TECHNICAL BULLETIN

GUIDELINES FOR THE CONTROL AND EVALUATION OF OCCUPATIONAL EXPOSURE TO WASTE ANESTHETIC GASES

HEADQUARTERS, DEPARTMENT OF THE ARMY
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*This bulletin supersedes TB MED 510, 1 July 1982.

CHAPTER 1

INTRODUCTION

1–1. Purpose

a. This bulletin provides guidance to Department of the Army (DA) industrial hygiene, preventive medicine, and medical maintenance personnel and anesthetists for recognizing, controlling, and evaluating occupational exposures to waste anesthetic gases (WAG) and vapors.

(1) This guidance applies to all DA locations and activities where inhalation anesthetic agents are administered, such as hospital operating, recovery, labor and delivery, and emergency rooms; dental operatories; veterinary activities; and research and teaching facilities.

(2) Personnel should adhere to this guidance as closely as combat zone operations allow.

b. For purposes of this document, WAG refers to gases and vapors used to provide clinical anesthesia which escape into the worksite air. WAG includes—

(1) Nitrous oxide (N_2O).

(2) Halogenated agents, such as halothane, enflurane, methoxyflurane, or isoflurane.

1–2. References

Referenced publications and selected bibliography are listed in appendix A.

1–3. Explanation of Abbreviations and Terms

Abbreviations and special terms used in this bulletin are explained in the glossary.

Use of trademarked names does not imply endorsement by the U.S. Army but is intended only to assist in identification of a specific product.

CHAPTER 2

CONTROLLING EXPOSURE

2–1. Occupational Exposure Limits

a. Although no Federal standard for WAG exists, the National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend control of occupational exposure to WAG.

(1) Appendix B provides information on the sources and factors that contribute to exposure of WAG.

(2) The recommendations below apply to all personnel who are routinely exposed to inhalation anesthetic agents that escape into locations associated with the administration of, or recovery from, anesthesia. The recommended levels of exposure are designed to protect personnel from adverse effects based on available scientific information.

b. The 8-hour time-weighted average (TWA) exposure limit for airborne concentrations of:

(1) N_2O used alone is 50 parts per million (ppm).

(2) Halogenated anesthetic agents used alone is 2 ppm.

(3) N_2O and halogenated anesthetic agents used in combination changes to 25 ppm for N_2O and 0.5 ppm for halogenated anesthetic agents. This change results from reported synergistic performance decrement effects in exposed U.S. Army Medical Department (AMEDD) personnel.

c. Excursions in employee exposure levels may exceed three times the exposure limits no more than 30 minutes during the work day. Under no circumstances should they exceed five times the exposure limit. In any case, the 8-hour TWA must not exceed the TWA exposure limit. Appendix C provides examples that further explain WAG excursion limits.

d. Since recommended exposure limits for N_2O and halogenated anesthetic agents when used in combination (para b(3) above) are based on performance decrements and not chronic health effects, medical surveillance action levels of 25 ppm for N_2O and 1.0 ppm for halogenated anesthetic agents are still based on the exposure limits of the agents when used alone.

2–2. Maintaining Recommended Waste Anesthetic Gases Levels

a. The early 20th century marked the development of removal systems to eliminate WAG from operating rooms. These systems were initially designed to protect personnel from the safety concerns identified with WAG, such as flammability and explosion hazards. The use of halogenated anesthetic agents further decreased the safety risks. Today's concerns regarding exposure to WAG extend beyond safety risks to the associated potential health effects and performance degradation.

b. It is virtually impossible to maintain levels of WAG below the recommended exposure limits in paragraph 2–1b without a combination of engineering and administrative controls, such as—

(1) Gas scavenging.

(2) General dilution ventilation.

(3) Proper maintenance of equipment.

(4) Application of work practices by anesthetists to minimize the release of anesthetic agents into the room.

c. If acceptable conditions cannot be met with properly maintained anesthetic units or proper ventilation systems, dental clinics and veterinary services must consider alternate work practices and different clinical methods, such as using injectable anesthetics for surgical procedures.

2–3. Gas Scavenging

a. Gas scavenging is a type of local exhaust ventilation where WAG released from the adjustable pressure limiting (APL, pop-off, or spill-off) valve of the anesthetic gas supply system and the exhaust portion of the ventilator is collected and exhausted outside the anesthetizing location. WAGs are released from rebreathing, nonrebreathing, and partially rebreathing systems.

b. At present, gas scavenging is the most practicable engineering control for removing WAG. Levels of WAG can be minimal when gas scavenging is combined with other recommended control procedures. When compared to dilution ventilation, gas scavenging requires very low air exhaust rates. Use of gas scavenging can result in a considerable savings in energy costs as well as protect employee health and safety. Although no Federal regulations currently exist for the exhaust of WAG to outside air, consult with air quality control boards to determine if local and State regulations apply.

c. After reviewing the available literature and surveying existing systems, consider the following when designing a WAG system:

(1) Compatibility of scavenging systems with anesthetic equipment. Review the requirements for gas scavenging with personnel responsible for anesthetic administration and equipment maintenance.

(2) Use a central vacuum for exhaust ventilation when the system is—

(a) Of adequate size to handle the expected load.

(b) Exhausted to outdoors, away from supply air intakes.

d. Confirm system reliability after installation by actual environmental monitoring. Any specifications should include performance requirements.

e. Because Deployable Medical Systems (DEPMEDS) use a recirculating heating and air conditioning system, which allows only a small percentage of fresh air exchange, personnel must make extra precautions for WAG. For instance—

(1) The DEPMEDS recirculating system precludes the exhaust of WAG. Whenever possible, fill vaporizers outside of DEPMEDS modules.

(2) When scavenging WAG from DEPMEDS modules, ensure that scavenging hose exhausts are as far away as possible from the environmental control unit fresh air intake.

f. Assistance in gas scavenging system design and criteria is available from several sources including—

(1) The U.S. Army Environmental Hygiene Agency (USAEHA). Obtain information from the Commander, USAEHA, ATTN: HSHB-MI-HE, Aberdeen Proving Ground, MD 21010-5422 (DSN 584-2241).

(2) Anesthetic equipment manufacturers.

(3) Consulting architectural engineering firms.

(4) A variety of reference journals and Government publications. The NIOSH referenced publications offer a comprehensive review of design requirements for gas scavenging systems. (See app A.)

2-4. General Dilution Ventilation

a. General dilution ventilation is necessary to reduce the residual amounts of WAG not removed by the gas scavenging system. Adequate dilution ventilation is especially critical where effective gas scavenging is not available.

b. General ventilation requirements for the most commonly encountered anesthetizing locations are presented in table 2-1. These and additional design criteria and locations can be found in Architectural and Engineering Instructions (A&EI). (See app A, para A-3, reference 17.) Any upgrade or redesign of the ventilation system will be per A&EI.

2-5. Daily Maintenance of Anesthetic Equipment

Maintain anesthetic equipment according to the manufacturer's specifications to minimize leakage of anesthetic gases. Include the following actions in your pre-operational checks:

a. Perform leak test procedures on pressurized breathing circuits daily, prior to the initiation of anesthesia.

b. Inspect face masks, tubing, breathing bags, and other components for cracks and other signs of deterioration after each cleaning and before each use.

c. Verify that all gaskets and valves are sealed properly.

d. Verify that disposable tubing and bags fit tightly.

2-6. Recommended Work Practices to Reduce Occupational Exposure to Waste Anesthetic Gases

a. Personnel administering the anesthetic agent retain responsibility for reducing WAG levels in the anesthetizing location. The implementation of proper work practices significantly reduces exposure.

b. In addition to performing the actions in paragraph 2-5, compliance with the following guidelines will reduce levels of WAG in the anesthetic environment without adverse effect on patient safety or anesthetic administration.

(1) Connect the waste gas scavenging system to the anesthetic machine and verify that all connections and fittings are tight and functioning properly prior to beginning administration.

(2) Fill vaporizers in a well-ventilated area. The operating room is most practical; however, the optimal practice is to fill the vaporizers when the operating room is not in use.

(a) If long cases require the vaporizers be refilled within the operating room while administering an anesthetic, hold a vacuum hose near the filling port to help suction off some or all of the vapors.

(b) Filler interlock kits can help reduce escaping vapors or spillage by providing a closed system to transfer the agent from the bottle to the vaporizer.

(c) If spillage occurs while filling the vaporizer, provide ample ventilation. (In most cases the halogenated anesthetic agent will vaporize immediately.)

Table 2–1. Interior mechanical design condition for specific areas

Area	Air Balance	Min A/C	Temperature	RH[a]
General OR[b]*	++	15**	68–76	55(±)5
Specialized OR	++	15**	68–76	55(±)5
Cystoscopy Room	++	15**	68–76	55(±)5
Delivery Room	++	15**	68–76	55(±)5
OR Recovery Room	+	6	75S[c]	55(±)5
General DOR[d]	o	6	75S, 68W[e]	—
Dental Surgery	++	12**	68–76	—
Teaching Surgical DOR	++	12**	68–76	—

NOTES:
[a] RH—Relative humidity
[b] OR—Operating room
[c] S—Summer temperature
[d] DOR—Dental operating room
[e] W—Winter temperature
+ Room exhaust and/or return is 10 percent less than supply.
++ Room exhaust and/or return is 20 percent less than supply.
o Room exhaust and/or return is equal to supply.
*General OR conditions apply to veterinary activities.
** Room shall be totally exhausted when in use. Unless cooling requirements dictate a higher rate, air supply shall be 15 air changes per hour during use. During periods of non-use, either—
(1) Recirculate 75 percent of the air, or
(2) Reduce the air supply to 3 air changes per hour, and shut off the exhaust to maintain the required air balance. If energy efficient, use exhaust air energy recovery to precondition the incoming outside air.

(3) Switch the vaporizer off when not in use and whenever disconnecting the breathing circuit.

(4) Perform a low pressure leak test daily prior to the first case. All leaks noted must be corrected.

(5) Select a face mask that will provide a tight fit with minimal pressure. Several different sizes and shapes of face masks are available.

(6) If it is necessary to empty the breathing bag, empty it into the scavenging system without disconnecting it from the absorber or patient.

CHAPTER 3

EVALUATING EXPOSURE

3–1. Exposure Evaluations

The implementation of controls will not guarantee that personnel are adequately protected from excessive exposure to WAG. Thus, the evaluation of the effectiveness of these controls is essential.

3–2. Surveying the Anesthetizing Location

a. Prior to determining exposure levels, the industrial hygienist or authorized preventive medicine representative, in coordination with a qualified medical maintenance person, should conduct quarterly surveys of each anesthetizing location.

b. As a minimum, the survey includes—

(1) Measuring room air exchange rates and comparing results with those in A&EI.

(2) Using MIRAN 103® or equivalent test instruments and following the manufacturer's specifications to conduct—

(a) Low pressure leak testing on the patient's breathing circuit.

(b) Leak testing on the scavenging tubes.

(c) High pressure leak testing on the equipment.

®MIRAN is a registered trademark of the Foxboro Company, 140 Water St., S. Norwalk, CT 06856.

3–3. Measuring Occupational Exposure (Time-Weighted Average) of Personnel to Waste Anesthetic Gases

a. Evaluate the anesthetizing location annually to determine personnel exposure levels. If personnel samples are expected to show exposures in excess of the standards presented in paragraph 2–1 (based on previous sampling) or if the ventilation is not in compliance with A&EI, perform quarterly surveys.

b. Both general area sampling and breathing zone (BZ) monitoring are necessary to determine exposure levels of WAG. As the terminology implies, area samples measure WAG levels within the anesthetizing location, while BZ samples measure WAG levels 6 to 10 inches from the mouth and nose area. To obtain accurate samples to calculate the TWA for an 8-hour workday, use state-of-the-art equipment, such as—

(1) Portable infrared analyzers (for example, MIRAN), for general area monitoring of N_2O.

(2) Charcoal tubes (200/400 milligrams (mg)) with constant flow sample pumps, for general area or BZ monitoring of halogenated anesthetic agents.

(3) N_2O passive monitors for BZ samples of N_2O and organic vapor passive monitors for BZ samples of halogenated anesthetic agents.

c. Collect samples representing a variety of inhalation anesthetic procedures. Clearly identify these procedures during the survey.

CHAPTER 4

MEDICAL SURVEILLANCE

4–1. Basis for Medical Surveillance

The installation medical authority (IMA) establishes the medical surveillance program for personnel with potential for exposure to WAG per AR 40–5, paragraph 5–3. Appendix D provides information on the potential health effects from exposure to WAG. Questions pertaining to medical surveillance may be directed to Commander, USAEHA, ATTN: HSHB–MO–O, Aberdeen Proving Ground, MD 21010–5422 (DSN 584–2714).

a. The occupational health (OH) physician determines the need, frequency, and scope of medical surveillance for personnel potentially exposed to WAG. In formulating the decision, the OH physician considers information from the industrial hygienist, the supervisor, and the employee. This information includes, but is not limited to, exposure data, work practices, toxicology data, medical and occupational histories and prior examination results.

b. Surveillance requirements for students and transient personnel cannot be clearly delineated, though the OH physician considers these individuals for surveillance based on their frequency, duration, and level of exposure at the worksite.

4–2. Baseline Evaluations

The occupational medicine and nursing staff conducts baseline evaluations on all personnel normally assigned to perform duties that result in the potential occupational exposure to WAG. The evaluation includes—

a. A physical examination.

b. Comprehensive medical and occupational histories with focus on the reproductive history. This includes the pregnancy outcomes of the employee or spouse and the status of the hepatic and renal systems, which may be affected by agents used as anesthetic gases.

4–3. Periodic Evaluations

a. The occupational medicine and nursing staff conducts periodic evaluations at least annually when exposure levels are at or above the corresponding action level of one-half the TWA exposure limits listed in paragraphs 2–1b(1) and (2).

b. Since the recommended exposure limits for N_2O and halogenated agents when used in combination are based on performance decrements and not chronic health effects, medical surveillance action levels are still based on the exposure levels of the agents when used alone.

c. The periodic evaluation will include an update of the health histories. The OH physician determines the need for an additional evaluation by physical examination or clinical studies on an individual basis.

4–4. Termination Evaluations

The occupational medicine and nursing staff provides medical evaluations to all personnel included in the medical surveillance program when they terminate employment (AR 40–5). A termination evaluation should encompass all components of the baseline evaluation as well as any other components which the OH physician deems appropriate.

CHAPTER 5

ADMINISTRATIVE REQUIREMENTS

5–1. Recordkeeping

a. Maintenance. The IMA ensures the military or civilian medical record is maintained and kept confidential according to AR 40–66.

b. Atmospheric monitoring records. Documentation of atmospheric sampling, even for negligible results, is important to maintain a full exposure history and to meet legal requirements.

(1) The industrial hygiene program manager maintains the monitoring records in accordance with part 1910, title 29, Code of Federal Regulations (29 CFR 1910) and AR 340–21.

(2) The IMA—

(a) Includes the results of atmospheric sampling affecting personnel in the military or civilian medical records using DA Form 4700 (Medical Record—Supplemental Medical Data) or other appropriate forms.

(b) Retains these records per AR 25–400–2.

(3) Any record of exposure or potential exposure above the action levels prescribed in paragraph 2–1 must include—

(a) The date, number, duration, location, and results of each sample taken.

(b) A written description of the sampling and analytical methods used, or a reference to a publication in the open literature describing these methods.

c. Access. The IMA—

(1) Removes all personal identifiers from the atmospheric sampling results (after incorporating data into the medical record if appropriate) and forwards recommendations to the supervisor for posting in the work area.

(2) Provides affected personnel, former personnel, or their designated representatives access to the atmospheric sampling records.

5–2. Information and Reporting Requirements

a. The employee's supervisor, in coordination with the industrial hygienist and the employee, provides the following information to the occupational medicine and nursing staff:

(1) A written description of the affected employee's duties as they relate to the potential exposure.

(2) The employee's potential exposure (measured or estimated).

b. If an employee is removed from work because of signs and symptoms commonly associated with exposure to WAG, the IMA ensures that the occurrence is—

(1) Reported in the Special Telegraphic Report of Selected Condition (RCS MED–16(R4)) as an occupationally related illness per AR 40–400.

(2) Noted in the remarks section of the DA Form 3076 (Army Occupational Health Report) covering the exposure period per AR 40–5.

(3) Documented in the military or civilian medical record.

(4) Reported and documented per AR 385–40.

5–3. Employee Information and Training

a. Employee health education program.

(1) The IMA establishes a health education program to inform personnel potentially exposed to WAG within 30 days of employment and at least annually of—

(a) The information contained in this bulletin with particular emphasis on health effects of exposure to WAG (app D) and the purpose, limitations, and implementation of work practices to reduce occupational exposure to WAG.

(b) The specific nature of operations that could result in exposure above the occupational exposure limit and the necessary steps to prevent such exposures. Methods of instruction may include medical screening interviews, formal classes, work area meetings, and audiovisual presentations as appropriate.

(2) In accordance with hazard communication directives—

(a) Supervisors will educate employees about the specific hazards of WAG in the workplace.

(b) The IMA will provide technical assistance, monitor selected training sessions, and approve, in writing, the program of instruction and lesson plans.

b. Access to health education materials. The IMA ensures that a copy of all materials used in the health education program or training, to include a copy of this bulletin, are readily available to all employees with the potential for exposure.

c. Documenting employee training. Document training, in writing, to include the signature of both the trainee and the approving authority. Document training for all DA personnel on Department of Defense (DD) Form 1556 (Request, Authorization, Agreement, and Certification of Training and Reimbursement) or other appropriate forms, and incorporate it as a permanent part of the official personnel folder.

5–4. Reproductive Hazards Policies

The occupational medicine and nursing staff informs personnel of reproductive age of their options according to AR 40–5, paragraph 5–20.

APPENDIX A

REFERENCES

A–1. Army Regulations

AR 40–5	Preventive Medicine.
AR 40–66	Medical Records Administration.
AR 40–400	Patient Administration.
AR 25–400–2	The Modern Army Recordkeeping System (MARKS).
AR 340–21	The Army Privacy Program.
AR 385–10	Army Safety Program.
AR 385–40	Accident Reporting and Records.

A–2. Other Publications

DHEW Pub. No. 75–137 (NIOSH)	Development and Evaluation of Methods for the Elimination of Waste Anesthetic Gases and Vapors in Hospitals.
DHEW Pub. No. 77–140 (NIOSH)	Criteria for a Recommended Standard—Occupational Exposure to Waste Anesthetic Gases and Vapors.
DHEW Pub. No. 77–171 (NIOSH)	Criteria for a Recommended Standard—Control of Operational Exposure to Nitrous Oxide in the Dental Operatory.
DHHS Pub. No. 88–119 (NIOSH)	Guidelines for Protecting the Safety and Health of Health Care Workers.
NFPA Std 99	Health Care Facilities.
29 CFR 1910	Occupational Safety and Health Standards.

NOTE: All of the publications in paragraph A–2 may be obtained from the Superintendent of Documents, U.S. Government Printing Office, WASH, DC 20402.

A–3. Selected Bibliography

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14. *Documentation of Threshold Limit Values,* American Conference of Governmental Industrial Hygienists (ACGIH), 6500 Glenway Ave, Bldg D–7, Cincinnati, OH 45211–4438.

15. *1991–1992 Threshold Limit Values and Biological Exposure Indices,* ibid. American Conference of Governmental Industrial Hygienists.

16. *Accreditation Manual for Hospitals,* Joint Commission on Accreditation of Healthcare Organizations.

17. *Architectural and Engineering Instructions,* Medical Design Standards, 10 July 1989. (This publication is available from HQ, US Army Corps of Engineers, Engineering Division, Directorate of Military Programs, Washington, DC 20314–1000.)

18. *Reproductive Hazards in the Workplace, Selected References,* DHHS, NIOSH, May 1991.

19. *Ventilation for acceptable indoor air quality,* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., (ASHRAE) 62–189.

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A–4. Forms

DA Form 3076	Army Occupational Health Report.
DA Form 4700	Medical Record—Supplemental Medical Data.
DD Form 1556	Request, Authorization, Agreement, and Certification of Training and Reimbursement.

APPENDIX B

SOURCES OF WASTE ANESTHETIC GASES EXPOSURE

B–1. Exposures to WAG occur in operating rooms; labor, delivery, and recovery rooms; cystoscopy rooms; dental clinics; emergency rooms; outpatient clinics; veterinary clinics; and other miscellaneous locations.

B–2. Factors that contribute to the overall exposure of WAG are—

a. Leakage from anesthetic equipment.

(1) The leaks may be related to poor work practices of the anesthesiologist and nurse anesthetists.

(2) Generally more leakage occurs when using a face mask than an endotracheal tube.

(3) Higher concentrations normally occur during procedures where the mask or tube is frequently moved or reinserted (that is, oral surgery).

b. Maintenance of anesthetic equipment.

(1) Special attention must be given to equipment tubing, gaskets, bags, valves, and fittings.

(2) Frequently, the wheels on various operating room equipment are rolled over flexible tubing (for example, gas scavenging exhaust system and high pressure circuit), which may result in cracks, holes, and tears.

B–3. The following are common sources of WAG:

a. Gas may escape during hookup and preoperational checks of the system.

b. Excess gas may seep over the lips of the patient.

c. Tenting of the patient during surgery may trap gases and vapor around the patient's BZ.

d. Leaking gas cylinders, both in use and auxiliary tanks.

e. Holes and breaks in the anesthetic system tubing and bags.

f. Leaking gaskets, gauges, and valves.

g. Incompatible fittings on gas lines.

h. Gas scavenging system may be misused or not used at all.

i. Exhaled breath of postoperative patients and operating room staff.

B–4. The manufacturer's instruction manual can be a good resource in the evaluation of an anesthetic gas machine. The local medical maintenance staff, a valuable asset, should be consulted during the evaluation of these units.

APPENDIX C

WASTE ANESTHETIC GASES EXCURSION LIMITS

Example 1. OR personnel have enflurane exposures of: 0.0 ppm for 150 min; 0.5 ppm for 120 min; 1.5 ppm for 50 min; 2.0 ppm for 105 min; 3.0 ppm for 35 min; and 8.0 ppm for 20 min.

The 8 hr TWA =

$$\frac{(0\times150) + (0.5\times120) + (1.5\times50) + 2.0\times105) + (3.0\times35) + (8.0\times20)}{480 \text{ minutes}} = 1.27 \text{ ppm}$$

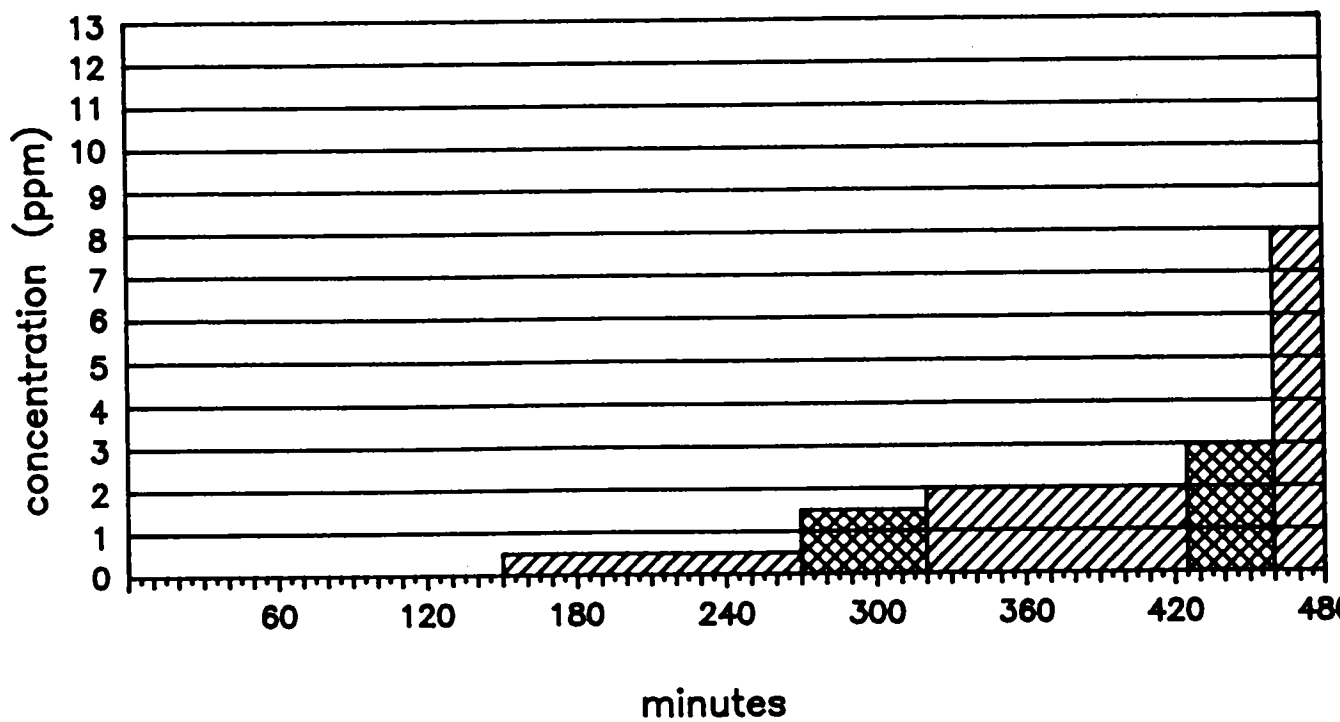

Figure C–1. Waste anesthetic gas exposure; example 1—enflurane.

The exposure is below the TWA and within the excursion guidance, but medical surveillance is required since exposure is above the action level. The industrial hygienist should develop ways to reduce the exposure even further.

Example 2. OR personnel have halothane exposures of: 0.0 ppm for 275 min; 1.0 ppm for 165 min; 7.0 ppm for 35 min; and 12.0 ppm for 5 min.

$$\text{The 8 hr TWA} = \frac{(0\times275) + (1.0\times165) + (7.0\times35) + (12.0\times5)}{480 \text{ minutes}} = 0.98 \text{ ppm}$$

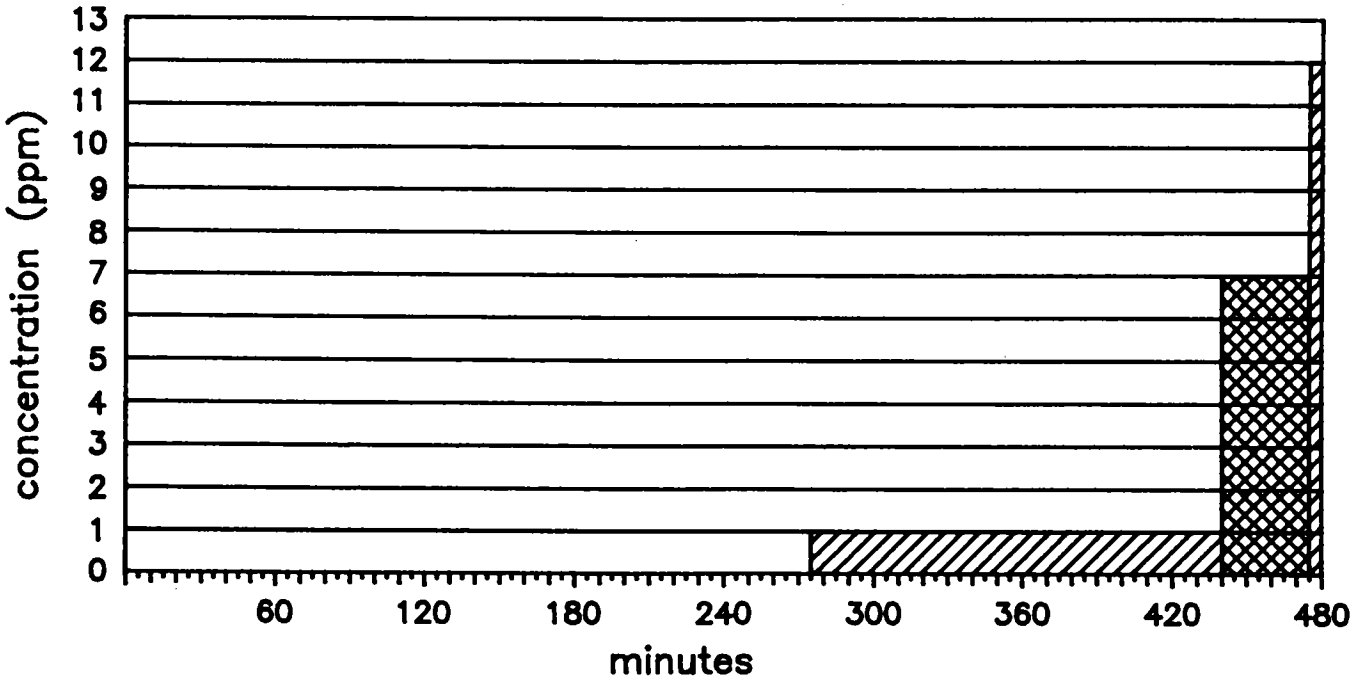

Figure C–2. Waste anesthetic gas exposure; example 2—halothane.

The exposure is below the calculated TWA, but exceeds both the 30 minute per day excursion and the 5 times exposure limit rules. The industrial hygienist should develop ways to reduce the exposure even further.

Example 3. OR personnel have halothane exposures of: 0.0 ppm for 240 min; 0.5 ppm for 75 min; 1.0 ppm for 120 min; 5.0 ppm for 10 min; 6.0 ppm for 15 min; and 8.0 ppm for 20 min.

The 8 hr TWA =

$$\frac{(0\times240) + (0.5\times75) + (1.0\times120) + (5.0\times10) + (6.0\times15) + (8.0\times20)}{480 \text{ minutes}} = 0.99 \text{ ppm}$$

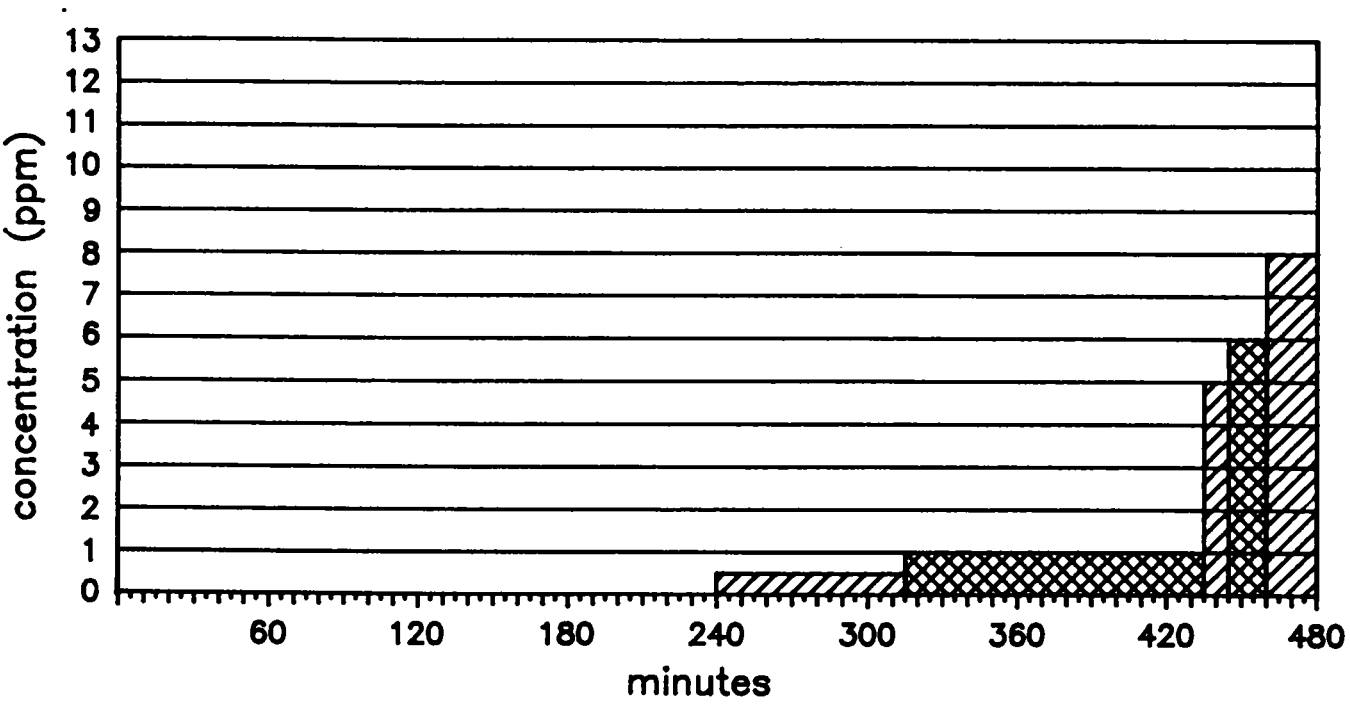

Figure C–3. Waste anesthetic gas exposure; example 3—halothane.

The exposure is below the calculated TWA, but exceeds the 30 minute per day excursion. The industrial hygienist should develop ways to reduce the exposure even further.

APPENDIX D

HEALTH EFFECTS FROM EXPOSURE TO WASTE ANESTHETIC GASES

D–1. General

a. The term WAG refers to gases and vapors which escape into worksite air during the course of administration of clinical anesthesia. Halothane is estimated to represent 60 percent of anesthetic used, but WAG may be composed of N_2O, enflurane, methoxyflurane, isoflurane, and other inhalation anesthetics in varying concentrations.

b. While the flammability of earlier agents led to safety concerns over their use, current concerns relate to health effects of occupational exposure to the newer agents. Two anesthetics, chloroform and trichloroethylene, are suspected carcinogens and are no longer used. The major health concerns for presently used anesthetics include possible reproductive, mutagenic and cytogenic, carcinogenic, nervous system, liver, kidney, and hematopoietic effects.

D–2. Reproductive System Effects

The association between occupational exposure to WAG in medical and dental personnel and adverse reproductive outcomes has been investigated repeatedly. Numerous studies have analyzed "exposed" pregnancies in medical, dental, and veterinary professionals, comparing them to workers in "unexposed" medical settings for rates of spontaneous abortion and congenital anomalies.[1–5*]

a. The limitations of these epidemiological investigations have been numerous, however.[1] All are retrospective studies and rely on questionnaires to assess outcomes. Many of the studies report surprisingly low rates of miscarriage or congenital anomalies among control groups. Participation rates (ranging from 41 percent to 94 percent) were sometimes quite low, and often varied between the exposed and controls, raising the issue of bias and differential recall. The amount, kind, and timing of the anesthetic "exposure" with respect to the pregnancy under consideration is poorly defined in most of these investigations. Problems exist with comparability between the exposed and control groups with respect to other factors such as stress, radiation exposure, nutrition, alcohol use, and in some cases, smoking and prior obstetric history. Nevertheless, when looked at collectively, the consistency in the direction of the findings suggest that WAG pose some increased reproductive risk from occupational exposures.

b. Most studies reported an increased risk of miscarriage in women occupationally exposed during pregnancy when compared with controls.[1–5] In most instances, the relative risk was found to be less than two, and the absolute frequency does not appear to be much greater than in the general population. A few studies found an increased rate of spontaneous abortions among women whose husbands had occupational exposures to WAG, but most of these studies resulted in negative findings.[5]

c. Most studies do not associate risk of congenital anomalies with occupational WAG exposure during pregnancy.[1–5] No consistent number or pattern of anomalies has been seen between exposed and control women.

D–3. Mutagenic and Cytogenic Effects

Cellular studies on anesthetic agents have been inconclusive. Some studies have shown abnormal cell formation and chromosomal aberrations. Other studies have shown negative mutagenicity for N_2O, halothane, methoxyflurane, enflurane, and isoflurane in Ames and sister chromatid exchange assays. One study showed induced mutations by the Ames assay using the urine of anesthesiologists, but the significance of this is unclear because the specific chemicals in the urine were not identified.[3]

D–4. Carcinogenic Effects

A possible association between cancer and anesthetic gases has been suggested from both experimental and occupational data. Relevance of reported animal studies to occupational risk, however, is debatable because of the high experimental levels of anesthetic employed.[1]

a. Three epidemiologic studies report a small increase in the incidence of cancer in women, but not men, occupationally exposed to anesthetic gases. Tumor types and locations were inconsistent among the three studies. Higher frequencies of cancers, especially leukemia and lymphoma, were seen among female operating room personnel; no effects of WAG were seen in men.[6–8]

*The numbers here and in the remainder of this chapter refer to the selected bibliography in appendix A, paragraph A–3.

b. One study found a 2.4-fold increase in cancer of the cervix with heavy occupational exposure to inhalation anesthetics in female dentists.[8]

c. Four studies which investigated deaths from cancer among personnel exposed to WAG were negative.[8–10]

D–5. Nervous System Effects

Animal and human experiments indicate that exposure to anesthetic gases affects the central nervous system. The effects are seen acutely.[14]

a. One study determined that the threshold at which N_2O started to affect performance occurred between 8,000 and 12,000 ppm. The effects of low-level exposures to WAG on health and performance are unclear.

b. A study among dental personnel has reported increased incidence of numbness, tingling, and muscle weakness. The NIOSH-recommended exposure limit of 25 ppm for N_2O was based on one study which reported audiovisual decrements at 50 ppm. Several subsequent studies have failed to confirm this report and have led ACGIH to set their 1990–1991 threshold limit value (TLV®) at 50 ppm.

D–6. Liver Effects

Liver damage has been reported in animal experiments after high-dose exposure to halogenated agents. Some human epidemiologic studies have reported an increased frequency of liver disease among anesthesia workers and dental personnel exposed to WAG. These were based on numbers of exposed individuals reporting current liver disease by questionnaire. Data include liver disease of various or unspecified types.[10–13] Most studies measuring liver function tests have been negative.[13]

D–7. Kidney Effects

Animal experiments have reported kidney damage after exposure to halothane.[6] A few human epidemiologic studies using retrospective questionnaires administered to exposed individuals have reported an increased frequency of kidney disease among the exposed.[10–13] The increase is less for male dentists (1.2 fold) as compared with female chair assistants (1.2–1.7 fold). Furthermore, the relatively small increase in renal disease in the male dentists reflects a specific increase in renal lithiasis, and the larger increase seen in females was due to infections of the urinary tract. No satisfactory explanation for these sex differences is available.[1]

D–8. Bone Marrow Effects

Animal studies and clinical observation have shown that prolonged, high-level exposures and treatments with N_2O can induce leukopenia. However, a study measuring hematological functions did not show a difference between personnel exposed or not exposed to WAG.[13]

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GLOSSARY

Section I. Abbreviations

ACGIH.....	American Conference of Governmental Industrial Hygienists
A&EI.....	Architectural and Engineering Instructions
AMEDD.....	U.S. Army Medical Department
APL	adjustable pressure limiting
BZ.....	breathing zone
CFR	Code of Federal Regulations
DA	Department of the Army
DD	Department of Defense
DEPMEDS..	Deployable Medical Systems
DHEW.....	Department of Health, Education, and Welfare
DHHS.....	U.S. Department of Health and Human Services
IMA	installation medical authority
mg.....	milligram
NFPA.....	National Fire Protection Association
N_2O	nitrous oxide
NIOSH.....	National Institute for Occupational Safety and Health
OH	occupational health
ppm.....	parts per million
TLV	threshold limit value
TM	technical manual
TWA.....	time-weighted average
USAEHA ...	U.S. Army Environmental Hygiene Agency
WAG	waste anesthetic gases

Section II. Special Terms

Action level

The exposure level at or above which periodic medical surveillance is required.

Anesthetizing location

Any location including but not limited to hospital operating, recovery, labor and delivery, and emergency rooms; specialty, dental operatories; and research and teaching facilities where inhalation anesthetic agents are administered.

Exposed personnel

All personnel occupationally exposed to WAG above the action level (para 2–1b), to include anesthesiologists, anesthetists, other operating room staff, oral surgeons, dental assistants, and other medical, dental, veterinary, and research personnel.

Installation medical authority

The unit surgeon, command chief surgeon, U.S. Army Medical Department Activity/U.S. Army Medical Center commanders, and the Director of Health Services, or his or her representative responsible for provision of medical support at the unit, command, or installation concerned.

Occupational medicine and nursing staff

Includes the chief, preventive medicine services, the OH physician, the OH nurse, and ancillary health professionals who perform such activities as—

a. Providing the first level of OH services under the auspices of the local Preventive Medicine Service.

b. Determining response to the work environment.

c. Correlating employee complaints with potential hazard areas.

d. Undertaking special biochemical tests to determine if normal bodily functions have been impaired.

e. Providing the employee medical guidance on general health problems in relation to the physical requirement of the job, through physical examinations.

f. Selecting workers for job assignments where preexisting conditions will not be aggravated nor will the worker's presence endanger the health and safety of others.

Scavenging

The collection of WAG in the anesthetizing location and removal of the gases from the workplace.

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