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Nitrous Oxide Sedation: A Basic Review

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Reviewed and Updated by Health Science Editor: Megan Wright, RDH, MS

Publication Date: January 2017

Revised Date: February 2020

Expiration Date: February 2023

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Objectives

Upon completion of this course, the student will be able to:

- Understand the history and background for Nitrous Oxide as an anesthetic agent.
- Identify indications for use in clinical dentistry.
- Identify contraindications for use in clinical dentistry.
- Evaluate patients suitable for nitrous oxide sedation.
- Know the basic equipment and its use in the dental operatory.
- Understand best clinical practices for nitrous oxide sedation.
- Implement workplace monitoring and safety guidelines per OSHA guidelines.
- Identify signs and symptoms of exposure.
- Understand nitrous monitoring systems, i.e. Laudauer Monitoring Badge.
- Maintain absolute safety for patients in the clinical setting.

Introduction

Clinical dentistry often needs chemical agents to maintain patient comfort and to allay anxiety (anxiolytic properties). The ideal agent would have a fairly rapid onset of action, good therapeutic effectiveness, a wide safety margin, quick recovery time, no "hangover" effect or excessive sedative effects, and which does not require the presence of an anesthesiologist.

An anesthetic which is ideally suited to clinical dentistry is nitrous oxide or N2O as nitrous oxide is commonly abbreviated. Nitrous oxide produces analgesic and anxiolytic effects when used correctly in a clinical setting. Nitrous oxide (N20 on many forms or chemical symbol N2O) gas has been available to the medical and dental community for over 150 years. The use of nitrous oxide as an anesthetic is common for anesthesiologists and dental practitioners as an adjunct to local anesthetic agents, and fulfills almost all of the criteria listed above.

This course reviews the general use of nitrous oxide for the dental practitioner and dental staff. The course emphasizes best clinical practices to support absolute patient safety and to assure that clinicians minimize exposure to themselves in the workplace. OSHA sets forth specific guidelines for clinical and workplace safety which will be discussed in detail. Also a review of common terms is provided as an appendix, as well as information about workplace safety and monitoring systems for exposure management in the dental clinical setting. Ironically, nitrous oxide exposure issues for the patient are relatively minimal. Of more concern are the long-term health issues for clinicians, particularly child bearing age women, who may be exposed on a daily basis and therefore subject to more cumulative effects based on the frequency of exposure.

History of Nitrous Oxide and Use in Dentistry


Joseph Priestly

Nitrous oxide, one of the first modern anesthetics, was first manufactured in 1772 by English chemist, Joseph Priestly. About 1800, Sir Humphrey Davy experimented with the physiological properties of the gas and stated: “As nitrous oxide in its extensive operation appears capable of destroying physical pain, it may probably be used with advantage during surgical operation”. The surgical world ignored his suggestion, and interest in the surgical use of nitrous oxide would have to wait another half century. After Sir Davy observed the amusing effects on people who inhaled nitrous oxide, he coined the term “laughing gas” which is also commonly used today.

Nitrous oxide was used for the first time as a dental anesthetic drug in 1844. Dr. Horace Wells, with assistance by Gardner Quincy Colton and John Mankey Riggs, collaborated successfully to use nitrous oxide on a patient for an extraction. In the following weeks, Wells treated the first 12-15 patients with nitrous oxide, and according to his own record only failed in two cases. In spite of these convincing results reported by Wells to the medical society in Boston, this new method of pain management was not immediately adopted by other dentists. In early 1845, Wells’ first public demonstration of nitrous oxide anesthesia for the medical faculty in Boston, was only partly unsuccessful, leaving his colleagues doubtful regarding its efficacy and safety. Wells was booed off the stage and in the aftermath, he lost his reputation and eventually committed suicide. However, to this day, Dr. Wells is considered the “discoverer of anesthesia”.

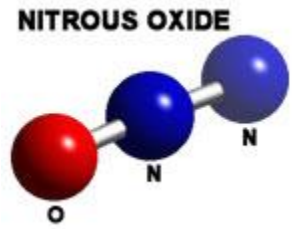
In 1863 nitrous oxide anesthesia came into general use, when Gardner Quincy Colton successfully began to use nitrous oxide in all his “Colton Dental Association” clinics. Up to the 1860’s nitrous oxide was used alone as an inhalational anesthetic with 100% concentration of the gas administered to patients. Oxygen was added to the gas mix, and soon Colton and his associates successfully administered nitrous oxide to more than 25,000 patients, with over

75,000 extractions completed with the use of N2O as an anesthetic. Now with the efficacy and safety demonstrated by large numbers of successful procedures, the use of

nitrous oxide rapidly became the preferred anesthetic method in dentistry. The gas is mild enough to keep a patient in a conscious and conversational state, and in most cases is strong enough to suppress the pain caused by dental procedures. Therefore, nitrous oxide remains today as the preferred anesthetic gas used in dentistry.

Every year approximately 45 million dental patients undergo anesthesia in North America, with nitrous oxide constituting a major component in about half of these procedures. A significant percentage of general dentists use nitrous oxide sedation in their practices to manage pain, anxiety, and excessive gag reflex. Nitrous is the most used gaseous anesthetic in the world, commonly administered for the purpose of decreasing the amount of more potent and usually more toxic agents during general anesthesia cases.

Properties and Mechanism of Action



Nitrous oxide produces analgesic (pain killing) and anxiolytic (anxiety reduction) effects. Nitrous oxide is the weakest of the inhalant anesthetics used for patient sedation in dentistry or medicine. The chemical formula is N2O. The gas is colorless, non-flammable, with a slightly sweet odor.

Nitrous oxide has low solubility in blood, diffuses rapidly across the alveolar-arterial membrane and is excreted unchanged through the lungs. As a result, nitrous takes effect rapidly and is quickly reversible on discontinuation. Nitrous oxide can induce loss of consciousness at high concentrations, typically 70% or higher. Nitrous oxide produces either no change, or a slight increase in blood pressure, while all other volatile anesthetics reduce blood pressure. There is no effect on heart rate, but high doses may cause myocardial depression.

The exact mechanism of action is unknown. However, the most widely accepted theory is that the analgesic effect is occurs by interaction with the opioid receptors. These are the same receptors activated by morphine and heroin. This stimulation occurs in the mid-brain leading to activation of the descending inhibitory pathways, which alters pain processing in the spinal cord. The anxiolytic effect is mediated by interaction with the GABA-A receptors. The mechanism of action closely resembles that of ethanol. GABA is an inhibitory neurotransmitter that inhibits the pre-synaptic cells from transmitting thus decreasing nervous system activity.

Nitrous oxide gas is used in both the medical and dental professions to ensure patient comfort during procedures. A 40%-70% N2O mixture (the remainder consisting of oxygen) is used as an adjunct to inhalation and IV general anesthesia. The gaseous

mixture is administered using either a mask, nasal canula, or an endotracheal tube. The onset of action for N2O is between 2-5 minutes. However, since the mean alveolar concentration (MAC) of N2O considered the ED50 for general anesthesia (the dose at which 50% of patients will experience anesthesia) is 105%, nitrous cannot be used alone as a general anesthetic. Typically, nitrous oxide is only used to start the anesthesia process.

In dentistry, nitrous oxide is typically used as an anxiolytic or as an anxiety reducing agent. N2O is given as a 25%-50% mixture with oxygen. Most often it is administered through a nasal mask or nasal canula.

The patient should be started out breathing 100% oxygen and then slowly allowed to breathe increasing amounts of N2O until the desired effect is achieved. It is important that the patient be reminded to breathe through the nose in order for the gas to work. The patient should be questioned as to how they are feeling to ensure an optimal level of nitrous is being administered. Therapeutic levels will vary from patient to patient. If the nitrous level being administered is too low, the patient will not be receiving an effective anxiolytic dose. If the nitrous level is too high, unwanted side effects may occur. After the procedure is finished, allow the patient to breathe 100% oxygen again for 2-5 minutes in order to clear the nitrous from the lungs and return the patient to a pre-anesthetic state or normal feeling.

Uses in Clinical Dentistry

Indications

- A fearful, anxious, or obstreperous patient
- Certain patients with special health care needs
- A patient whose gag reflex interferes with dental care
- A patient for whom profound local anesthesia cannot be obtained
- A cooperative child undergoing a lengthy dental procedure

Contraindications

- Some chronic obstructive pulmonary diseases
- Severe emotional disturbances or drug-related dependencies (see abuse)
- First trimester of pregnancy
- Treatment with bleomycin sulfate
- Methylenetetrahydrofolate reductase deficiency (B12)

The contraindications for use of nitrous are important especially when considering that nitrous oxide is the only inhaled anesthetic proven to be teratogenic (causing birth defects) in animals, so is to be avoided in the first trimester of pregnancy. Patients with pulmonary hypertension or major cardiac disease should be evaluated carefully and in consultation with the medical doctor before using nitrous. Patients with severely compromised cardiac function are not candidates for nitrous oxide sedation because of the slight myocardial depressant action of the gas on the circulatory system. And patients who are claustrophobic may be unable to tolerate a nasal mask although use of a nasal canula may solve the issue. Some patients may fear “losing control” of themselves and adamantly refuse N2O sedation. Patients with persistent nasal congestion or obstruction or who unable to breathe comfortably through the nose, may not be candidates for nitrous oxide sedation.

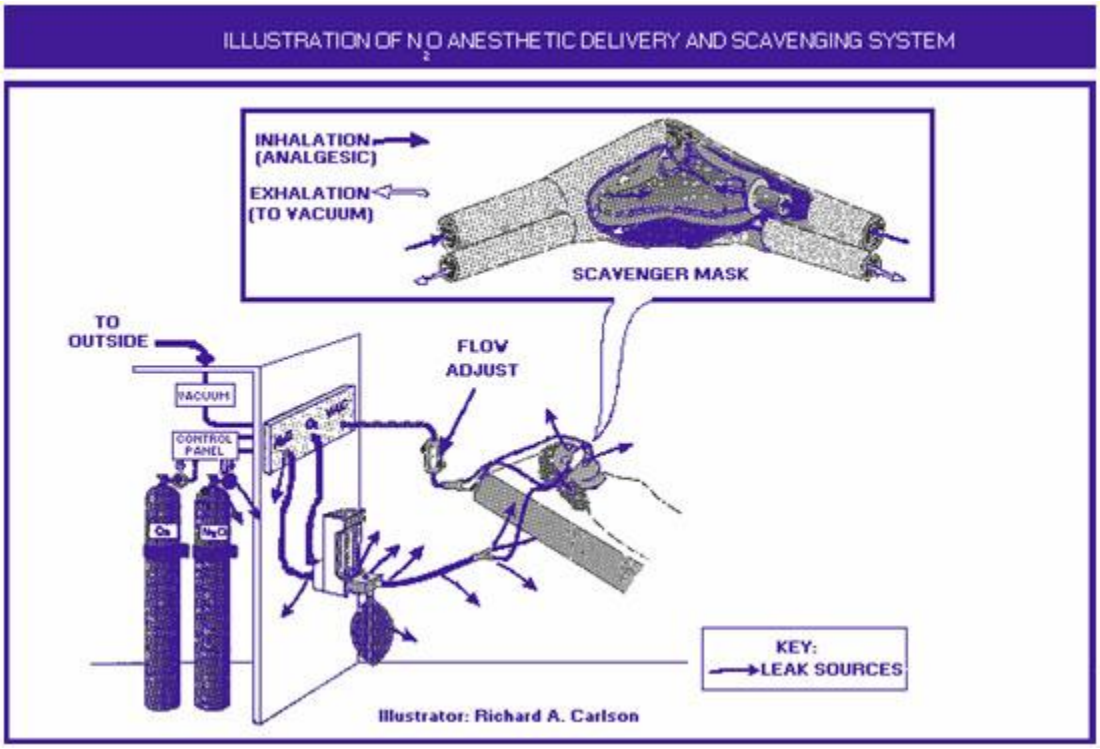
Review of patient’s current medical history is critical prior to the decision to use nitrous oxide sedation and a medical consultation with the patient’s physician may be necessary. This assessment should include:

- Allergies and previous allergic or adverse drug reactions
- Current medications including dose, time, route, and site of administration
- Diseases, disorders, or physical abnormalities and pregnancy status
- Previous hospitalization to include the date and purpose
- Obtain written consent from patient or the guardian of a minor patient.

Equipment

Mixtures of N2O and oxygen have been used in dentistry as general anesthetic agents, analgesics, and sedatives for more than 100 years. The usual analgesia equipment used by dentists includes a N2O and O2 delivery system, a gas mixing bag, and a nasal mask or nasal canula with a positive pressure relief valve.

Figure one below shows basic N20 equipment set up and arrows represent possible leakage areas, discussed below.



Engineering Controls / Maintenance Procedures

The following engineering controls and maintenance procedures have been shown to be feasible and effective in reducing workplace exposure to N2O during anesthetic administration.

Figure 1 illustrates sources of possible leaks from anesthetic delivery systems in dental operatories. These sources include leaks from the high-pressure connections present in the gas delivery tanks, the wall connectors, the hoses connected to the anesthetic machine, and the anesthetic machine (especially the on-demand valve). Low-pressure leaks occur from the connections between the anesthetic flowmeter and the scavenging mask. This leakage is due to loose- fitting connections, loosely assembled or deformed slip joints and threaded connections, and defective or worn seals, gaskets, breathing bags, and hoses.

All newly installed dental facilities that deliver nitrous oxide/oxygen must be checked for proper gas delivery and fail-safe function prior to use. Inhalation equipment must have the capacity for delivering 100%, and never less than 30%, oxygen concentration at a flow rate appropriate to the child's or adult's size. Additionally, inhalation equipment must have a fail-safe system that is checked and calibrated regularly according to the dental practitioner's state laws and regulations. All nitrous oxide delivery system

equipment must have an appropriate scavenging system.

The dental clinician, who utilizes nitrous oxide/oxygen analgesia for a pediatric or general practice dental patient, shall possess appropriate training and skills and have available the proper facilities, personnel, and equipment to manage any reasonably foreseeable emergency. Training and certification in basic life support are required for all clinical personnel and per state regulation. These individuals should participate in periodic review of the office's emergency protocol, the emergency drug cart, and simulated exercises to assure proper emergency management response. Ideally the dental team meets regularly to review clinical emergency management protocols. All dental personnel need current CPR and basic life support training.

An emergency cart (kit) must be readily accessible. Emergency equipment must be able to accommodate adults and children of all ages and sizes. It should include equipment to resuscitate a non-breathing, unconscious patient and provide continuous support until trained emergency personnel arrive.

A positive pressure oxygen delivery system capable of administering >90% oxygen at a 10 liters/minute flow for at least 60 minutes (650 liters, "E" cylinder) must be available. When a self-inflating bag valve mask device is used for delivering positive pressure oxygen, a 15 liters/minute flow is recommended. There should be documentation that all emergency equipment and drugs are checked and maintained on a regularly scheduled basis. Where state law mandates equipment and facilities, such statutes should supersede this guideline.

Analgesia machines for dentistry are designed to deliver up to 70 percent (700,000 ppm) N2O to a patient during dental treatment. The machine restricts higher concentrations of N2O from being administered to protect the patient from hypoxia (lack of oxygen). In most cases, patients receive between 30 and 50 percent N2O during a procedure. The amount of time N2O is administered to a patient depends on the dentist's judgment of an individual patient needs and the complexity of the case.

A newer type of mask is a frequent choice in dental practice: a single patient use nasal hood or single use nasal canula. This single use mask or canula does not require sterilization after surgery because it is used once and is disposable.

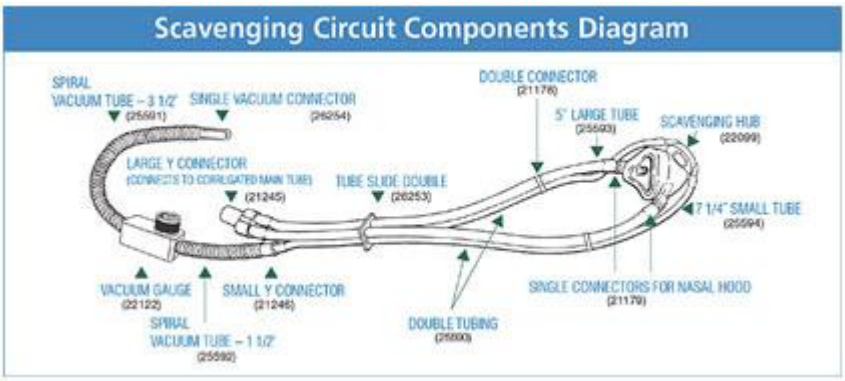
In a dental operatory, a scavenging system is part of a high-volume evacuation system used with a dental unit. The vacuum system may dispose of a combination of waste gases, oral fluid, and debris, and is not limited to waste gas removal. The exhaust air of

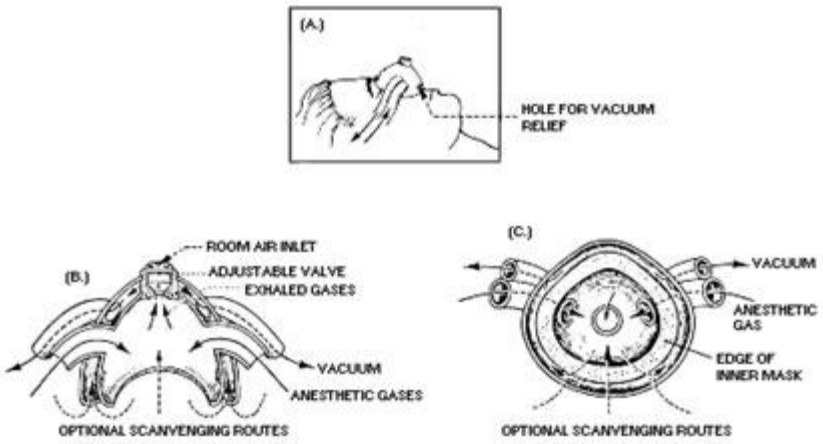
the evacuation system should be vented outside the building and away from fresh-air inlets and open windows to prevent re-entry of gas into the operatory.

Scavenging System

A **scavenging system** designed to pick up excess gases consists of five basic components:

1. **Gas collection** assembly which captures excess anesthetic gases at the site of emission, and delivers it to the transfer tubing.
2. **Transfer tubing**: conveys the excess anesthetic gases to the interface.
3. **The interface**: provides positive (and sometimes negative) pressure relief and may provide reservoir capacity. It is designed to protect the patient's lungs from excessive positive or negative scavenging system pressure.
4. **Gas disposal assembly tubing**: conducts the excess anesthetic gases from the interface to the gas disposal assembly.
5. **Gas disposal assembly**: conveys the excess gases to a point where they can be discharged safely into the atmosphere. Several methods in use include a non-recirculating or recirculating ventilation system, a central vacuum system, a dedicated (single-purpose) waste gas exhaust system, or a passive duct system.





Circle breathing system connected to a closed reservoir scavenging interface. (Reproduced by permission of North American Dräger, Telford, Pennsylvania).

The general ventilation should provide good room / air mixing. In addition, auxiliary (local) exhaust ventilation should be used in conjunction with a scavenging system and has been shown to be effective in reducing excess N2O in the breathing zone of the dental professional/s, from nasal mask leakage and patient mouth breathing. This type of ventilation captures the waste anesthetic gases at their source. However, there are practical limitations in using it in the dental operatory. These include proximity to the patient, interference with dental practices, noise, installation and maintenance costs. It is most important that the dentist not work between the patient and a free-standing local exhaust hood. Doing so will cause the contaminated air to be drawn through the dentist's breathing zone.

Pre-clinical and Post-clinical Work Practices

- Prior to first use each day of the N2O machine and every time a gas cylinder is changed, the low-pressure connections should be tested for leaks. High-pressure line connections should be tested for leaks quarterly. A soap solution may be used to test for leaks at connections. Alternatively, a portable infrared spectrophotometer can be used to detect an insidious leak.
- Prior to first use each day, inspect all N2O equipment (e.g., reservoir bag, tubing, mask, connectors) for worn parts, cracks, holes, or tears. Replace as necessary. Connect mask to the tubing and turn on vacuum pump. Verify appropriate flow rate (i.e., up to 45 L/min or manufacturer's recommendations).

- A properly sized mask should be selected and placed on the patient. A good, comfortable fit should be ensured. The reservoir (breathing) bag should not be over or under-inflated while the patient is breathing oxygen (before administering N2O).

- Encourage the patient to minimize talking, mouth breathing, and facial movement while the mask is in place.
- During N2O administration, the reservoir bag should be periodically inspected for changes in tidal volume, and the vacuum flow rate should be verified.
- On completing anesthetic administration and before removing the mask, non-anesthetic gases/agents should be delivered to the patient for a sufficient time based on clinical assessment that may vary from patient to patient. In this way, both the patient and the system will be purged of residual N2O. Do not use an oxygen flush.

Clinical Protocols

Some dentists administer N2O at higher concentrations at the beginning of the procedure, and then decrease the amount as the procedure progresses. Others administer the same amount of N2O throughout the procedure. When the procedure is completed, the N2O is turned off. Some dentists turn the N2O on only at the beginning of the operation, using N2O as a sedative during the administration of local anesthesia, and turn it off before operating procedures. Based on variations in dental practices and other factors in room air, N2O concentrations can vary considerably for each operation and also vary over the course of the dental procedure.

In the typical dental office procedure, the nasal mask or nasal cannula is placed on the patient, fitted, and adjusted prior to administration of the nitrous oxide/ oxygen gases. The mask or cannula is designed for the nose of the patient since access to the patient's mouth is essential for dental procedures.

A local anesthetic, if needed, is typically administered after the N2O takes effect. The patient's mouth is opened and the local anesthetic is injected. The dental procedure begins after the local anesthetic takes effect. The patient opens his/her mouth but is instructed to breathe through the nose. Nonetheless, a certain amount of mouth breathing frequently occurs. The dentist may periodically stop the dental procedure for a moment to allow the patient to close the mouth and breathe deeply to re-establish an appropriate concentration of N2O in the patient's body before resuming the procedure. Depending on the nature of the procedure, high velocity suction is regularly used to remove intra-oral debris and, when used, creates a negative air flow and captures some of the gas exhaled by the patient.

At the end of the procedure, the nosepiece is left on the patient while the N2O is turned off and the oxygen flow is increased. The anesthetic mixture diffuses from the circulating blood into the lungs and is exhaled. Scavenging is continued while the patient is eliminating the N2O.

Protocols for Monitoring the Patient

The response of patients to commands during procedures performed during nitrous oxide anesthesia serves as a guide to their level of consciousness. Clinical observation of the patient must be done during any dental procedure. During nitrous oxide/oxygen analgesia, continual clinical observation of the patient's responsiveness, color, and respiratory rate and rhythm must be performed. Spoken responses provide an indication that the patient is breathing. If any other pharmacologic agent is used in addition to nitrous oxide/oxygen and a local anesthetic, monitoring guidelines for the appropriate level of sedation must be followed.

The use of a pulse oximeter is also indicated. The oximeter measures the amount of oxygen saturation in the bloodstream via a sensor device placed on a finger or in the case of an infant, on a foot. If the reading falls below 90%, the attending dental personnel need to increase oxygen by increasing flow by making sure the airway is unobstructed and that the patient is breathing deeply enough to maintain appropriate levels. Pulse oximeters are relatively inexpensive and are extremely helpful in monitoring the patient during nitrous oxide administration. Most pulse oximeters have a sound notification if the oxygen saturation in the blood falls below 90%.

Side Effects of Nitrous Oxide / Oxygen Inhalation

The side effects of N2O take three main forms:

1. Metabolic inhibition
2. Pressure/volume problems
3. Problems related to the administration of oxygen.

Metabolism of Nitrous Oxide

Nitrous oxide irreversibly oxidizes the cobalt atom of vitamin B12, inhibiting the activity of the cobalamin-dependent enzyme methionine synthase. Synthesis of the enzyme is required to restore activity and takes several days. A 50% decrease in methionine synthase activity is seen after only 2 hours of exposure. Loss of this enzyme shuts off

the synthesis of methionine, a principle substrate for assembly of myelin sheaths and DNA synthesis, and leads to an accumulation of its precursor homocysteine. In adults with untreated B12 deficiency exposed to nitrous or those who chronically abuse N2O leading to depletion of body stores of cobalamin, a myeloneuropathy is seen which is identical to subacute combined degeneration of the spinal column as seen in pernicious anemia. A high degree of suspicion is necessary for any patient who develops neurologic symptoms after nitrous anesthesia. For these reasons, patients with suspected B12 deficiency (history of B12 supplementation, post gastrectomy, ileal malabsorption) or anemia should not receive nitrous.

Pressure/Volume Toxicity

The other major cause of adverse events from nitrous oxide is due to pressure/volume complications. Compared to nitrogen, nitrous oxide is 34 times more soluble in blood. It will thus diffuse from the blood into any closed air-filled cavity in the body faster than the nitrogen can diffuse out. In a cavity with thick or noncompliant walls, the pressure inside such a cavity will immediately begin to increase. On the other hand, if the nitrous diffuses into a compliant, thin-walled air-filled space such as a pulmonary cyst or a loop of incarcerated bowel, the elevation in pressure will lead to distention of the structure. The major example of nitrous diffusing into a poorly compliant cavity is the eyeball.

Ophthalmologists frequently inject inert gases, e.g., sulfur hexafluoride or perfluoropropane, into the eye to treat retinal detachments. These injections are administered during retinal surgery but may also be done in an office setting. These gas bubbles can remain in the eyeball for weeks before they are reabsorbed. If a patient with an intraocular gas bubble receives nitrous oxide anesthesia, the nitrous will diffuse into the gas bubble and lead to an immediate and dangerous elevation of intraocular pressure. The elevated pressure leads to central retinal artery occlusion and irreversible vision loss. Cases of total vision loss have been reported in patients with diabetic retinopathy followed by nitrous anesthesia. Therefore, the first question to be asked of any patient before nitrous oxide anesthesia is given should ascertain whether the patient has had any ocular procedures, injections, or surgery in the previous 3 months prior to the contemplated use of nitrous oxide.

Ideally, such a patient will still be wearing their green plastic wristband, issued by the ophthalmologist warning against the use of nitrous oxide.

Oxygen Toxicity

Nitrous oxide administration should be avoided in patients who have received therapy with Bleomycin, an anti-neoplastic antibiotic, which is known to cause pulmonary toxicity. Acute respiratory distress syndrome has occurred in patients who have received bleomycin and is felt to be due to fluid overload and high inspired oxygen

concentrations given during the surgical procedure.

Post-inhalation Hypoxia (lack of oxygen)

In 1955, Dr. Raymond Fink published a paper documenting oxygen desaturation of up to 10% occurring after patients given N2O /O2 anesthesia were placed on room air, with the effect lasting up to 10 minutes. For this reason, the standard of care is to administer 100% oxygen for at least 5 minutes to all patients at the conclusion of inhalation anesthesia with N2O /O2. This has been shown to completely prevent this so-called post-inhalation hypoxia.

Acute and chronic adverse effects of nitrous oxide on the patient are rare. Nausea and vomiting are the most common adverse effects, occurring in 0.5% of patients. A higher incidence is noted with longer administration of nitrous oxide/oxygen, fluctuations in nitrous oxide levels, and increased concentrations of nitrous oxide. Fasting is not required for patients undergoing nitrous oxide analgesia. The practitioner, however, may recommend that only a light meal be consumed in the 2 hours prior to the administration of nitrous oxide to avoid any possibility of aspiration of vomit during a procedure.

Disinfection

Disposable nose masks are available and widely used due to their convenience. However, if a reusable nosepiece is used, it is important to disinfect it between each patient. Nosocomial infections have occasionally been linked with the use of unsterile inhalation devices due to cross contamination. The recommended technique for disinfection of these masks is to soak in an alkaline glutaraldehyde solution. It may not be enough to simply spray off between patients, which can cause cross-contamination.

Documentation

Documentation is critical to protect a dentist in the case of a lawsuit. All aspects of a procedure must include the percentage of N2O administered, the length of time the patient was sedated, and the flow of gas during administration.

An acceptable example of documentation for the procedure:

> *"Pt. given 25% N20/75%O2 for 45 minutes @ 7L/min. Pt. initially given 35% N20/65% O2 and reported "slight uneasy feeling' – N2O was subsequently adjusted and comfortable level of sedation achieved". In 10:45am – Out 11:30am".*

Documentation must be consistent and accurate. If in doubt more documentation is better than less.

Workplace Safety Information From OSHA and NIOSH

Health Effects

Animal studies have shown adverse reproductive effects in female rats exposed to airborne concentrations of N2O. Data from these studies indicate that exposure to N2O during gestation can produce adverse health effects in the offspring.

Per guidelines in article revised in 2013 with the American Academy of Pediatric Dentistry, “long-term exposure to nitrous oxide used as a general anesthetic has been linked to bone marrow suppression and reproductive system disturbances. In an effort to reduce occupational health hazards associated with nitrous oxide, the AAPD recommends exposure to ambient nitrous oxide be minimized through the use of effective scavenging systems and periodic evaluation and maintenance of the delivery and scavenging systems.”

Pregnancy and Nitrous Usage

*It is wise **NOT** to use nitrous sedation in pregnant patients, no matter what trimester they are in, though it is believed to be most harmful in the 1st trimester.*

It is important to keep in mind that some cases of miscarriages in female practitioners can be attributed to having worked on patients undergoing nitrous sedation, though scavenger systems WERE in use. Nitrous escaping out of the patient’s mouth, while in use, from talking or from moving around can be just as damaging as a failing scavenger system. Having an assistant use the high vacuum suction and a rubber dam in place can reduce nitrous escaping from a patient’s mouth, but in some treatments, such as procedures by Hygienists, this is not practical.

IF PREGNANT, IT IS BEST TO AVOID WORKING ON PATIENTS, DIRECTLY, WHO WILL BE USING NITROUS IN PROCEDURES!

Several studies show workers with occupational exposure to N2O causes adverse effects such as reduced fertility, spontaneous abortions, and neurologic, renal, and liver disease. A recent study reported that female dental assistants exposed to un-scavenged N2O for 5 or more hours per week had a significant risk of reduced fertility compared with unexposed female dental assistants. The exposed assistants had a 59% decrease in probability of conception for any given menstrual cycle compared with the unexposed assistants.

Workers Exposed

More than 600,000 workers (i.e., dentists, dental assistants, and dental hygienists) practice dentistry in the United States. In 2010, the American Dental Association (ADA) reported that 35% of all dentists used N2O to control pain and anxiety in their patients. The ADA Survey of Dental Practice indicated that 58% of dentists reported having N2O anesthetic equipment, and 64% of those practitioners also reported having a scavenging system.

General Workplace Controls

Occupational exposure for dental clinicians can be controlled by the application of a number of well-known principles including engineering and work practice controls, administrative controls, personal protective equipment, and monitoring.

Exposure may be controlled by some or all of the following:

- Effective anesthetic gas scavenging systems that remove excess anesthetic gas at the point of origin.
- Effective general or dilution ventilation.
- Good work practices on the part of the health-care workers, including the proper use of controls.
- Proper maintenance of equipment to prevent leaks.
- Periodic personnel exposure and environmental monitoring to determine the effectiveness of the overall waste anesthetic gas control program.
- Limiting conversation and mouth-breathing by patient during nitrous use. Pt should be instructed to breath slowly through nose and to not talk unless important.

Occupational Exposure Limits

The Occupational Safety and Health Administration (OSHA) does not currently have an exposure limit standard for N2O.

Currently, and as of 2014, NIOSH recommended exposure limit (REL) for N2O is 25 ppm as a time-weighted average (TWA) during the period of anesthetic administration [NIOSH 1977b]. This REL is intended to prevent decreases in mental performance, audiovisual ability, and manual dexterity during exposures to N2O. An REL to prevent adverse reproductive effects cannot be established until more data are available.

The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for N2O is 50 ppm as an 8-hour TWA.

Guidelines for Minimizing Exposure

Exposure monitoring should be the first step in developing work practices and worker education programs, since measurements of N2O are needed to determine the type and extent of controls that are necessary. Guidelines for this section are provided from OSHA and NIOSH websites:
https://www.osha.gov/dts/sltc/methods/inorganic/id166/id166.html

Determination of a worker's exposure to airborne nitrous oxide can be made using one of the following techniques:

- Landauer Passive Dosimeter badge, which can be used for a minimum sampling duration of 1 hour (maximum duration 40 hours). Analysis is performed by the manufacturer of the badge as described in the OSHA Computerized Information System.
- Use of an ambient air or bag sample with a minimum collection volume of two spectrophotometer cell volumes. Analysis is conducted using a long-path length portable infrared spectrophotometer as described in NIOSH Method No. 6600.
- ADA (American Dental Association) approved manufacturer of various dosimeter badges for nitrous oxide exposure measurement.

Nitrous Oxide Badge Monitors

The United States Department of Labor recommends healthcare workers and dental clinicians monitor exposure to N20 by use of badges. Several manufacturers make monitoring badges. Landauer is specifically mentioned by the Labor Department and offers the information below from their website:

The Landauer nitrous oxide monitor (NITROX®) is a diffusion type air monitoring badge assembly worn in the breathing zone of personnel to evaluate potential exposure to N2O gas. Nitrous oxide gas is adsorbed on the selected adsorbent material (molecular sieve), sent to the laboratory and thermally desorbed and analyzed by the manufacturer using IR. Both an active cartridge sample collected by drawing air through the cartridge with a calibrated sampling pump, (referred to as "active samples" in this report), and a passive monitor sample which requires no sampling pump to collect the sample (referred to as "passive samples" in this report) were taken. Both use the same proprietary adsorbent material.

Advantages and Disadvantages
(per Dept. of Labor)

This badge monitor method, such as Landauer has adequate sensitivity for measuring workplace atmosphere concentrations of N2O.

The sampling procedure for this method involves no liquid and mechanical pumps. A somewhat bulky direct-reading instrument is not used and pre- and post-calibration is not necessary.

One disadvantage is the requirement that the monitor is analyzed at the manufacturer's laboratory, which does not allow for immediate results as given by a direct-reading instrument. Quality control is dependent mainly on the manufacturer; this makes it difficult for those laboratories which prefer to conduct their own quality control program. It is recommended that users occasionally prepare spiked samples to assure adequate quality control.

Signs and Symptoms of Exposure

Acute exposure: The signs and symptoms of acute exposure to nitrous oxide include dizziness, difficult breathing, headache, nausea, fatigue, and irritability. Acute exposure to nitrous oxide concentrations of 400,000 to 800,000 ppm may cause loss of consciousness.

Chronic exposure: The signs or symptoms of chronic overexposure to nitrous oxide may include tingling, numbness.

The following worker fact sheet is issued by NIOSH (National Institute of Safety and Health) and should be clearly visible and posted in a clinical dental workplace.

(WORKER FACTSHEET)

Controlling Exposures to Nitrous Oxide

During Anesthetic Administration

WARNING!

Workers exposed to nitrous oxide (N2O) may suffer harmful effects.

Take the following steps to protect yourself from waste N2O in the workplace:

1. Be aware that N2O may cause the following health effects:
    - Decreases in mental performance, audiovisual ability, and manual dexterity
    - Adverse reproductive effects
2. Make sure that the following monitoring procedures are performed when the anesthetic equipment is installed and every 3 months thereafter:
    - Leak testing of equipment
    - Monitoring of air in the worker's personal breathing zone
    - Environmental (room air) monitoring
3. Prevent leakage from the anesthetic delivery system through proper maintenance and inspection of equipment. Eliminate or replace the following:
    - Loose-fitting connections
    - Loosely assembled or deformed slip joints and threaded connections
    - Defective or worn seals, gaskets, breathing bags, and hoses
4. Control waste N2O with a well-designed scavenging system that includes the following:
    - Securely fitting masks
    - Sufficient flow rates for the exhaust system
    - Properly vented vacuum pumps
5. Make sure that the room ventilation is effectively removing waste N2O. If concentrations of N2O are above 25 ppm, take the following steps:
    - Increase the airflow into the room.
    - Use supplemental local ventilation to capture N2O at the source. Engineering controls, work practices, and respirators (when necessary) should be used to minimize the exposure of healthcare workers to N2O. Dental employers should ensure that their dental staff are adequately protected from N2O exposure by preparing a written monitoring and maintenance plan for each dental office facility that uses N2O. This plan should be developed by knowledgeable persons who consider the equipment manufacturers' recommendations, frequency of use, and other circumstances that might affect the equipment.

Abuse of Nitrous Oxide

- The substance disrupts learning ability. In a typical experiment volunteers who inhaled a low dose of the drug showed worsened reaction time, worsened ability to do arithmetic, and general sedation accompanied by nervous system depression (as opposed to stimulation).
- Interference with driving ability has been noted one-half hour after a dose.
- Short-term exposure can cause dizziness, nausea, vomiting, and breathing difficulty.
- Some recreational users quickly inhale as much nitrous oxide as possible and hold their breath. This technique causes a sudden change of pressure inside the lungs and can rupture small interior structures needed for breathing.
- Blood pressure can go up or down, depending on dosage. Users can lose consciousness, which may be hazardous in a recreational context due to falls or inability to shut off the gas source.
- The substance deactivates vitamin B12, an effect that can cause numbness and difficulty in moving arms and legs.
- Other results can be impotence and involuntary discharge of urine and feces.
- Nitrous oxide interferes with blood clotting, and long-term exposure has caused blood abnormalities.
- Persons with chronic industrial exposure have more kidney and liver disease than usual.
- Nitrous oxide can become very cold when released as a gas from a pressurized container, cold enough to cause frostbite upon meeting skin or throat.
- Breathing nitrous oxide without an adequate supply of oxygen can be fatal; a little in a closed space or a lot from a face mask can suffocate a user.
- Although nitrous oxide is called nonflammable, when inhaled it can seep into the abdominal cavity and bowels, mixing with body gases to create a flammable combination. If ignited the result would be like setting off an explosive inside the body; the danger is real enough that surgical personnel administering nitrous oxide as an anesthetic have been warned about it.

Updates in N2O

According to a 2014 online article in *Dentistry Today*, Nitrous Oxide is being tested to treat patients with clinical depression.

The article goes on to explain:

> “The research team from Washington University conducted a study of 20 patients who didn’t see their mental health improve after using other forms of treatment

for their issues. This group of people was then given either laughing gas or a placebo. The patients were later asked about how they felt after 2 hours and 24 hours later. Some patients stated that they felt better after receiving the placebo but there were major improvements among the patients who inhaled the laughing gas. Seven study participants said they felt minor improvement in their symptoms, which included insomnia, problems sleeping and feelings of sadness or guilt. Seven other participants stated there was a major improvement in how they felt. More research is necessary but the initial results look promising. The impact of the laughing gas came quickly and lasted for as long as a week in some cases. That's why it's possible that laughing gas could be a solution for patients suffering from severe depression and require treatment promptly. Some of the medication may take as long as 2 weeks to have a positive result. The nitrous oxide may work much faster than that."

There are other medicinal uses of nitrous oxide, in this day and age, and Ally N Alai, MD, FAAD explains,

> "Although not standard practice, additional described uses may include colonoscopy, sigmoidoscopy, laser procedures, obstetrical labor pain [not to be confused with any other trimester in pregnancy EXCEPT during delivery of child], ophthalmic procedures, emergency medical care of patients in accidents and during ambulance transport, and minor invasive medical procedures, including joint injections.
>
> Less commonly, self-administered nitrous oxide is reported for chronic pain from terminal illness and pain associated with cancer treatment.
>
> Nitrous oxide use in children undergoing basic procedures including lumbar puncture, venous cannulation, or dressing changes has demonstrated a significant reduction in pain levels, allowing for a shorter recovery. The children who were administered nitrous oxide displayed less anxiety and distress during medical procedures. A 2009 prospective, randomized study showed that a 70:30 mix of nitrous oxide in oxygen, administered for 3 minutes, was effective in reducing pain in children undergoing venipuncture.
>
> Nitrous oxide has been proven beneficial in young children receiving injections for juvenile arthritis. Additionally, nitrous oxide has been used successfully as an anesthetic for children undergoing minor surgeries such as cyst surgery and abscess drainage."

Conclusion

Nitrous oxide / oxygen anesthesia is used in a standard way in dentistry and medicine. And review of the standards on a regular basis is invaluable to maintain the highest standard of care. Professional use and administration of nitrous oxide is a tried and true method to manage patients' anxiety for dental procedures. The overall patient experience is enhanced by careful and professional use of this practice-building anesthetic gas. Dental team members must adhere to the best clinical protocols and know the standard of care to ensure absolute safety for the patient and to minimize exposure to themselves. Nitrous oxide is safe and effective for use by qualified dental professionals in a wide variety of situations requiring pain and anxiety management in the dental office setting.

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Glossary of Terms

The following glossary of terms relates to use of N20 sedation. This list is abbreviated from the OSHA list. The full glossary is available by searching the OSHA website: http://www.osha.gov/dts/osta/anestheticgases/index.html

Air is the elastic, invisible mixture of gases (chiefly nitrogen and oxygen) that may be used with medical equipment; also called medical air.

Anesthesia machine is equipment intended for dispensing and delivering anesthetic gases and vapors into a breathing system.

Anesthetic agent is a drug that is used to reduce or abolish the sensation of pain, e.g., halothane, enflurane, isoflurane, desflurane, sevoflurane, and methoxyflurane.

Anesthetic gas is any gaseous substance, e.g., nitrous oxide, used in producing a state of anesthesia.

Anesthetizing location is any area in a facility where an anesthetic agent or drug is administered in the course of examination or treatment. This includes operating rooms, delivery rooms, emergency rooms, induction rooms, and other areas.

Area sample is a sample collected at a fixed point in the workplace.

Breathing system is a gas pathway in direct connection with the patient's lungs, through which gas flow occurs at respiratory pressures, and into which a gas mixture of controlled composition may be dispensed. The function of the breathing system is to convey oxygen and anesthetic gases to the patient's lungs and remove waste and anesthetic gases from the patient's lungs. Scavenging equipment is not considered part of the breathing system. The system is also referred to as breathing or patient circuit, respiratory circuit or system.

Breathing zone is defined as the area immediately adjacent to the employee's nose and mouth; a hemisphere forward of the worker's shoulders with a radius of approximately 6 to 9 inches.

Carbon dioxide (CO2) is a colorless, odorless gas, and is a normal end product of human metabolism. It is formed in the tissues and eliminated by the lungs.

Carcinogenicity is the ability of a substance to cause cancer.

Check valves are also known as unidirectional valves, one-way valves, and inspiratory and expiratory valves (refer to definition of unidirectional valve).

Compressed gas is defined as any material or mixture having in the container an absolute pressure exceeding 40 psig at 70°F or having an absolute pressure exceeding 104 psig at 130°F.

Congenital anomaly is a structural or functional abnormality of the human body that develops before birth but is not inherited. One type of birth defect.

Cylinder supply source is a cylindrical-shaped tank that is color-coded and pin-indexed or Compressed Gas Association (CGA)valve-specific and used to contain a specified medical gas.

Cylinder pressure gauge monitors the pressure of gas within a cylinder.

Epidemiology is the study of health and illness in human populations.

Excess gases are those gases and anesthetic vapors that are delivered to the breathing circuit in excess of the patient's requirements and the breathing circuit's capacity These gases are removed from the breathing circuit by the waste gas scavenging system.

Exhalation check valve, also known as expiratory unidirectional valve, refers to that valve that ensures that exhaled gases flow away from the patient and into the waste gas absorber.

Flow control valve, also known as the needle valve, controls the rate of flow of a gas through its associated flow meter by manual adjustment.

Flowmeter is a device that measures and indicates the flow rate of a gas passing through it.

Gas is defined as a formless fluid that expands readily to fill any containing vessel, and which can be changed to the liquid or solid state only by the combined effect of increased pressure and decreased temperature.

General anesthesia is a state of unconsciousness in which there is an absence of pain sensation.

HVAC system, also known as the heating, ventilating, and air conditioning system, supplies outdoor replacement (make-up) air and environmental control to a space or building. HVAC systems condition the air by supplying the required degree of air cleanliness, temperature and/or humidity.

Medical gas is any gaseous substance that meets medical purity standards and has application in a medical environment. Examples are oxygen, nitrous oxide, helium, air, nitrogen, and carbon dioxide.

Medical gas mixture is a mixture of two or more medical gases to be used for a specific medical application.

NIOSH RELs (recommended exposure limits) are occupational exposure limits for a 40 hour work week.

Nitrous oxide (N2O) is used as an anesthetic agent in medical, dental, and veterinary operatories. N2O is a weak anesthetic with rapid onset and rapid emergence. In dental offices, it is administered with oxygen, primarily as an analgesic (an agent that diminishes or eliminates pain in the conscious patient) and as a sedative to reduce anxiety.

Occupational exposure to waste anesthetic gases includes exposure to any inhalation anesthetic agents that escape into locations associated with, and adjacent to, anesthetic procedures. Oxygen (O2) is an element which, at atmospheric temperatures and pressures, exists as a colorless, odorless, tasteless gas. Outstanding properties are its ability to sustain life and to support combustion.

Oxygen flush valve is a separate valve designed to rapidly supply a large volume of oxygen to the breathing system.

PACU (post-anesthesia care unit) is also known as the recovery room.

Pin Index Safety System is a safeguard to eliminate cylinder interchanging and the possibility of accidentally placing the incorrect gas on a yoke designed to accommodate another gas.

Pipeline supply source is a permanently installed piped distribution system that delivers medical gases such as oxygen, nitrous oxide, and air to the operating room.

Reservoir bag is also known as the respiratory bag or breathing bag. It allows accumulation of gas during exhalation so that a reservoir is available for the next inspiration. It can serve, through visual and tactile observation, as a monitor of a patient's spontaneous respirations and acts to protect the patient from excessive pressure in the breathing system.

Respiration is the process by which a rapid exchange of oxygen and carbon dioxide takes place between the atmosphere and the blood coming to the pulmonary capillaries. Oxygen is taken up and a proportional amount of carbon dioxide is released.

Scavenging is defined as the collection of excess gases from the breathing circuit and removal of these gases to an appropriate place of discharge outside the working environment.

Scavenging system is defined as a device (assembly of specific components) that collects and removes the excess anesthetic gases that are released from the breathing circuit.

Source sample is a sample collected at the origin of contamination.

Teratogenicity is the ability of a substance to cause birth defects in offspring, as a result of maternal (before or after conception) or paternal exposure to the toxic substance.

Tracheal tube also called the endotracheal tube, intratracheal tube, and catheter is inserted into the trachea and is used to conduct gases and vapors to and from the lungs.

TWA is a time-weighted average concentration. It is a way of expressing exposure such that the amount of time spent exposed to each different concentration level is weighted by the amount of time the worker was exposed to that level.

Unidirectional valve is a valve that allows gas flow in one direction only.

Vapor is the gaseous phase of a substance which at ordinary temperature and pressure exists as a liquid.

Ventilation is (1) the physical process of moving gases into and out of the lungs. (2) It

is also defined for the purposes of industrial hygiene engineering as a method for providing control of an environment by strategic use of airflow.

Waste anesthetic gases are those gases that are inadvertently released into the workplace and/or can no longer be used.

Course Test: Nitrous Oxide Sedation: A Basic Review

1. Nitrous oxide produces the following effects:

    a. analgesic
    b. anxiolytic
    c. A only
    d. A & B

2. The “discoverer of anesthesia” is considered to be:

    a.. Dr. Blackwell
    b. Gardner Quincy Colton
    c. Dr. Horace Wells
    d. John Mankey Riggs

3. A standard mixture of nitrous oxide and oxygen which is administered to patients to achieve comfort during dental treatment, consists of:

    a. 5% nitrous and 95% oxygen
    b. 40% to 70 % nitrous oxide gas with the remainder oxygen
    c. 70% nitrous and three liters per minute oxygen
    d. ED50 for general anesthesia

4. Contraindications for use of nitrous oxide would be patients with:

    a. treatment with bleomycin sulfate
    b. suspected B12 deficiency
    c. first trimester of pregnancy
    d. all of the above

5. Review of a patient’s medical history prior to administration of nitrous oxide should include all of the following, except:

    a. allergies or drug reactions
    b. current medications
    c. recent vaccinations
    d. diseases, disorders, and pregnancy status

6. In a dental operatory, a scavenging system is part of a _____ evacuation system used with a dental unit.

    a. high-volume
    b. voluntary
    c. low-volume
    d. OSHA

7. Nitrous oxide machines should be checked:

    a. weekly
    b. monthly
    c. daily
    d. daily and when a cylinder is changed

8. During administration of nitrous oxide a patient should be monitored:

    a. for response to commands
    b. with a pulse oximeter to measure oxygen saturation
    c. color and respiratory rate
    d. all of the above

9. To prevent post-inhalation hypoxia, a patient is administered:

    a. oxygen and epinephrine
    b. 100% oxygen for at least 5 minutes
    c. a slow decrease of nitrous oxide, then 70% oxygen for at least 5 minutes
    d. desaturated oxygen

10. Guidelines for monitoring exposure in the workplace to nitrous oxide are provided by:

    a. the supervising dentist
    b. NIOSH and OSHA
    c. American Conference of Industrial Hygienists (ACGIH)
    d. B and C