOSH REL of 25 ppm. Figure 2 shows the exposure (TWA = 335 ppm) of a dental assistant during an acrylic resin filling.

Figure 3 shows the exposure (TWA = 540 ppm) of a dental hygienist during a cleaning procedure. The peaks in the figures appeared to occur when the worker leaned closer to the patient.

A personal bag sample collected during a 35-minute teeth cleaning procedure measured a TWA exposure of 1270 ppm nitrous oxide. Another bag sample collected from a dental assistant during a 48-minute evaluation and tooth extraction measured a TWA exposure of 1730 ppm.

Figure 4 shows the results of ambient air sampling for nitrous oxide. The sampling (20-30 minutes in duration at each interval) was conducted near the X-ray machine in the hallway. Sampling was conducted before the nitrous gas tank valve was opened, after the valve was opened, and after administration was initiated. The relatively low concentration of nitrous oxide (0.6 ppm) found before the tank's valve was opened indicated that the nitrous oxide substantially clears the building over-night. One hour after the valve was opened, the ambient concentration increased to 1.1 ppm. This indicated that the nitrous oxide administration system may have some minor leakage. Substantial increases in ambient nitrous oxide concentrations occurred after administrations started. By early afternoon, the ambient concentration of nitrous oxide reached 145 ppm.

Glutaraldehyde

The glutaraldehyde area sampling results are listed in Table 1 (end of report). The two samples collected in the sterilization room had 0.01 ppm glutaraldehyde vapor. The sample collected in the reception office had no detectable glutaraldehyde. Since these samples were collected for 5 hours, the results cannot be directly compared to the NIOSH and ACGIH ceiling criteria of 0.2 ppm. However, it can be mathematically demonstrated that if the glutaraldehyde concentration for one 15-minute period exceeded the ceiling limit of 0.2 ppm, then the 5-hour TWA would have been greater than 0.01 ppm (assumes zero exposure for 4.75 hours). Since worker activities involving glutaraldehyde were minimal throughout the day, it is more reasonable to assume that the glutaraldehyde vapor concentration was about the same at any given time during sampling. In this scenario, the exposures would not exceed the ceiling criteria. The results also indicate negligible glutaraldehyde vapor contamination in the building.

The glutaraldehyde results were below the NOAEL concentration of 0.125 ppm for rats (NTP study, discussed previously). In this study the rats were exposed 6 hours per day, 5 days a week, for 2 weeks. This comparison is presented for perspective; it should be noted that the NOAEL for rats does not directly translate to an acceptable glutaraldehyde exposure limit for humans.

HVAC/Facility Inspection

A visual inspection of three of the four heat pumps showed that the coils were clean and free of biological growth (coils were cleaned in July 1993), but the interior insulation was deteriorated and in poor condition because of previous dampness and apparent mold growth. Condensate drain pans were free of standing water or evidence of biological growth, although this was not the time of year when air-conditioning would be running often. One unit (serial # R060610) had a distinctive musty odor. The other two inspected units (serial # NO60088 and # M960414) also had an odor, but not as strong. Although the units were designed with an outside air intake, these

intakes had metal shields permanently installed to stop outside air from entering. There were no air filters in the units; it was uncertain whether the units could accommodate a filter. The only filters (22" X 22" X 1", electrostatic type) were located in the return air vents.

A limited inspection of the supply duct near the diffusers in selected areas did not show obvious residue build-up or microbiological growth. The main supply manifolds, however, could be seen from the heat pump's interior. In one unit (serial # R060610 - the unit with the strongest odor), the supply ductwork appeared darker than the other units. This darkening could be due to dirt or microbiological damage. It should be noted that the interior fiberglass within ventilation systems has the potential for being or becoming a substrate for mold or other biological growth, especially if subject to high moisture conditions.

The crawl space had a sand floor and was dry. Some insulation appeared damaged; probably the result of a sewage pipe leak in the past. However, the crawl space did not appear to be a likely contributor to indoor environmental quality problems in the building.

Environmental Parameters

The environmental monitoring results are shown in Table 2. Serial measurements were obtained near the X-Ray machine throughout the day. Measurements showed a general increase in CO_2 throughout the building, reaching 975 at 11:45 a.m. In the afternoon, the front and back doors of the building were opened to reduce the odor from the air-conditioning system. Although the levels did not exceeded the 1000 ppm criteria, it is likely that the criterion would have been exceeded had the doors not been opened. CO_2 concentrations greater than 1000 ppm generally indicate insufficient outside air intake. Given the fact that the heat pumps do not have operational outside air intakes, it was expected that elevated CO_2 concentrations might be found in the building.

Temperature and relative humidity measurements indicated levels to be within acceptable ranges. Since outdoor environmental conditions were moderate, these measurements were not as likely to reveal deficiencies related to the HVAC system.

Recommendations

The following recommendations are offered to reduce nitrous oxide exposures and improve general indoor environmental quality in the dental office building. Several positive changes had already occurred before the NIOSH visit. These changes, including discontinuing the use of formaldehyde, changing the type and concentration of glutaraldehyde, and cleaning the heat pump coils, probably improved indoor environmental quality in the building.

1. A suction pump for the nitrous oxide scavenging system should be installed. It is recommended that a flow metering device, such as a rotameter, be used to monitor the proper exhaust flow rates. Generally, suction pumps should have enough power to maintain scavenging flow at the nasal mask at 45 liters per minute.[20] The mask manufacturer should be consulted regarding the recommended flow rate. The scavenged nitrous oxide should be exhausted to the outside (not the crawl space).

   In most circumstances, hazardous gases and vapors and gases follow air currents and are not subject to appreciable motion either upward or downward because of their own density.[26] Consider the following example:

   Density of air = 1
   Density of nitrous oxide = 1.53
   100,000 ppm (10%) = 1 part nitrous oxide : 9 parts air
   0.1 X 1.53 = 0.153
   0.9 X 1.00 = 0.900
   1.053 = effective density of mixture

The nitrous oxide - air mixture compared to clean air would have a tendency to move downward by the ratio 1.053/1-- and not the ratio 1.53/1 as frequently implied. The effects of the ventilation system, heat, and other factors can dwarf the effect of density into insignificance. Therefore, the waste nitrous oxide will not significantly flow through the scavenging tubing into the crawl space because of its density.

2. It is recommended that the nitrous oxide not be turned on until: (1) the vacuum system scavenging unit is turned on to the recommended flow rate, and (2) the scavenging nasal mask is placed over the patient's nose. Masks should be carefully fitted on the patient to reduce leakage. Following the procedure, oxygen should be flushed through the analgesia equipment, especially the breathing bag, prior to disconnecting the gas delivery system, and prior to turning the scavenging system vacuum off. All personnel who administer nitrous oxide should be trained on the correct work practices to reduce nitrous oxide concentrations.

3. A preventive maintenance program should be implemented that includes reviewing the nitrous oxide delivery system and conducting periodic leak checks. Periodic monitoring of ambient nitrous oxide levels should also be conducted.

4. A minimum of 20 cubic feet per minute (CFM) outside air per person should be supplied to the building through the ventilation system. This recommendation is based on the American Society of Heating, Refrigerating, and Air-conditioning Engineer's recommendation for general office space.[27] Increased outside air intake may be beneficial in reducing nitrous oxide and other potential contaminants in the building. The outside air should be filtered upstream of the coils.

5. The insulation in the heat pumps has been water damaged and may be causing the unpleasant odor in the building. The insulation should be removed and replaced with a non-porous material. A preventive maintenance program should be instituted for inspecting and servicing the heat pumps. The fiberglass duct insulation should be inspected and removed if it is found to be water or mold damaged. This inspection will require installation of access ports in the ductwork. In the future, use ductwork that does not have a porous inner lining.

References

1. NIOSH [1992]. NIOSH recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control; National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 92-100.

2. ACGIH [1993]. Threshold limit values and biological exposure indices for 1993-1994. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists.

3. Code of Federal Regulations [1989]. OSHA Table Z-1. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

4. Frost, A [1985]. A history of nitrous oxide. In: nitrous oxide, Edmond I, Eger II, eds. Chapter 1, pp 1-22, Elsevier, New York.

5. Hathaway GJ, Proctor NH, Hughes JP, Fischman MF [1991]. Chemical hazards of the work place, 3rd. Ed. New York: Van Nostrand Reinhold Company.

6. Lassen H, Henricksen E, Neukrich F, Kristensen H [1956]. Treatment of tetanus: severe bone-marrow depression after prolonged nitrous oxide anaesthesia. Lancet 1:527.

7. Sando M, Lawrence J [1958]. Bone-marrow depression following treatment of tetanus with protracted nitrous oxide anaesthesia. Lancet 274:588.

8. NIOSH [1977]. Criteria for a recommended standard: occupational exposure to waste anesthetic gases and vapors. Cincinnati, Ohio: 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.

9. Viera E, Kleaton-Jones P, Austin J, Moyes D, Shaw R [1980]. Effects of low concentrations of nitrous oxide on rat fetuses. Anesth Anal 59:175-177.

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

11. 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 101:21-31.

12. 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. N Eng Jrnl Med 327(14):993-997.

13. Bruce D, Back M [1976]. Effects of trace anesthetic gases on behavioral performance of volunteers. Br J Anaesth 48:871.

14. Stollery B, Broadbent D, Lee W, Keen R, Healy T, Beatty P [1988]. Mood and cognitive functions in anesthetists working in actively scavenged operating theatres. Br J Anaesth 61(4):446-455.

15. Smith G, Shirley A [1978]. A review of the effects of trace concentrations of anesthetics on performance. Br J Anaesth 50(7):701-712.

16. 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 9:391-396.

17. Clayton GD, Clayton FE [1982]. Patty's Industrial Hygiene and Toxicology. Vol 2C -- General Principles, 3rd Revised Ed. New York: John Wiley & Sons.

18. Millard R, Corbett T [1974]. Nitrous oxide concentrations in the dental operatory. J. Oral Surgery 32:593.

19. 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.

20. NIOSH [1990]. In-depth survey report: control of anesthetic gases in dental operatories at University of California at San Francisco, Oral Surgical Dental Clinic. U.S. Department of Health and Human Services, Public Health Service, 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.

21. NIOSH [1983]. Health hazard evaluation report: National Jewish Hospital, Denver, CO. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. NIOSH Report No. HETA 83-074-1525.

22. Gorman SP, Scott EM, et al. [1980]. A review: antimicrobial activity, uses and mechanism of action of glutaraldehyde. Journal of Applied Bacteriology 48:161-190.

23. ACGIH [1986]. Documentation of the threshold limit values and biological exposure indicies. 5th edition. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

24. NTP [1993]. NTP technical report on toxicity studies of glutaraldehyde - administered by inhalation to F344/N rats and B6C3F_1 mice. Toxicity report series number 25. Research Triangle Park, NC: Department of Health and Human Services, Public Health Service, National Institutes of Health. National Toxicology Program Publication 93-3348.

25. NIOSH [1993]. Registry of toxic effects of chemical substances. Cincinnati, OH: Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health.

26. ACGIH [1986]. Industrial ventilation: a manual of recommended practice, 19th edition. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

27. ASHRAE [1990]. Ventilation for acceptable indoor air quality. Atlanta, GA: American Society of Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 62-1989.

Authorship and Acknowledgements

Evaluation Conducted and Report Prepared By:	John A. Decker, M.S. Regional Industrial Hygienist NIOSH Atlanta Regional Office
Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations, and Field Studies NIOSH Cincinnati, Ohio
Laboratory Support	Charles Neumeister Measurements Research Support Branch Division of Physical Sciences and Engineering NIOSH Cincinnati, Ohio

Report Distribution and Availability

Copies of this report may be freely reproduced and are not copyrighted. Single copies of this report will be available for a period of 90 days from the date of this report from the NIOSH Publications Office, 4676 Columbia Parkway, Cincinnati, Ohio 45226. To expedite your request, include a self-addressed mailing label along with your written request. After this time, copies may be purchased from the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Dr. Gammuchia
2. HHE Requestor
3. Department of Labor/OSHA Region IV
4. PHS/NIOSH Regional Office
5. Designated state health and safety agencies

For the purpose of informing affected employees, a copy of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

Dr. Gammuchia Dental Office, Apopka, Florida
November 30, 1993 - HETA 94-0017
Glutaraldehyde Sample Results

Location	Sample Rate (mL/min)	Sample Volume (liters)	Concentration (parts per million)
Sterilization Room	99	29.9	0.01
Sterilization Room	108	32.3	0.01
Reception Office	103	30.3	not detected

Table 2

Dr. Gammuchia Dental Office, Apopka, Florida
November 30, 1993 - HETA 94-0017
Comfort Parameters

Location	**Time**	**Carbon Dioxide**	**Relative Humidity**	**Temp ºF**
X-Ray Machine	7:00 am	500	50.5	69.4
Outside	7:05 am	375	46.3	55.6
X-Ray Machine	9:15 am	775	54.3	70.6
Outside	9:20 am	350	50.6	59.8
X-Ray Machine	11:45 am	975	57.8	72.8
Outside	11:50 am	350	54.9	69.2
X-Ray Machine	2:35 pm	775	53.9	74.1
Outside	2:40 pm	375	52.4	74.2

Figure 1

Nitrous Oxide Personal Exposure - Dentist
Dr. Gammuchia Dental Office, Apopka, Florida
November 30, 1993 - HETA 94-0017

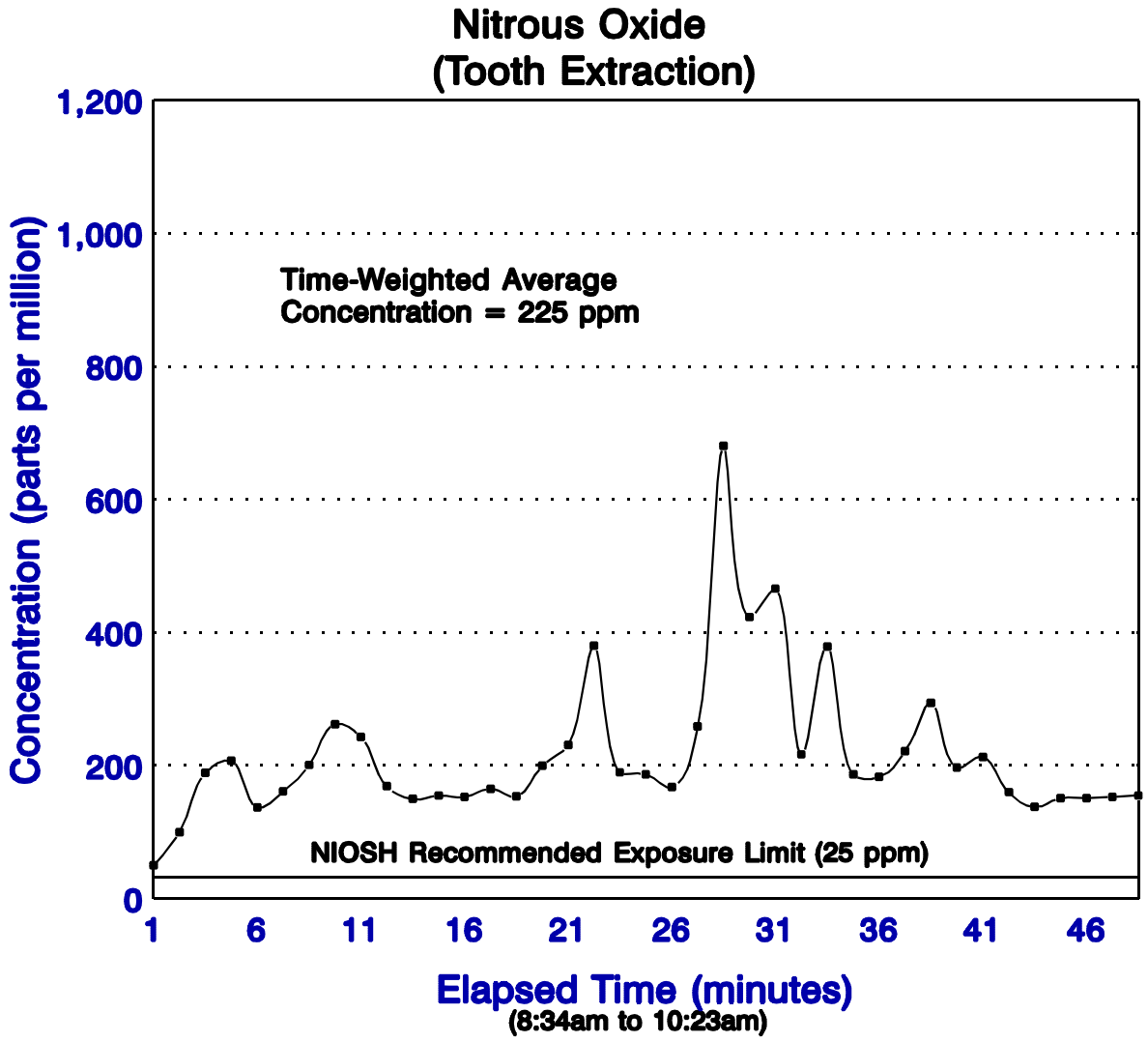


Figure 2

Nitrous Oxide Personal Exposure - Assistant
Dr. Gammuchia Dental Office, Apopka, Florida
November 30, 1993 - HETA 94-0017

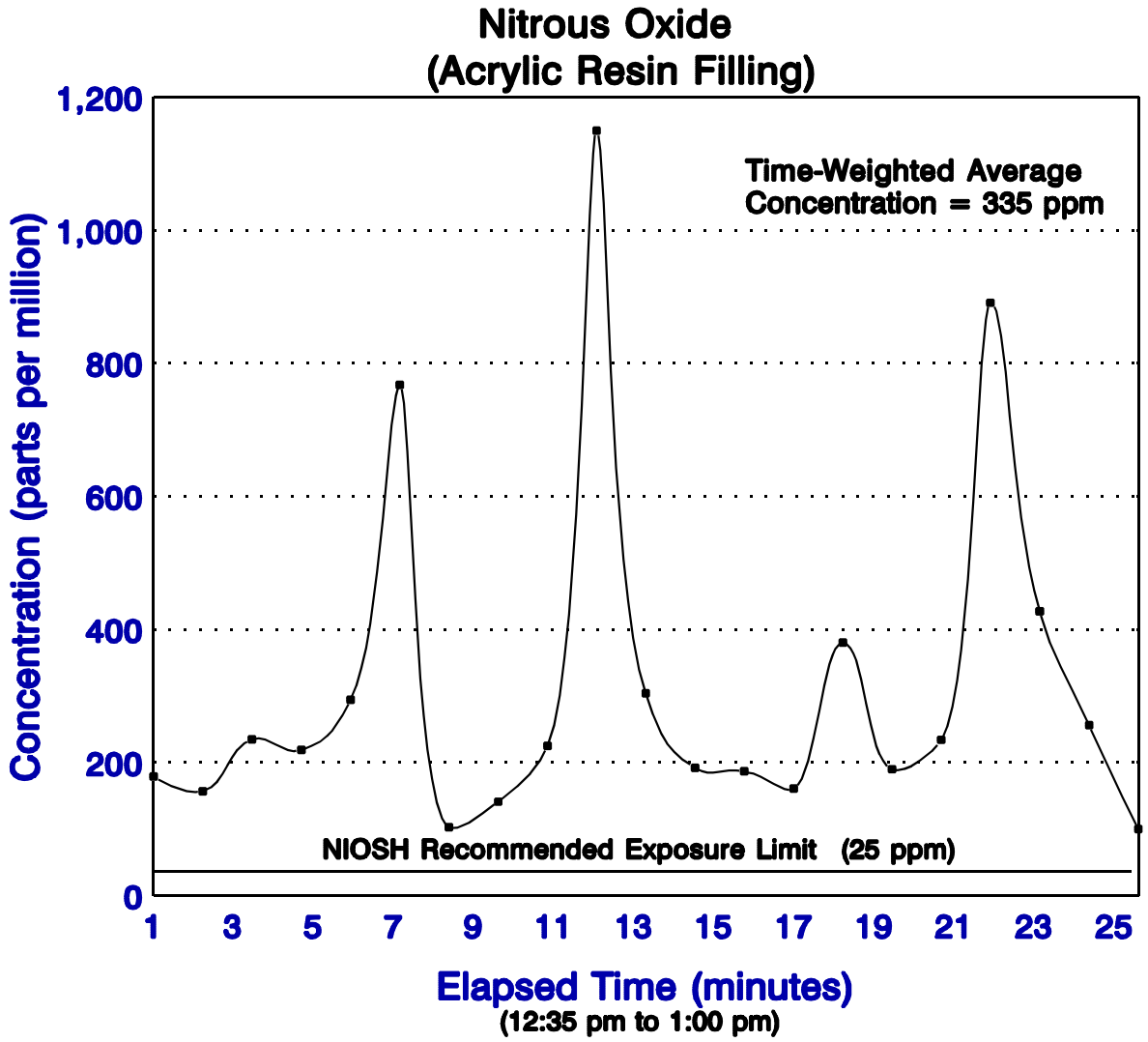


Figure 3

Nitrous Oxide Personal Exposure - Dental Hygienist
Dr. Gammuchia Dental Office, Apopka, Florida
November 30, 1993 - HETA 94-0017

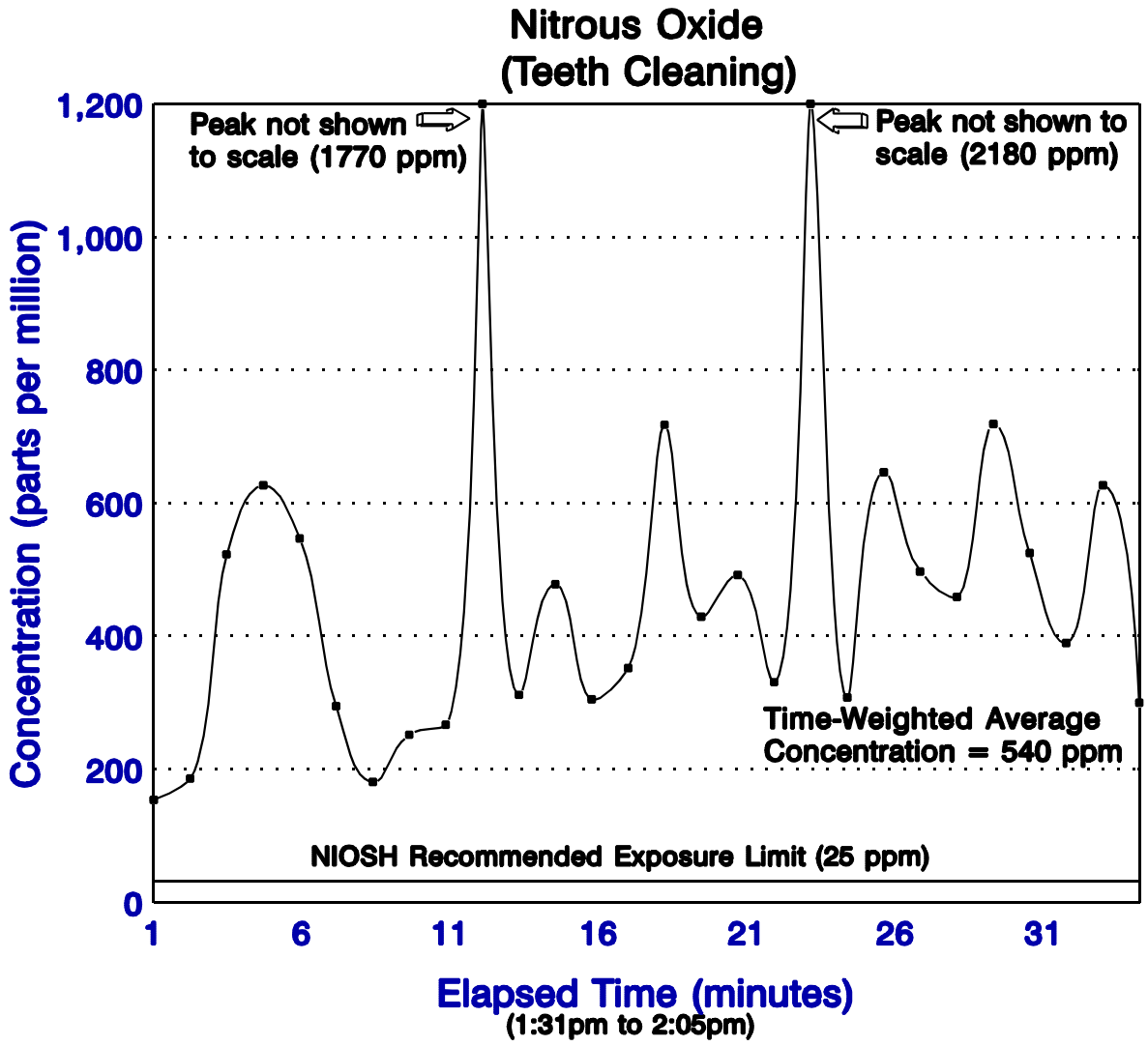
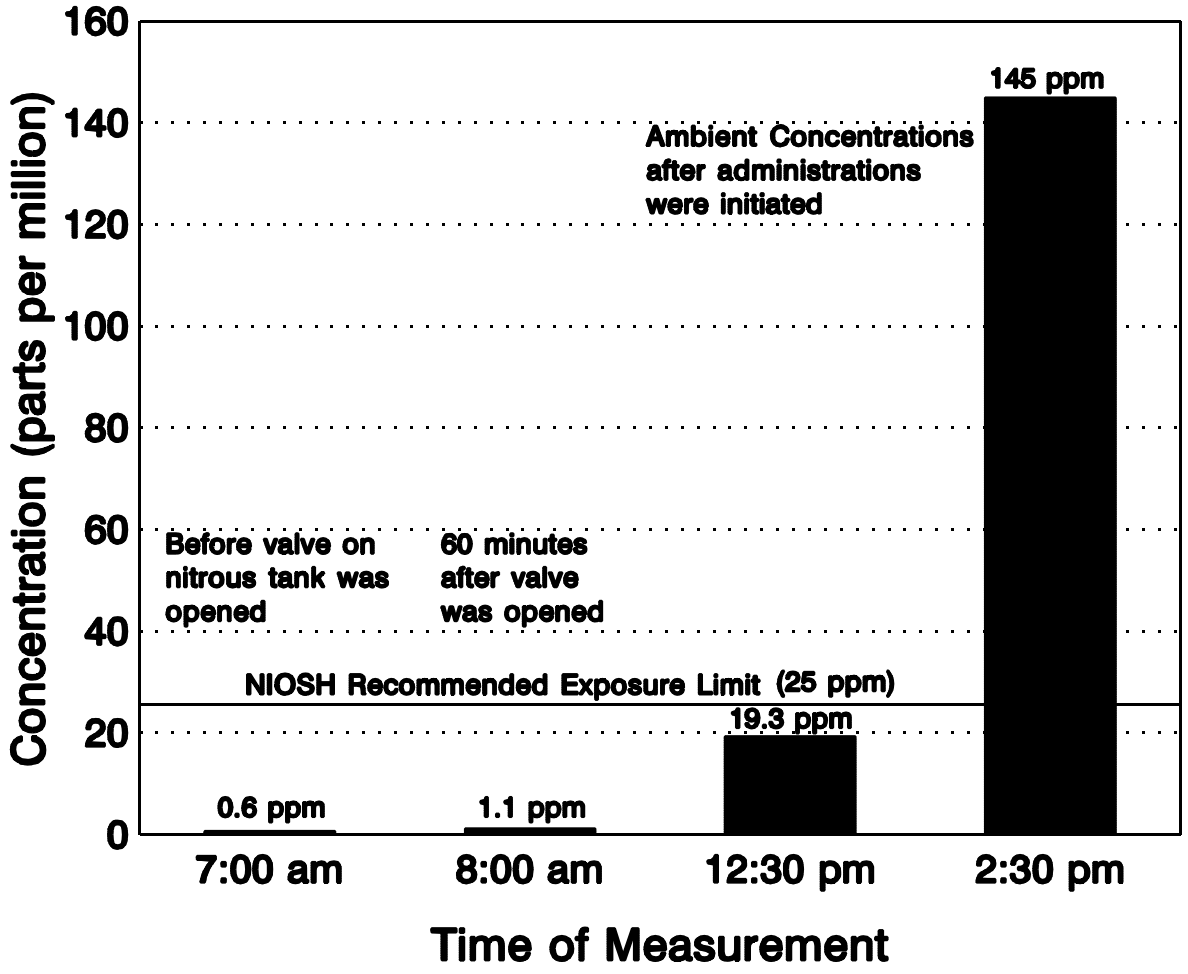


Figure 4

Ambient Concentrations - Nitrous Oxide
Hallway, Near X-Ray Machine
Dr. Gammuchia Dental Office, Apopka, Florida
November 30, 1993 - HETA 94-0017



Appendix A - Evaluation Criteria

Indoor Environmental Quality

Indoor environmental quality (IEQ) is affected by the interaction of a complex set of factors which are constantly changing. Four elements involved in the development of IEQ problems are:

- sources of odors or contaminants,
- problems with the design or operation of the HVAC system,
- pathways between contaminant sources and the location of complaints,
- and the activities of building occupants.

A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

The symptoms and health complaints reported to NIOSH by non-industrial building occupants have been diverse and usually not suggestive of any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, unusual fatigue, varying degrees of itching or burning eyes, irritations of the skin, nasal congestion, dry or irritated throats, and other respiratory irritations. Usually, the workplace environment has been implicated because workers report that their symptoms lessen or resolve when they leave the building.

Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[1,2] Among these factors are imprecisely defined characteristics of heating, ventilating, and air-conditioning (HVAC) systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.[3-8] Indoor environmental pollutants can arise from either outdoor sources or indoor sources.
There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related to the occurrence of symptoms than any measured indoor contaminant or condition.[9-11] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[11-14]

Problems NIOSH investigators have found in the non-industrial indoor environment have included poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals from furnishings, machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and outside air pollutants; comfort problems due to improper temperature and relative humidity conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psychosocial stressors. In most cases, however, these problems could not be directly linked to the reported health effects.

NIOSH, the Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards or recommended limits for occupational exposures.[15-17] In most cases, pollutant concentrations observed in non-industrial indoor environments fall below these published occupational standards or recommended exposure limits. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.[18,19]

Measuring ventilation and comfort indicators such as CO_2, temperature and relative humidity, has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems. The basis for these measurements is described below:

Carbon Dioxide

CO_2 is a normal constituent of exhaled breath and, if monitored, may be useful as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. The ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for office spaces and conference rooms, and 15 cfm/person for reception areas, and provides estimated maximum occupancy figures for each area.[18] Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 350-400 ppm). When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased.

Temperature and Relative Humidity

The perception of comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. ANSI/ASHRAE Standard 55-1992 specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[19] Optimum temperature ranges in winter range from 68 ^{o}F to 74 ^{o}F at 60% relative humidity and 69 ^{o}F to 76 ^{o}F at 36 ^{o}F dew point. The summertime range is from 73 ^{o}F to 79 ^{o}F at 60% relative humidity and 74 ^{o}F to 81 ^{o}F at 36 ^{o}F dew point.

Bioaerosols

Bioaerosols are airborne particles, that are living or were released from a living organism[20]. Exposure limits have not been established for bioaerosols. In more than 500 IEQ investigations, only 5% of NIOSH's indoor air investigations involved microbiological contamination[21]. However, in some cases, this type of contamination can cause or contribute to adverse health outcomes. These outcomes include hypersensitivity pneumonitis (a potentially severe disease) or allergic rhinitis, which can be caused by bacteria, fungi, protozoa and other bioaerosols. Note that microbial organisms will be found throughout the environment (including buildings that are not experiencing indoor air quality problems) and their presence should not be construed as proof of the cause of worker health problems. However, obvious signs of bioaerosol reservoirs, amplifiers and disseminators should be corrected to reduce the potential for these sources to create health problems.[22]

Potential sources include the building HVAC system (stagnant water in condensate pans, filters that become moist, porous acoustical liner in ducts), and water damaged carpet, ceiling tile and other furnishings. Odor can be another indicator of microbial contamination. If the work area smells moldy, fungi are probably present, and their reservoirs should be identified and removed[20,22].

Air sampling is generally considered to be a last resort as their is very little criteria available to interpret the data, dose-response relationship information is scant, and the presence of organisms does not prove a causal relationship with complaints[20,22]. Air sampling can be used, however, to compare biaerosols in complaint, non-complaint and outdoor environments.

Appendix A References

1. Kreiss K [1989]. The epidemiology of building-related complaints and illness. Occupational Medicine: State of the Art Reviews. 4(4):575-592.

2. Norbäck D, Michel I, Widstrom J [1990]. Indoor air quality and personal factors related to the sick building syndrome. Scan J Work Environ Health. 16:121-128.

3. Morey PR, Shattuck DE [1989]. Role of ventilation in the causation of building-associated illnesses. Occupational Medicine: State of the Art Reviews. 4(4):625-642.

4. Mendell MJ, Smith AH [1990]. Consistent pattern of elevated symptoms in air-conditioned office buildings: A reanalysis of epidemiologic studies. Am J Public Health. 80(10):1193-1199.

5. Molhave L, Bach B, Pedersen OF [1986]. Human reactions during controlled exposures to low concentrations of organic gases and vapours known as normal indoor air pollutants. Environ. Int., 12, 167-175.

6. Fanger PO [1989]. The new comfort equation for indoor air quality. ASHRAE J 31(10):33-38.

7. Burge HA [1989]. Indoor air and infectious disease. Occupational Medicine: State of the Art Reviews. 4(4):713-722.

8. Robertson AS, McInnes M, Glass D, Dalton G, Burge PS [1989]. Building sickness, are symptoms related to the office lighting? Ann Occup Hyg 33(1):47-59.

9. Wallace LA, Nelson CJ, Dunteman G [1991]. Workplace characteristics associated with health and comfort concerns in three office buildings in Washington, D.C. In: Geshwiler M, Montgomery L, and Moran M, eds. Healthy buildings. Proceedings of the ASHRAE/ICBRSD conference IAQ'91. Atlanta, GA. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

10. Haghighat F, Donnini G, D'Addario R [1992]. Relationship between occupant discomfort as perceived and as measured objectively. Indoor Environ 1:112-118.

11. NIOSH [1991]. Hazard evaluation and technical assistance report: Library of Congress Madison Building, Washington, D.C. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 88-364-2104 - Vol. III.

Appendix A References

12. Skov P, Valbjørn O, Pedersen BV [1989]. Influence of personal characteristics, job-related factors, and psychosocial factors on the sick building syndrome. Scand J Work Environ Health 15:286-295.

13. Boxer PA [1990]. Indoor air quality: A psychosocial perspective. J Occup Med 32(5):425-428.

14. Baker DB [1989]. Social and organizational factors in office building-associated illness. Occupational Medicine: State of the Art Reviews. 4(4):607-624.

15. CDC [1992]. NIOSH recommendations for occupational safety and health: Compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 92-100.

16. Code of Federal Regulations [1989]. OSHA Table Z-1-A. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

17. ACGIH [1991]. 1991-1992 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

18. ASHRAE [1990]. Ventilation for acceptable indoor air quality. Atlanta, GA: American Society of Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 62-1989.

19. ASHRAE [1993]. Thermal environmental conditions for human occupancy. Atlanta, GA: American Society for Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 55-1992.

20. ACGIH [1989]. Guidelines for the assessment of bioaerosols in the indoor environment. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists.

21. NIOSH [1987]. Guidance for indoor air quality investigations. Cincinnati, OH: Hazard Evaluations and Technical Assistance Branch, National Institute for Occupational Safety and Health.

22. NIOSH/EPA [1991]. Building air quality, a guide for building owners and facility managers. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 91-114.