ENVIRONMENTAL HEALTH & SAFETY
UNIVERSITY of WASHINGTON

UNIVERSITY OF WASHINGTON ANESTHETIC GASES: SAFE USE GUIDELINES

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INTRODUCTION

One of the principal goals of general anesthesia is to prevent patients, both human and animal, from feeling pain during surgery. A common method of anesthesia is the purposeful inhalation of a gas that provides general sedative effects and/or induces unconsciousness. Anesthetic gases can be separated into two categories: Halogenated anesthetic gases/vapors and nitrous oxide. These may be administered in combination to produce surgical levels of anesthesia in humans. Halogenated anesthetic gases/vapors are also commonly used during veterinary care or experiments in animal research.

Anesthetic gases and vapors that leak into the surrounding room are considered waste anesthetic gases (WAGs). If equipment is not set up or functioning properly, the WAG is not properly exhausted or captured via scavenging, or the ventilation is not adequate, healthcare workers, researchers, and veterinary personnel may be exposed to WAGs. This exposure creates a risk of potentially developing adverse health effects.

Potential exposure to WAGs at the UW could occur in the following settings:

- UW Medicine operating rooms or other clinical applications with anesthesia
- School of Dentistry facilities and UW Medicine-affiliated dental clinics
- Department of Comparative Medicine (DCM) facilities (vivaria)
- Washington National Primate Research Center (WANPRC) facilities
- Research laboratories conducting work with animals

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PURPOSE

The purpose of this document is to inform users and others who may be exposed to anesthetic gases of the potential health hazards and methods of controlling exposures.

The state of Washington has established permissible exposure limits for nitrous oxide in the Washington Administrative Code (WAC 296-841-20025).

Currently there are no enforceable regulatory requirements to limit an employee's exposure to halogenated anesthetic gases/vapors in the work environment. However, recommended exposure limits, established by the National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH), are widely used and accepted as exposure limit guidelines. Refer to the Exposure Limits for Anesthetic Gases section below for more information.

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ROLES AND RESPONSIBILITIES

Table 1: Roles and responsibilities

Role	Responsibilities
Managers, supervisors, principal investigators, responsible parties	• Conduct a hazard analysis prior to conducting new or modified procedures. • Develop, implement, and enforce standard operating procedures (SOPs) that include information about anesthetic gas exposure hazards and methods to control them. • Develop and implement training on the hazards of anesthetic gases, proper procedures, and anesthesia equipment. Ensure workers are trained prior to any work. • Ensure safety data sheets (SDS) for the anesthetic gases and liquids are available, either physically or digitally, and workers know how to obtain and understand them. • Ensure all hazardous chemicals are inventoried in MyChem, the UW's online chemical SDS inventory. • Ensure machines, equipment, and ventilation systems used with anesthetic gases are maintained and inspected on a regular basis to ensure safe operation for workers, patients, researchers, and research subjects. • Ensure proper labeling of gas cylinders, containers, and equipment containing anesthetic gases and liquids. • Rooms with hazardous materials must post an up-to-date Caution Sign at the entrance. • Report incidents via the UW Online Accident Reporting System (OARS).
Personnel working with anesthetic gases (e.g., clinical, research, and veterinary staff)	• Complete training to ensure knowledge of hazards of anesthetic gases, importance of engineering controls, safe work practices and procedures to follow to avoid exposures, and proper personal protective equipment (PPE) to wear for protection. • Review safety data sheets (SDS) for chemicals prior to use. • Follow SOPs and safe work practices to limit exposure to anesthetic gases and liquids. • Reports all incidents to a supervisor immediately.
Environmental Health & Safety (EH&S)	• Establish and oversee University requirements and best practices for working safely with anesthetic gases. • Assist University departments, units, and organizations with training personnel on the hazards of anesthetic gases, engineering controls, safe work practices, procedures to avoid exposures, and proper PPE to wear. • Conduct personal or area air monitoring and testing as needed.

HOW PERSONAL EXPOSURES CAN OCCUR

All work with anesthetic gases must be performed with either dedicated exhaust (e.g., fume hood, local exhaust ventilation) and/or a scavenging system (preferred) to prevent exposure.

Exposures can occur when handling the gases or liquids, leakage from equipment, from the patient or animal breathing circuit during delivery of anesthesia, or as exhaled by the patient or research animal (for most anesthetic gases, less than 5% of gas is absorbed and metabolized, the majority is exhaled unchanged).

Anesthetic gases are heavier than air and can accumulate lower in rooms and in the breathing zones of personnel. Due to the gas/vapor nature of these anesthetics, the most common exposures are via the inhalation route. Splashes to the skin or eyes from the liquid form are also possible.

Even when scavenging and venting systems are in place, workers may be exposed to WAGs under the following conditions:

Clinical/dental

- When leaks occur in the anesthetic breathing machine, breathing system, hoses, and connections; this happens if the connectors, tubing, and valves are not maintained and/or tightly connected.
- When anesthetic gas seeps over the lip of the patient's mask or from endotracheal coupling, particularly if the mask is poorly fitted (e.g., during pediatric anesthesia)
- During dental operations, especially with patient mouth-breathing or talking
- Leaks from around tracheal tubing

Animal

- During induction of anesthesia, both while using liquid anesthetics (drop method) and induction boxes; this is more common with rodents.
- Opening of induction boxes
- Failure to promptly discontinue the flow of anesthetic gas prior to removing an animal from an anesthetic breathing line (e.g. removing and replacing animals on a single nose cone)
- Misuse or over-saturation of charcoal canister in scavenging system

All applications

- When anesthetic gases escape during hookup and disconnection of the anesthesia system or scavenging system
- When filling refillable vaporizers
- Leaks between subject and facemask/nose cone
- Spills of liquid anesthetics

- When the anesthesia system is flushed or purged at the conclusion of a procedure
- Insufficient ventilation system or gas scavenging system

Clinical personnel who may be exposed to WAGs include, but are not limited to:

- Anesthesiologists
- Nurse anesthetists
- Dentists
- Dental assistants
- Dental hygienists
- Operating-room nurses
- Operating-room technicians
- Other operating-room personnel
- Recovery-room nurses
- Other recovery-room personnel
- Surgeons

In animal research, the following personnel may be exposed to WAGs:

- Research personnel
- Veterinary personnel
- Animal care technicians

It is important to know that most anesthetic gases have high odor thresholds. This means that anesthetic gases cannot be detected by their odor until concentrations are very high. For example, halothane cannot be detected by 50% of the general population until the concentration is more than 125 times the NIOSH recommended exposure limit (REL). Therefore, **workers should never rely on odor as a warning of potential exposure to anesthetic gases**.

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OCCUPATIONAL EXPOSURE LIMITS FOR ANESTHETIC GASES

The state of Washington has established permissible exposure limits for nitrous oxide of 50 parts per million (ppm) averaged over an 8-hour work day and a short-term exposure limit (STEL) of 75 ppm averaged over a 15-minute period (WAC 296-841-20025).

Recommended exposure limits were established (1977) by NIOSH for nitrous oxide and halogenated anesthetic gases as a class of chemicals. ACGIH has since released more recent threshold limit values (TLVs) for specific halogenated anesthetic gases and nitrous oxide (1989; with some more recent updates). For the purpose of EH&S evaluations, PELs, STELs, and TLVs will be referenced as the "limits where corrective action is required." In the absence of PELs, STELs, and TLVs, the 1977 NIOSH REL value will be referenced as the limit at which corrective action is required.

The U.S. Department of Labor Occupational Safety and Health Administration (OSHA) published Anesthetic Gases: Guidelines for Workplace Exposures on their website in 1999 to assist employers in providing a safe and healthful workplace. It should also be noted that citations may be issued under the General Duty Clause of the U.S. Occupational Safety and Health Act (1970) if protective measures are not employed that are reasonable and in keeping with industry recognized controls and exposure limits.

Specific anesthetic gases and liquids used at the UW are listed in Table 2 below with their regulated state exposure limits, recommended exposure limits established by ACGIH, potential health effects, and hazard warnings. At room temperature, nitrous oxide is a gas, and when mixed with oxygen, it is commonly used for sedation and pain relief in dentistry. The halogenated anesthetic agents are volatile liquids that are vaporized and mixed with other gases prior to inhalation by the patient or subject before or during surgery. Other gas mixtures always include oxygen (or air) but may also include gases such as nitrous oxide.

TABLE 2: REQUIRED AND RECOMMENDED EXPOSURE LIMITS

Anesthetic Gas	WAC[1]/OSHA PEL/STEL	ACGIH TLV [2]	Potential Health Effects[3]	Hazard warnings (from SDS)[4]
Nitrous Oxide Gas Dinitrogen monoxide	WAC TWA 50 ppm[6] WAC STEL 75 ppm[6]	50 ppm[6]	Prolonged exposure may inhibit DNA synthesis; avoid in the first trimester of pregnancy.	GHS: Danger - may cause or intensify fire; oxidizer; contains gas under pressure; may explode if heated.
Isoflurane (Forane®) Clear liquid 1-Chloro-2,2,2-trifluoroethyl difluoromethyl ether	None	50 ppm[6]	Effects on pregnancy not well characterized.	GHS: Warning – may cause drowsiness or dizziness; may cause damage to organs through prolonged or repeated exposure.
Halothane (Fluothane®) Clear liquid 2-Bromo-2-chloro-1,1,1-trifluoroethane	None	5 ppm[6]	Liver damage; effects on pregnancy not well characterized; experiments in pregnant rats showed possible developmental toxicity in neonates.	GHS: Danger - causes serious eye damage; causes skin irritation; may cause respiratory irritation; may damage fertility or the unborn child.
Desflurane (Suprane®) Clear liquid 2-(Difluoromethoxy)-1,1,1,2-tetrafluoroethane	None	None[5,6] (NIOSH REL of 2ppm 1-hour TWA used)	Effects on pregnancy not well characterized; experiments in rats and rabbits indicate potential toxicity at high exposure levels.	GHS: Danger – causes serious eye irritation; causes skin irritation; may cause respiratory irritation; may cause drowsiness or dizziness; may damage fertility or the unborn child.
Sevoflurane (Ultane®) Clear liquid Fluoromethyl 2,2,2-trifluoro-1-(trifluoromethyl) ethyl ether	None	50 ppm[6]	Effects on pregnancy not well characterized; some human epidemiology studies suggest that there may be impacts on lactation rates and duration after birth.	GHS: Warning – may cause drowsiness or dizziness; Suspected of damaging fertility or the unborn child.

1. WAC PEL: Permissible exposure limit as a time-weighted average (TWA) averaged over an 8-hour workday; STEL: Short term exposure limit (15-minute)
2. TLV: threshold limit value TWA; these values can refer to an 8-hour workday and a 40-hour work week averaged exposure or a short-term exposure limit.
3. National Institute of Health (NIH) 2019
4. GHS: Globally Harmonized System for chemical hazard classification and labeling; GHS information was sourced from NIH's PubChem
5. There is currently no regulatory occupational exposure limit nor recommended threshold limit value established by ACGIH for desflurane. As such, the NIOSH Recommended Exposure Limit (REL) for halogenated anesthetic gases will be referenced when sampling for this substance. This particular NIOSH REL is measured as a TWA over one hour.
6. When used in combination with nitrous oxide, NIOSH recommends exposures to halogenated gases to be kept below 0.5 ppm over a sampling period not to exceed 1-hour.

TABLE 3: ANESTHETIC GASES/VAPORS COMMONLY USED IN SPECIFIC UW AREAS FOR MEDICAL AND DENTAL PATIENTS AND RESEARCH ANIMALS

UW anesthetic gas use areas	Anesthetic gas/vapor commonly used
Medical/Clinical settings	Combination nitrous oxide and isoflurane or sevoflurane, desflurane in some cases
Dental	Nitrous oxide unless patient is undergoing more extensive surgery, then defer to clinical practices (typically nitrous oxide with isoflurane)
Research non-human primates and other large animals	Isoflurane, sevoflurane, and halothane in rare cases
Research rodents	Isoflurane

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HEALTH EFFECTS FROM ANESTHETIC GAS EXPOSURE

In 1977, NIOSH issued a criteria document detailing the potential health hazards of worker exposures to waste anesthetic gases and vapors. It includes exposure control procedures and work practices to prevent the potential health effects of acute exposure and reduce the risks associated with long term exposure. The following health effects data was reported based on human and animal studies at that time:

- Chronic exposure increased the risk of both spontaneous abortion and congenital abnormalities in offspring of female workers and wives of male workers.
- Increased risks of hepatic and renal diseases
- Impaired psychological functions
- Increased risk of cancer in some studies
- Acute exposure effects on the central nervous system (CNS) associated with headaches, nausea, fatigue, and irritability

In response to more recent studies, the ACGIH has published or updated TLVs for certain anesthetic gases. Where applicable, UW EH&S will reference the TLVs when performing exposure assessments. The specific health effects for nitrous oxide and the halogenated anesthetic gases are summarized below.

An *acute exposure* is defined as a short-term exposure (i.e., minutes to days) to a relatively high concentration of an anesthetic gas.

A *chronic exposure* includes long term exposures (i.e., months to years) to relatively low concentrations of anesthetic gases.

NITROUS OXIDE

Acute exposure can cause:

- Lightheadedness
- Shortness of breath

Chronic exposure has been linked to:

- Reduced fertility
- Spontaneous abortion
- Birth defects
- Reproductive harm
- Neurologic disease
- Liver/kidney disease

HALOGENATED ANESTHETIC GASES

Acute exposure can cause:

- Headache
- Drowsiness
- Nausea
- Dizziness
- Fatigue
- Irritability
- Transient blurring of vision
- Difficulties with judgement and coordination
- Liver and kidney disease

Chronic halogenated anesthetics exposure may be linked to:

- Sterility
- Miscarriages
- Birth defects
- Genetic damage
- Cancer
- Liver and kidney disease
- Asphyxia

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ENVIRONMENTAL EFFECTS OF ANESTHETIC GASES

While anesthetic gases are crucial tools in safe and humane clinical and research use, they are also potent greenhouse gases and/or ozone-depleting chemicals. Anesthetic gases have long atmospheric lifetimes, and many are accumulating in the atmosphere faster than they are degrading. As such, their use must be carefully controlled; therefore, waste gases must be captured to the extent feasible to reduce their environmental impact in addition to their occupational health impacts.

Researchers and clinicians should assess the anesthetics they use and consider substituting high Global Warming Potential (GWP) anesthetics for lower GWP anesthetics when clinically appropriate while taking into account the quantities needed to induce the desired effects. For example, nitrous oxide is less potent than other anesthetic gases and requires larger quantities to achieve the same effect; thus, in clinically relevant doses, it has similar global warming impacts as desflurane. The GWP of select anesthetic gases from lowest to highest are sevoflurane, isoflurane, desflurane.

Spills of liquid anesthetics must be promptly absorbed and contained in airtight bags or containers to minimize the amount lost to evaporation and exposed to personnel. Refer to the Spills and Releases section of this document for information on responding to anesthetic spills.

"Action guidance for addressing pollution from inhalational anaesthetics" provides useful tools and case studies for groups looking to limit their greenhouse gas emissions with respect to anesthetic gas use.

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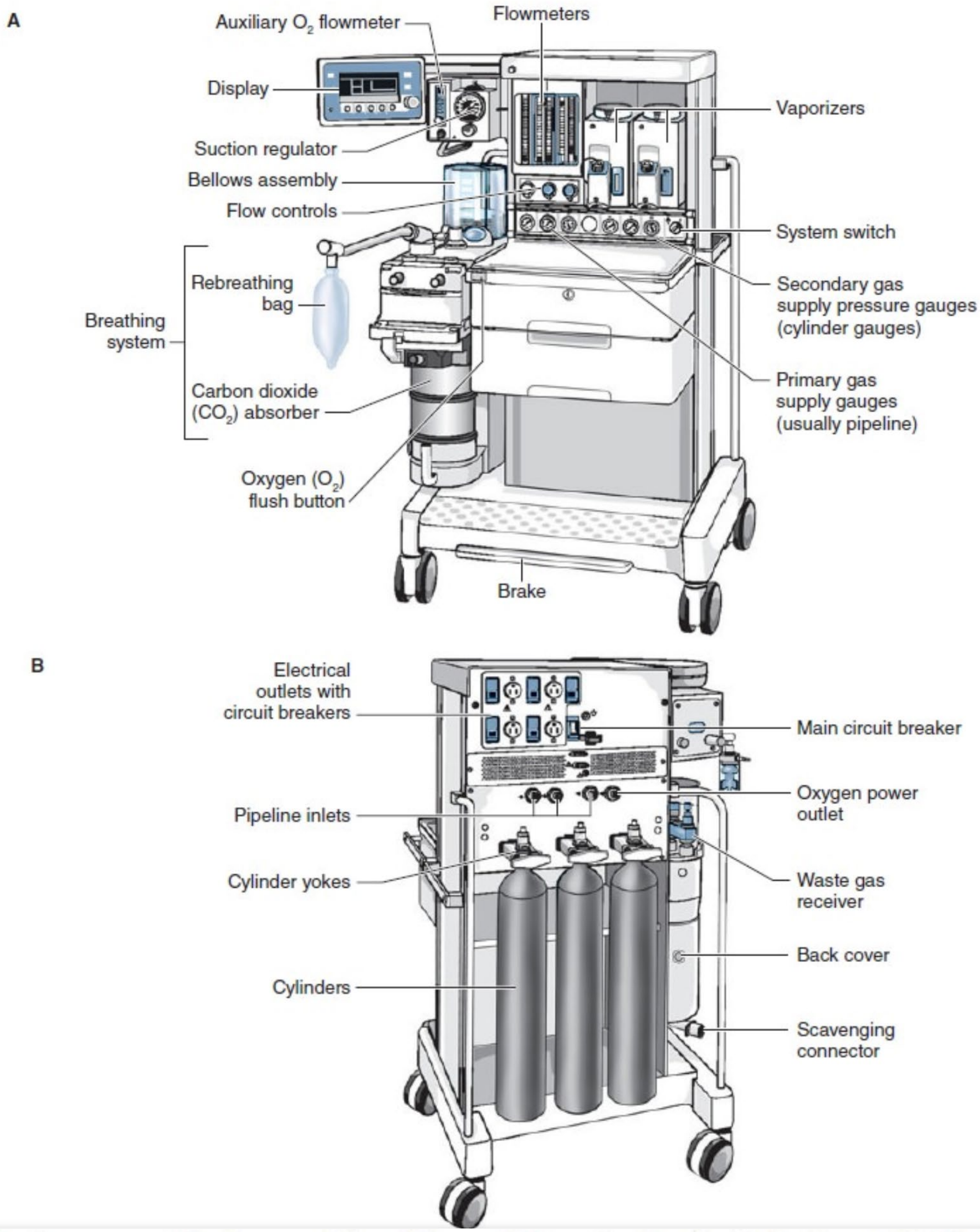
ANESTHETIC GAS DELIVERY METHODS

CLINICAL

Anesthesia machines

In its most basic form, the anesthesia machine in a clinical setting, illustrated in Figures 1A and 1B below, does the following:

1. Receives medical gases (such as nitrous oxide and oxygen) from a gas supply;
2. Controls the flow and reduces the pressure of desired gases to a safe level;
3. Vaporizes volatile anesthetics (such as the volatile liquid halogenated anesthetics) into the final gas mixture; and
4. Delivers the gases to a breathing circuit or system connected to the patient's airway.



Modern anesthesia machine (Datex-Ohmeda Aestiva). **A**: Front. **B**: Back.

Source: Butterworth JK, Mackey DC, Wasnick JO: Morgan & Mikhall's Clinical Anesthesiology, 5th Edition: www.accessmedicine.com

DENTAL

Mixtures of nitrous oxide and oxygen are commonly used in dentistry as general anesthetic agents, analgesics, and sedatives. The common anesthesia equipment used by dentists includes a nitrous oxide and oxygen delivery system, a gas mixing bag, and a nasal mask or nasal cannula with a positive pressure relief valve. A typical system is shown below in Image 1 and Image 2 with gas lines coming out of the wall and mobile gas delivery system. A dental mask is illustrated below in Figures 2A, 2B, and 2C. Note the shroud over the mask under vacuum that exhausts excess anesthetic gas and exhaled gases.

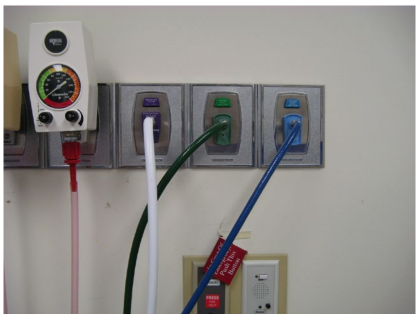
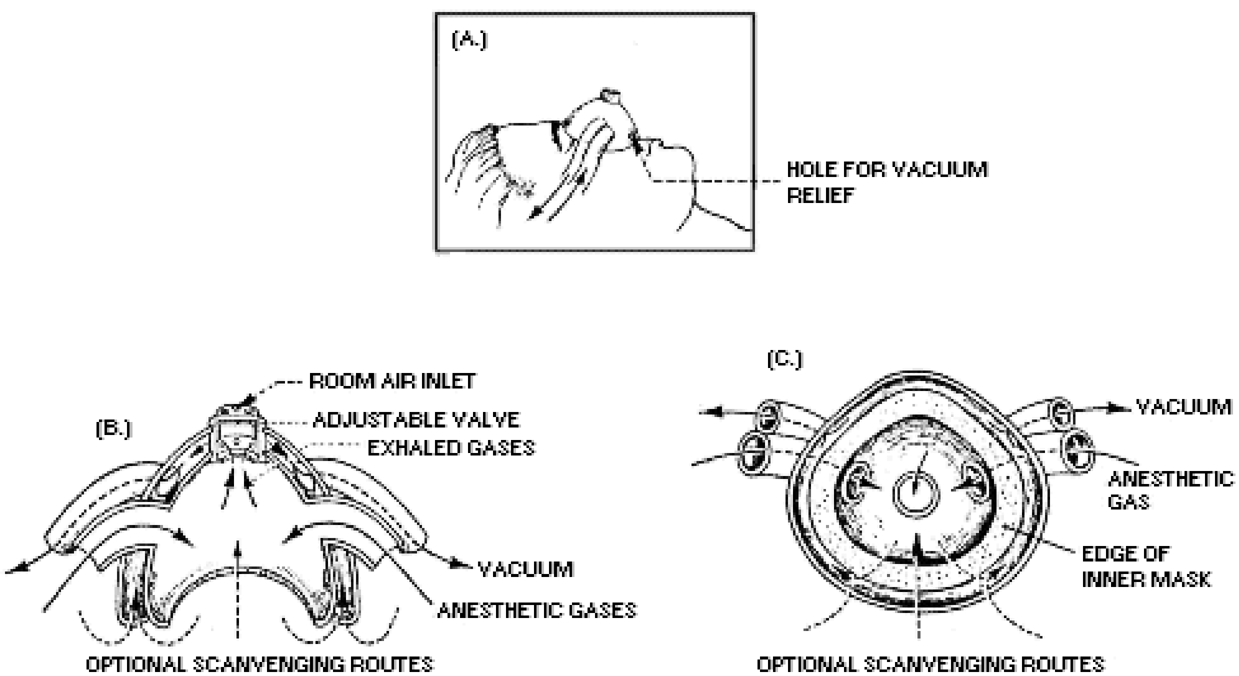


Image 1: Gas lines from wall in dental office/clinic

Image 2: Mobile gas delivery system in dental office/clinic



Figures 2A, 2B and 2C: Dental mask - Circle breathing system connected to a closed reservoir scavenging interface. (Reproduced by permission of North American Dräger, Telford, Pennsylvania).
Source: OSHA [Anesthetic Gases: Guidelines for Workplace Exposures]

ANIMAL

In research settings, the following methods of anesthesia delivery include:

Nose cone

Typical tabletop vaporizer anesthesia machines for rodents are illustrated in Images 3 and 4 with various nose cone types and sizes shown in Images 5 through 7. Some nose cone systems have an inner and outer nose cone (a double versus a single nose cone). The small inner cone is connected to the anesthetic gas delivery system. The large outer cone is connected to an exhaust scavenging system to control gas exposure to researchers. Some nose cones also include a diaphragm, which creates a tight seal around the animal's mouth and reduces anesthetic gas leakage.

Exposure control depends on:

- The fit of the cone around the animal's nose or position in stereotaxic frames;
- The direction of gas delivery relative to researcher; and
- The outer cone extending ¼ inch beyond the inner cone to capture and exhaust waste anesthetic gas.

Ensure the animal's nose fits snugly into the cone. If possible, place the animal so the body is oriented left to right such that anesthetic gas flow is directed to the left or right of the researcher, rather than directed at the researcher. The vaporizer unit should be filled and refilled in an area with local exhaust (as shown in the Local Exhaust Ventilation section below) or in a chemical fume hood.

Image 3: Tabletop rodent anesthesia machine
Source: Parkland Scientific

Image 4: Tabletop low flow rodent anesthesia machine
Source: Kent Scientific Corporation

Image 5: Single nose cone

Image 6: Double nose cones

Image 7: Diaphragm nose cone system

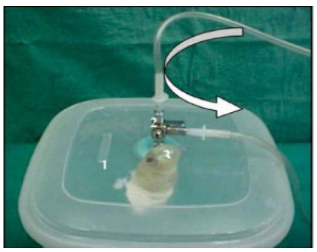


Image 8: Snap-on lid container as induction box

Image 9: Desiccator as induction box

Image 10: Induction boxes with sliding lid; the box on the right is designed for use with an active scavenging system and is preferable over the box on the left.

Image 11: Induction boxes
Source: [Smith Medical]

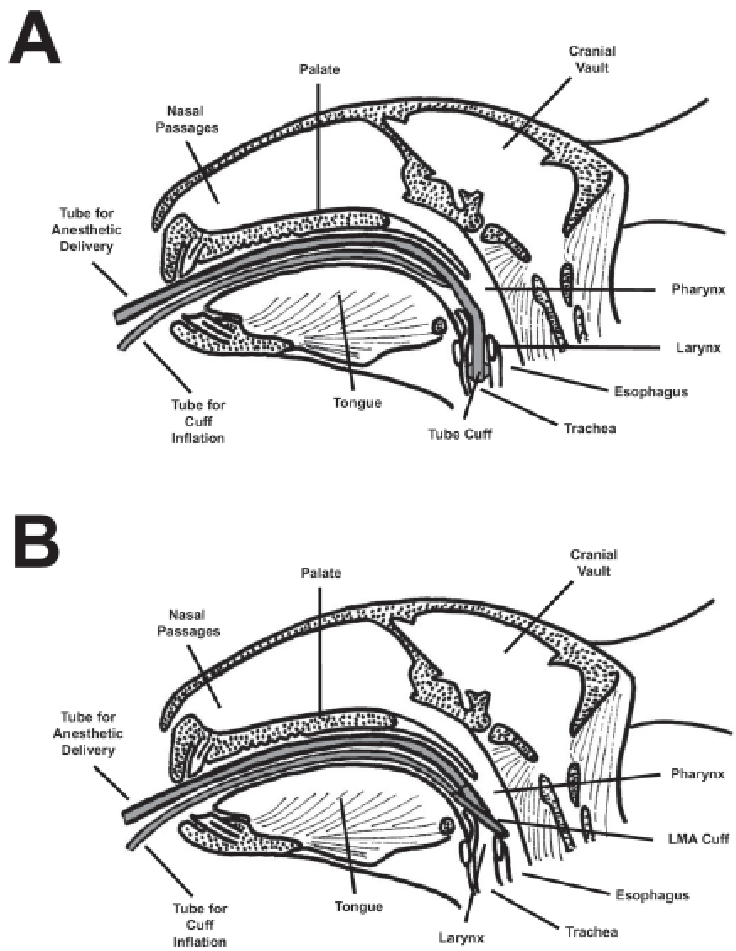
Induction box

Induction boxes and other containers are used with rodents and other small animals. The animal is placed in the box or container and the anesthetic gas mixture is introduced into the box through an inlet port. Gas flows out of the box through an outlet port to exhaust and/or a scavenging system. Various types of induction boxes and containers are illustrated above in Images 8 through 11. Note that an induction box with a sliding top may release less anesthetic gas (minimizing potential exposure) when opened by the researcher than a box or container with a hinged or lidded top. Desiccators, bell jars, and snap-on or screw-on lidded containers have been used for induction boxes.

To minimize potential exposure to researchers, all hinged induction boxes, desiccators, and other similar containers used as induction boxes should be used in a chemical fume hood or a Class II B2 biosafety cabinet (total exhaust biosafety cabinet) to contain, capture, and remove anesthetic gases.

Intubation

Intubation is the process of inserting a flexible tube through the mouth and into the trachea (airway) to deliver and exhaust anesthetic gas to and from the animal. Large animals, such as non-human primates and pigs, are typically anesthetized by intubation. Exposure control depends on proper intubation techniques when anesthetizing the animal. An active mechanical exhaust gas scavenging system is used during intubation. Refer to Figures 3A and 3B below for an example of a rabbit intubation.



Figures 3A and 3B: Schematic diagrams to show the proper placement of an endotracheal tube (A) and laryngeal mask airway (B) with regard to typical features in the rabbit oral cavity and upper airway. Source: Smith, J. et al. 2004. Endotracheal Tubes Versus Laryngeal Mask Airways in Rabbit Inhalation Anesthesia: Ease of Use and Waste Gas Emissions. Contemp Top Lab Anim Sci. 43:4:22-25.

Drop method

The drop method involves the application of liquid anesthetic to an absorbent material (gauze or cotton ball) that is then placed in the bottom of an anesthetic chamber (induction box or other chamber) or nose cone device. Perform this process in either a vented biosafety cabinet, chemical fume hood, or under another local exhaust system due to the increased potential for occupational exposure to anesthetic gases. Perform any subsequent openings of the liquid anesthetic container or anesthetic chamber within the biosafety cabinet, chemical fume hood, or local exhaust system.

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EXPOSURE CONTROL METHODS

ENGINEERING CONTROLS

Anesthetic gases must always be used in a well-ventilated room (greater than or equal to six (6) air changes per hour) with no recirculation of locally exhausted air. Anesthetic gases must always be used with a scavenging/ventilation mechanism that eliminates inhalation exposure to the worker.

General ventilation

In surgical operating rooms, it is recommended to have a ventilation system that circulates and replenishes the air in operating rooms with at least 20 air changes per hour, and a minimum of four (4) air changes of outdoor air per hour (based on ANSI/ASHRAE/ASHE 170-2021: Ventilation of Health Care Facilities).

In recovery rooms, it is recommended to have a ventilation system that circulates and replenishes the air with at least six (6) air changes per hour, and a minimum of two (2) air changes of outdoor air per hour to prevent exposure to waste anesthetic gases exhaled by patients or subjects (based on ANSI/ASHRAE/ASHE 170-2021: Ventilation of Health Care Facilities).

In animal operating/procedure rooms, it is recommended to have ventilation of at least 15 air changes per hour, with at least three (3) air changes of outdoor air per hour (Guidelines for Reducing Veterinary Hospital Pathogens: Hospital Design and Special Considerations, J.A. Portner and J.A. Johnson, *Compendium* May 2010).

Research that takes place outside of vivaria must be discussed with the Office of Animal Welfare (oawrss@uw.edu) and/or Environmental Health & Safety (EH&S) (ehsdept@uw.edu) regarding the ventilation of the space and whether it is appropriate to conduct anesthesia procedures there.

Local exhaust ventilation

Use local exhaust ventilation whenever possible in clinical and laboratory areas for operations that involve handling and use of liquid and gaseous anesthetic agents and to control and exhaust or dispose of WAGs. Conduct procedures using a chemical fume hood, hard-ducted biosafety cabinet, ducted downdraft table, snorkel trunk, or other local exhaust device, especially for small scale procedures such as in dental operations, animal research, and veterinary procedures. It should be noted that the local exhaust capture hood (e.g., snorkel hood) should be positioned between the isoflurane source and the individual using it (as a general rule, within six (6) inches of the source). When positioned this way, WAGs are not drawn through the breathing zone of the individual prior to being captured, which can happen with some ventilation designs (e.g., canopy hoods).

Image 13: Slot exhaust

Image 12: Local exhaust snorkel

Image 14: Downdraft table
Source: http://www.fischersci.com

Scavenging systems

Active scavenging

Engineering controls involving active scavenging (i.e., using negative pressure to manage unwanted material) are critical for working safely with anesthetic gases. Scavenging systems are installed with the anesthesia delivery system to remove waste anesthetic gases close to the source and prevent them from entering the operating room. They are a form of local exhaust ventilation. The exhaust from the scavenging system must be routed to an area where waste gases will not be reintroduced into the air intake for the facility. Leak checks should occur before each use. Follow the manufacturer's recommendations for maintenance and service. Check regularly to ensure that scavenging material/canister is not expired.

The preferred method of exhausting WAGs from the workplace is with a dedicated vacuum system in the facility or hard-ducted device (e.g., chemical fume hood, hard-ducted biosafety cabinet, ducted downdraft table, snorkel trunk within six (6) inches from the source, or other local exhaust device).

WAGs can be exhausted through a ductless device if it first enters a canister of activated charcoal. Note that activated charcoal does not adsorb nitrous oxide. Canisters must be changed out regularly as they become saturated with WAGs. The capacity of the canister is monitored by change in weight.

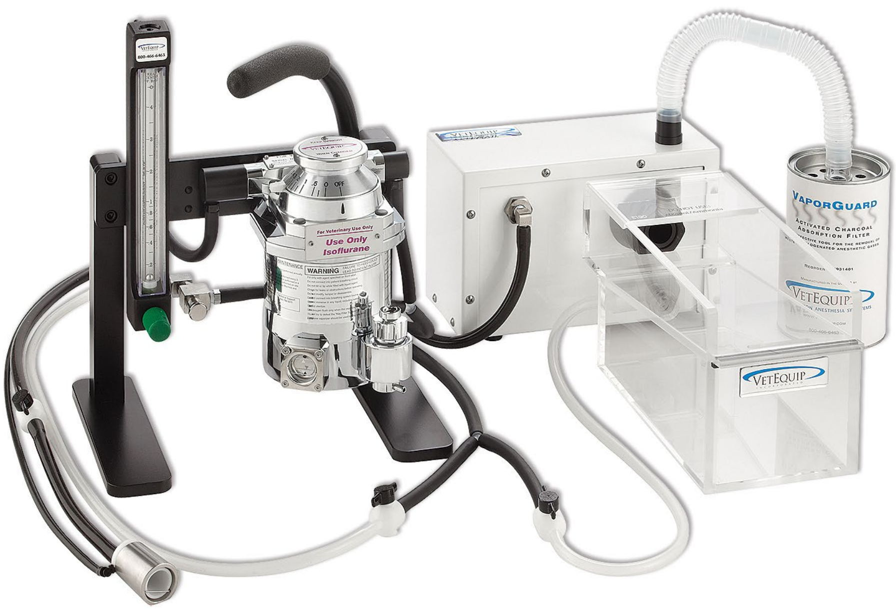

Image 15: Lab animal anesthesia system with active scavenging cube and evacuation accessories. Source: www.vetequip.com

Passive scavenging

Overall, passive scavenging is less effective at controlling exposure for the individual performing the procedure. Passive scavenging involves adsorbing WAGs on a device without negative pressure and discharging it directly into the working environment. Adsorption devices, such as canisters containing activated charcoal, can be used as WAG collection and disposal systems instead of active scavenging systems, especially when portability is an issue. However, effectiveness may vary with different brands and types of canisters, changes in the rate of gas flow through the canister, and the exhalation rate of the person or animal. Note that activated charcoal is not effective for adsorption of nitrous oxide.

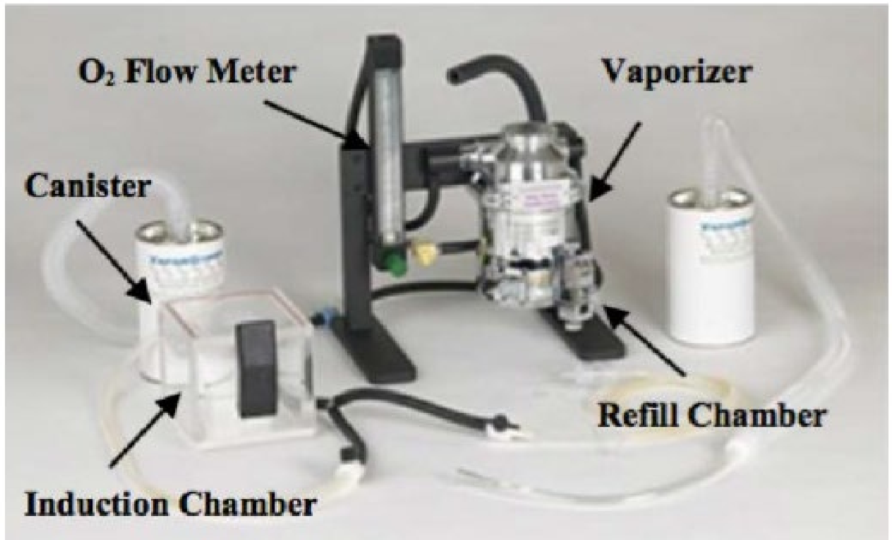

Image 16: Passive scavenging system
Source: ehs.stanford.edu

Refer to the General Use SOP: Passive Scavenging Using Charcoal Canisters (PDF) for additional information.

Key fill bottle adaptors

Key fill bottle adaptors are devices that help prevent spills by eliminating the need to pour liquid anesthetic into vaporizers. The cap of the liquid anesthetic bottle is removed and is replaced with the key fill bottle adaptor. The liquid anesthetic bottle with adaptor can then be directly connected to the vaporizer. The use of key fill bottle adaptors is highly recommended.

Image 17: Key fill bottle adaptor for isoflurane.
Source: E-Z Systems Inc.

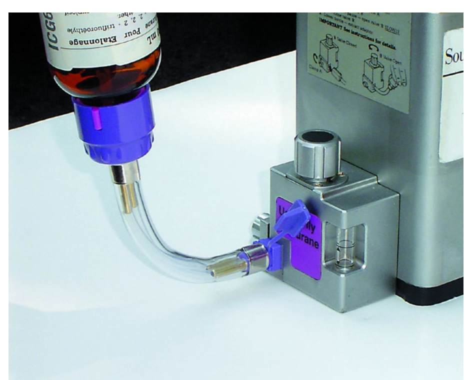

Image 18: Key fill bottle adaptor connects the liquid anesthetic bottle directly to the vaporizer.
Source: Integris Equipment

WORK PRACTICES

Standard operating procedures (SOPs)

The department/unit/organization must develop and document SOPs for work with anesthetic gases. A blank SOP template and example SOPs are available on the EH&S website. SOPs must include specifics on anesthesia machines and equipment, procedures for maintenance, leak checking, use of ventilation systems, spill and exposure response, and safe work practices to ensure workers are not exposed to levels of anesthetic agents or waste anesthetic gases above regulated exposure limits for nitrous oxide or recommended exposure limits for the halogenated anesthetic liquids/gases.

Transporting chemicals

Refer to the Laboratory Safety Manual (Section 2.F.) for information on the safe transport of chemicals.

Leak testing, pre-anesthesia checkout, and preventive maintenance of machines/systems

A critical part of ensuring the safety of patients, subjects, and workers during anesthesia are the pre-anesthesia checkout (PAC) procedures of the anesthesia machine before every procedure. This includes checking the functioning of all components of the anesthesia machine, leak testing, and scavenging system operation. PAC procedures can be developed based on the machine manufacturer's operation manual and maintenance schedule, and recommended PAC procedures developed by the Food and Drug Administration (FDA) Anesthesia Apparatus Checkout Recommendations, 1993.

Preventive maintenance of anesthesia machines, breathing circuits, and waste-gas scavenging systems is critical to minimize leaks of anesthetic gases into the operating rooms. This includes regularly scheduled maintenance procedures based on the manufacturer's operation manuals of all the systems. Within the UW Medical Centers, Clinical Engineering is responsible for maintaining these pieces of equipment. Leak testing and subsequent repairs may be performed by Clinical Engineering personnel or a maintenance vendor per the approved procedures for that specific clinical setting. For more information, refer to the UW Medicine Hazardous Materials and Waste Management Plan and/or Administrative Policies and Procedures (APOP) 150-7: Hazardous Gases and Vapors for more detailed requirements on leak testing.

A routine leak testing and maintenance program must be in place for anesthesia systems used outside of the medical centers' scope. It is the responsibility of the unit/department that owns this equipment to implement this program. EH&S is available to consult on leak testing as needed.

Sources of possible leaks from anesthetic delivery systems in dental procedures 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 may be due to loose-fitting connections, loosely assembled or deformed slip joints and threaded connections, and defective or worn seals, gaskets, breathing bags, and hoses.

The following procedures are suggested in the CDC/NIOSH publication Waste Anesthetic Gases, Occupational Hazards in Hospitals for operating room personnel to reduce exposures to WAGs before anesthesia begins:

1. Inspect the anesthetic delivery system before each use. Look for irregularities or breaks.
2. Check the patient's breathing circuit for negative pressure and positive pressure relief as part of the daily machine checklist.
3. Turn on the room or local ventilation system.
4. Make sure the scavenging equipment is properly connected.
5. Connect the gas outlet to the hospital's central scavenging system.
6. Start the gas flow after the laryngeal mask or endotracheal tube is installed.
7. Fill vaporizers under a ceiling-mounted hood with an active evacuation system.
8. Fill vaporizers before or after the anesthetic procedure.
9. Make sure that uncuffed endotracheal tubes create a completely sealed airway.
10. Use the lowest anesthetic gas flow rates possible for the proper functioning of the anesthesia delivery system and for patient safety.
11. Avoid very high anesthetic gas flow rates to prevent leaks.
12. Do not deliver anesthesia by open drop (dripping liquid, volatile anesthetic onto gauze).
13. If a mask is used, make sure it fits the patient or subject well.
14. Eliminate residual gases through the scavenging system as much as possible before disconnecting a patient/subject from a breathing system.
15. Turn the gas off before turning off the breathing system.

Improper work practices

Proper work practices are critical in minimizing worker exposure to WAGs. Improper anesthetizing techniques may include:

- Not using low-flow anesthesia when appropriate
- Poorly selected, fitted or positioned face masks
- Allowing patients to speak frequently during dental procedures with nitrous oxide
- An insufficiently inflated tracheal tube or laryngeal mask airway cuff
- Improperly connected tubes and fittings for the anesthesia machine
- Turning on the anesthetic gas before the scavenging system is active
- Not turning the gas off when the mask is removed from the patient's or subject's face or removing the mask too quickly before the system has been flushed

ADMINISTRATIVE CONTROLS

The following administrative controls must be maintained as part of a complete program for controlling occupational exposures to anesthetic gases/liquids and WAGs:

- Train all personnel in hazard awareness, prevention, and control of exposures to anesthetic agents and WAGs before starting work. Refer to the Training section below for additional information on training requirements.
- Conduct refresher training as needed and especially when new equipment, anesthetic gases, or procedures are introduced.

PERSONAL PROTECTIVE EQUIPMENT

Standard personal protective equipment (PPE) worn in a clinical or laboratory setting must be worn when working with anesthetic agents. However, PPE must *not* be used as a substitute for engineering controls, safe work practices, and/or administrative controls in anesthetizing locations and post-anesthesia recovery rooms. Exposure to WAGs is *not* effectively reduced by gloves, goggles, and surgical masks. A tight-fitting cartridge respirator or powered-air-purifying respirator (PAPR) with organic vapor cartridges may provide protection from halogenated anesthetic gases and vapors (but not nitrous oxide) for a limited time.

Employees who wear respirators must be enrolled in the UW Respiratory Protection Program which requires medical clearance, annual training, and annual fit testing. Air-supplied respirators with self-contained air source (SCBA) are appropriate for responding to a large liquid spill of an anesthetic agent but are not a practical alternative to good engineering controls, safe work practices, and other controls during normal use.

Personnel must use the proper PPE including the appropriate gloves, lab coat, and safety glasses or goggles with one-way vents (especially for contact lens wearers) when pouring or filling vaporizers with liquid anesthetic agents. When working in BSL-2 or higher or vivaria settings, PPE use must be consistent with facility policy. Use of your facility's designated PPE is appropriate if you are only handling liquid anesthetic bottles with a key bottle fill adaptor already in place.

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EXPOSURE MONITORING/LEAK TESTING

EH&S is available to evaluate anesthetic gas SOPs, gas use, systems, and potential personnel exposures. This includes air monitoring to evaluate the effectiveness of WAG control systems, personal and area monitoring to determine potential exposures, and direct-reading air monitoring to assist in leak-checking of systems. EH&S may, at its discretion or at the request of other regulatory and auditing bodies, request to perform area and/or personnel sampling for certain units and operations. Where optimal engineering controls (as described in this document) cannot be implemented, area and/or personnel exposure monitoring must be requested from EH&S by the responsible party. Contact EH&S at 206.543.7388 or ehsdept@uw.edu to request a consultation.

Exposure monitoring data from workplaces where anesthetic gases are used is critical for identifying specific exposure controls to decrease potential exposures. This includes monitoring the air for leaks in anesthetic gas delivery and scavenging systems/equipment, monitoring workers' breathing zones to ensure proper work practices when handling anesthetic gases and monitoring the effectiveness of general and local exhaust ventilation systems.

EH&S conducts air monitoring for nitrous oxide and halogenated anesthetic gases by different methods:

- Personal exposure monitoring is done in the breathing zone of selected individuals working with anesthetic gases during a specific activity or present during anesthesia to determine exposure levels and if exposure exceeds a PEL, TLV, or REL.
- Area monitoring is done in general work areas to determine potential exposure areas.
- Real-time sampling provides direct, immediate, and continuous readout of anesthetic gas concentrations to immediately determine sources of anesthetic gas leakage and effectiveness of control measures. This could be done on an annual basis, when there are exposure signs or symptoms, or when there are equipment or process changes.

SAMPLING AND ANALYTICAL METHODS

EH&S uses the following methods and equipment to sample for nitrous oxide and halogenated anesthetic gases.

Personal and area samples are collected using passive dosimeters described below. For personal sampling, the dosimeter is placed in the employee's breathing zone (to the extent possible) to determine the waste anesthetic gas/nitrous oxide exposure to the employee during the period of anesthesia administration. Samples are collected for 15 minutes when evaluating the 15-minute time weighted exposure for comparison against a STEL or one (1) to eight (8) hours when evaluating an exposure for comparison against a PEL or TLV. To compare samples to the NIOSH REL ceiling limits, samples are collected for a period not to exceed 60 minutes.

- Assay Technology 574 Anesthetic Gases Monitor diffusion sampler is used to collect personal and area samples for desflurane, enflurane, halothane, isoflurane, and sevoflurane. Samples are submitted to Assay Technology for analysis by the Modified OSHA Method 103.

- Assay Technology 575 Nitrous Oxide Monitor diffusion samplers are used to collect personal and area samples for nitrous oxide. Samples are submitted to Assay Technology for analysis by the AT SOP L575 Method.

Image 19: Nitrous oxide monitor Source: Assay Technology

Area sampling is conducted to determine WAG levels over a period of time near equipment or in the general work area.

EH&S primarily performs **real-time sampling** for nitrous oxide and halogenated anesthetic gases with a portable Fourier transform infrared (FTIR) gas monitor (Gasmet GT5000 Terra). Other gas-specific instruments may also be used. If needed, these monitors are calibrated with known concentrations of nitrous oxide and/or specific anesthetic gas or gases before surveys occur.

Image 20: Gasmet GT5000 Terra FTIR gas monitor Source: Gasmet.com

REPORTING OF RESULTS

If exposure levels exceed a permissible exposure limit (PEL) for a chemical (in this case, nitrous oxide), EH&S must notify the department/unit/organization within five (5) business days of receipt of laboratory results. The department/unit/organization will disseminate exposure assessments and monitoring results to personnel who were, or who may have been, exposed. Affected personnel must also be notified within 15 business days of receipt of results and the steps the unit/department will take to reduce exposure levels. This includes engineering controls, work practices and/or administrative controls, and the schedule for completion of corrective action(s). In the event that the exposure levels cannot be lowered to or below the PEL, personnel must be informed why this is not possible.

Similarly, if exposure levels exceed the TLVs and/or RELs listed in Table 2, EH&S will notify personnel. EH&S will also work with the department/unit/organization to reduce exposure levels to or below the TLV/REL.

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TRAINING

Training must be provided by the responsible party (RP), laboratory manager, chemical hygiene officer (CHO), or supervisor. Although personnel engaged in anesthetic gas use in a clinical or veterinary setting are required to receive detailed written and hands-on instruction on the delivery of anesthesia in their formal training, additional training on hazard communication and exposure risk mitigation strategies is also required. Reviewing this document with personnel will cover many of the requirements; however, it will need to be supplemented with information specific to their work.

Training on WAGs must include:

- Which anesthetic gases are used
- Health effects of nitrous oxide/halogenated agents
- Exposure limits
- Symptoms of exposure/odor is not a warning
- Sources of exposure
- Engineering controls
- Work practices
- Administrative controls
- Scavenging systems
- Anesthetic gas equipment inspections
- Exposure monitoring/leak testing
- Accommodations for reproductive health concerns (refer to the UW Reproductive Hazards Guidelines)
- What to do if symptoms develop
- What to do if you suspect a leak
- What to do if liquid compound spills

Training must be documented by the responsible party (RP), laboratory manager, chemical hygiene officer (CHO), or supervisor, and records must be retained for at least six (6) years after termination of employment. The EH&S SOP template includes a training documentation page to assist units with this responsibility.

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WASTE COLLECTION AND DISPOSAL

Waste halogenated anesthetic liquids must be disposed of as chemical hazardous waste. This includes:

- Expired or unwanted anesthetic gas or liquid containers
- Used charcoal canisters

Label containers with accumulated waste and submit an online request for pickup via the MyChem inventory or on the EH&S website.

For more information about waste collection, disposal, and waste collection forms, refer to the Chemical Waste Disposal webpage on the EH&S website, or contact EH&S Environmental Programs at chmwaste@uw.edu or 206.616.5835.

Compressed gas canisters/cylinders for anesthetic gases must be disposed of through the compressed gas supplier.

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EMERGENCY RESPONSE, EXPOSURE INCIDENTS AND ACCIDENT REPORTING

SPILLS AND RELEASES

Small volumes of liquid anesthetic agents such as halothane, enflurane, isoflurane, desflurane, and sevoflurane evaporate readily at room temperature, and may dissipate before any attempts to clean up or collect the liquid(s) are initiated.

For large spills, evacuate the area and call 9-1-1 on any campus phone for help, or follow your facility-specific procedures for chemical spill response, such as in the medical centers. An example of a large spill is dropping a 250 ml bottle of liquid anesthetic that breaks on the floor.

When large spills occur, specific cleaning and containment procedures are necessary, and appropriate disposal is required (American Association of Nurse Anesthesiology, 2023). The recommendations of the chemical manufacturer's SDS that identify procedures for spills and emergencies must also be followed.

If a spill or release occurs, stop work. Properly protected and trained personnel must clean up spills immediately to minimize exposures. If comfortable and trained to do so, clean up the spill as follows:

- Use personal protective equipment (PPE), typically including gloves, goggles, and protective clothing such as a lab coat or gown.
- Cover and soak up liquid anesthetics with absorbent materials, which should be included in your chemical spill kit.
- Bag or contain the spilled material and debris, cleanup materials, and contaminated PPE. Seal bag or container to contain any vapors.
- Double bag all waste in plastic bags labeled with a hazardous waste label for EH&S pickup.

Refer to the Chemical Spills in Laboratories webpage for additional instruction on spill cleanup; spills of liquid anesthetic agents may be handled in a similar manner to other chemicals. For questions on spill cleanup, contact EH&S Spill Advice at chmwaste@uw.edu or 206.543.0467.

EXPOSURE INCIDENTS

Follow the procedures in the EH&S posters for Spill Response and Exposure Response. In cases where personnel develop signs or symptoms of anesthetic gas exposure:

- Work must be stopped immediately.
- Personnel must notify their supervisor immediately and seek medical attention.
- Access to the work area must be restricted to prevent others from unknowingly entering a contaminated area.
- Contact UW Employee Health at emphlth@uw.edu or 206.685.1026 to consult with an occupational medical professional regarding anesthetic gas exposures.

- UW Medicine personnel can contact their respective employee health office to consult with an occupational medical professional regarding anesthetic gas exposures.

INCIDENT REPORTING

Report all accidents and incidents to the UW Online Accident Reporting System (OARS) within 24 hours; however, some incidents require immediate notification.

UW Medicine personnel follow UW Medicine incident reporting procedures.

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RECORDKEEPING

University units/departments/organizations must keep personnel training records.

Record Type	Minimum Retention Time
Personnel training	6 years after termination of employment

EH&S will maintain the following records:

Record Type	Minimum Retention Time
Exposure assessments/air monitoring data	30 years or duration of employment plus 20 years, whichever is longer
Medical records	30 years or duration of employment plus 20 years, whichever is longer

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REFERENCES

National Institute for Occupational Safety and Health (NIOSH): Waste Anesthetic Gases, Occupational Hazards in Hospitals DHHS (NIOSH) Publication No. 2007–151, September 2007.

Occupational Safety and Health Administration (OSHA): Anesthetic Gases: Guidelines for Workplace Exposures (2000).

Food and Drug Administration (FDA): Anesthesia Apparatus Checkout Recommendations (1993).

NIOSH: NIOSH Criteria Document 77-140. Criteria for a Recommended Standard of Exposure to Waste Anesthetic Gases and Vapors. (1977)

American Association of Nurse Anesthetists (AANA): Management of Waste Anesthetic Gases (2023)

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