NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2001-0066-3019
Morton Plant Hospital
Dunedin, Florida

October 2006

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluation and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employers or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Bradley King and Joel McCullough of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Lisa Delaney and Ewa Kulgowskowa. Analytical support was provided by DataChem Laboratories, Inc., (Salt Lake City, Utah). Desktop publishing was performed by Robin Smith. Editorial assistance was provided by Ellen Galloway.

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

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a management request for a health hazard evaluation (HHE) at Morton Plant Hospital in Dunedin, Florida. This request noted that employees had concerns regarding the health effects of exposure to the byproducts of surgical smoke. These byproducts are produced during surgical operations where electrocautery knives are used. NIOSH investigators conducted investigations in March and May 2001.

What NIOSH Did

- We tested the air for chemicals commonly found in surgical smoke produced by electrocautery knives during surgery.
- We asked employees about health symptoms they feel are associated with exposures to the surgical smoke.

What NIOSH Found

- Of the compounds tested, formaldehyde, acetaldehyde, and toluene were found to have measurable levels in the air.
- Levels of these compounds were below the relevant criteria for occupational exposure.
- Of the employees surveyed, 44% reported at least one symptom they associated with surgical smoke exposure.
- Thirty-three percent of employees described irritation of their eyes and upper respiratory tract after surgical smoke exposure.
- Fifty-eight percent of employees reported annoyance with the odor from the surgical smoke.

What Morton Plant Hospital Managers Can Do

- Implement engineering controls during procedures where surgical smoke is produced. Recommended ventilation techniques include using local exhaust ventilation as close as possible to the point of smoke production, combined with general room ventilation.

What the Morton Plant Hospital Employees Can Do

- Report instances of health symptoms thought to be associated with exposure to surgical smoke to the hospital's occupational health staff.

CDC Workplace Safety and Health

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for
HETA Report #2001-0066-3019

NIOSH

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SUMMARY

On November 13, 2000, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from the management at Morton Plant Hospital in Dunedin, Florida. The request noted concerns from surgery department employees about possible health effects from exposure to byproducts of surgical smoke in the operating room.

In March 2001, NIOSH investigators conducted a site visit to the facility and met with management and employee representatives. A return site visit was made in May 2001. A questionnaire regarding symptoms potentially associated with exposure to surgical smoke and its byproducts was distributed to employees of the surgery department. Personal breathing zone and area air samples were collected during 15 procedures over 3 days for substances commonly found in surgical smoke plume. These substances included volatile organic compounds (including benzene, toluene, and xylene), acrolein, phenol, cresols, hydrogen cyanide, formaldehyde, acetaldehyde, polycyclic aromatic compounds, and carbon monoxide.

Although exposures to chemical compounds above the permitted or recommended limits were not identified, low concentrations of compounds found in surgical smoke may be sufficient to cause irritative effects on the eyes and mucous membranes, especially in sensitive individuals. In fact, almost half of employees surveyed associated at least one symptom with exposure to surgical smoke and most employees surveyed found the odor associated with surgical smoke annoying and/or objectionable. Although not studied in this evaluation, past NIOSH research has also shown the possibility of mutagenic airborne particulates being present in surgical smoke. The use of engineering controls such as a smoke evacuator is recommended to reduce the levels of surgical smoke in the operating rooms.

Keywords: SIC 8062 (General Medical and Surgical Hospitals), NAICS 622110 (General Medical and Surgical Hospitals), surgical smoke, laser, electrocautery, eye irritation, throat irritation, asthma symptoms, hospitals, surgery, formaldehyde, acetaldehyde, toluene.

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INTRODUCTION

On November 13, 2000, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from the management at Morton Plant Hospital in Dunedin, Florida. The request noted concerns from surgery department employees about possible health effects from exposure to by-products of surgical smoke in the operating room (OR).

On March 1-2, 2001, NIOSH medical and industrial hygiene investigators visited the facility to conduct an initial site visit. An opening conference was held with management and employee representatives to discuss the request, and a walk-through of the facility was conducted to gain an understanding of its layout and procedures.

On May 7-11, 2001, NIOSH investigators returned to the facility and met with management and employee representatives. A questionnaire regarding symptoms potentially associated with exposure to surgical smoke and its byproducts was distributed to employees of the surgery department. Personal breathing zone (PBZ) and area air samples were collected during 15 procedures over 3 days for compounds commonly found in surgical smoke plume. These compounds include volatile organic compounds (VOCs) (including benzene, toluene, and xylene), acrolein, phenol, cresols, hydrogen cyanide, formaldehyde, acetaldehyde, polycyclic aromatic compounds, and carbon monoxide. An interim letter reporting the results from the industrial hygiene sampling was mailed to Morton Plant Hospital management and employee representatives on October 16, 2001.

BACKGROUND

Established in 1916, Morton Plant Hospital is a 687-bed healthcare facility located at 300 Pinellas Street, in Dunedin, Florida. Morton Plant Hospital provides a full range of medical-surgical services including cardiology, emergency medicine, oncology, women's and children's services, neurosciences, orthopedics, diabetes care, rehabilitation, vascular surgery, and neurosurgery. Types of surgery performed include general, plastic/cosmetic, vascular, otolaryngology, orthopedic, thoracic, and urology. Additional procedures include laparoscopy, a technique that reduces the recovery time for many operations including appendectomy, gallbladder removal and gynecological surgery. Procedures are performed in 19 ORs. Approximately 150 employees are on the payroll in the surgery department, including nurses and scrub technicians. Laser and electrocautery units are used in surgical procedures at the hospital; a smoke evacuator is used only during the use of laser cautery.

METHODS

Medical

A one-page self-administered questionnaire was distributed to OR personnel on the days of the return site visit by NIOSH investigators. The questionnaire contained demographic information, including job title and number of years working in an OR. The questionnaire also inquired about symptoms that occurred during exposure to surgical smoke in the previous 4 weeks. These symptoms included coughing, wheezing, shortness of breath, chest tightness, eye irritation, burning in nose or throat, nasal symptoms, and headache. The questionnaire inquired if the respondent had ever been diagnosed with asthma by a doctor and, if yes, when. The questionnaire also asked about annoyance caused by the odor of surgical smoke.

Industrial Hygiene

On the initial site visit, a walk-through of the facility was conducted to gain an understanding of its layout and procedures. During the return site visit, PBZ and area air sampling for chemical components commonly found in surgical smoke was performed. Over the 3-day sampling period, air samples were collected during 15 surgical procedures; all varied with respect to type of procedure, length of procedure, and duration of use of the electrocautery unit (i.e., amount of smoke production).

On May 8, 2001, sampling was performed during five surgical procedures. These included a colostomy, a laparoscopic cholecystectomy, a left carotid endarterectomy, a total hip replacement, and a total knee replacement. On May 9, 2001, four surgical procedures were sampled: a cystoscopy-transurethral resection of the prostate (TURP), two mastectomies, and a triple-bypass open heart surgery. Six surgical procedures were sampled on May 10, 2001. These included a takedown colostomy, a shoulder Bankhart repair, a total hip replacement, an anal fistula, a right hip lipoma excision, and a left thyroid lobectomy.

Qualitative area air sampling was performed in the OR for identification of airborne VOCs. A thermal desorption tube containing different sorbents for collecting a wide range of compounds was typically placed within several feet of the surgical table to collect an area air sample during each procedure. Tubing connecting the sampler, and a personal sampling pump allowed air to be drawn through the sampling train at a calibrated flow rate of 20 milliliters per minute (mL/min). Analysis of the desorption tubes for captured VOCs was performed according to the NIOSH Manual of Analytical Methods (NMAM) Method 2549 using a Perkin-Elmer ATD 400 thermal desorption system interfaced directly to a gas chromatograph with a mass selective detector (TD-GC-MSD).[1]

Area air sampling was performed for specific VOCs including toluene, benzene, and xylene, and a variety of compounds detected during the qualitative screening; samplers were typically placed within several feet of the surgical table at an average shoulder height to collect the area air samples during each procedure. Typically during each procedure sampled, one individual at the surgical table (such as a scrub nurse) and one individual (such as a circulating nurse) stationed at the periphery of the room wore a sampling pump to obtain a PBZ sample for these VOCs. During the site visit, 16 area air samples and 25 PBZ samples were collected. These samples were collected using solid sorbent (coconut shell charcoal) tubes and pumps calibrated to provide a volumetric flow rate of 100 mL/min. Analysis of the samples was conducted using a combination of the conditions from NIOSH Methods 2537, 1400, 3701, 1300, 1550, 1501, 1500, and OSHA method 103 with modifications.[1,2] The sorbent tubes were analyzed using gas chromatography with flame ionization detection. The limits of detection (LOD) for these compounds were: 0.4 micrograms (µg) benzene/sample, 0.4 µg toluene/sample, 2 µg xylene/sample, and 0.4 µg total hydrocarbons/sample. The limits of quantitation (LOQ) were 1 µg benzene/sample, 1 µg toluene/sample, 8 µg xylene/sample, and 1 µg total hydrocarbons/sample.

In a similar fashion, PBZ and area air sampling was performed for aldehydes, particularly formaldehyde and acetaldehyde. Samples were collected on 2,4-dinitrophenylhydrazine (DNPH)-treated silica gel cartridges. Tubing connected to the sampler and sampling pump allowed air to be drawn at a calibrated flow rate of 100 mL/min. Twenty-five PBZ samples and 16 area air samples were collected for aldehydes. Analysis of the cartridges was performed according to NIOSH Method 2016, with modifications.[1] The LODs were 0.01 µg formaldehyde/sample and 0.01 µg acetaldehyde/sample. The LOQs were 0.03 µg formaldehyde/sample and 0.03 µg acetaldehyde/sample.

Fourteen area air samples were collected for acrolein using XAD-2 solid sorbent tubes connected to sampling pumps calibrated to provide a volumetric flow rate of 100 mL/min. Analysis of the samples was conducted using gas chromatography according to NIOSH Method 2539 with modifications.[1] The LOD for acrolein was 0.8 µg/sample; the LOQ was 2 µg/sample.

Area air sampling was performed for polycyclic aromatic compounds (PACs) using polytetrafluoroethylene (PTFE) filters and XAD-2 solid sorbent tubes connected to sampling pumps calibrated to provide a volumetric flow rate of 100 mL/min. Analysis of the 15 samples was conducted using fluorescence detection according to NIOSH Method 5800.[1] The LOD for PACs was 0.6 µg/sample; the LOQ was 2 µg/sample.

Area air sampling was performed for cresols and phenol using XAD-7 solid sorbent tubes connected to sampling pumps calibrated to provide a volumetric flow rate of 100 mL/min. Analysis of the 15 samples was conducted using gas chromatography with flame ionization detection according to NIOSH Method 2546.[1] The LODs were 0.6 µg phenol/sample and 1 µg cresols/sample. The LOQs were 2 µg phenol/sample and 4 µg cresols/sample.

Area air sampling was performed for hydrogen cyanide using soda lime solid sorbent tubes connected to sampling pumps calibrated to provide a volumetric flow rate of 100 mL/min. Analysis of these 15 samples was conducted using spectrophotometry according to NIOSH Method 6010 with modifications.[1] The LOD for hydrogen cyanide was 0.2 µg/sample and the LOQ was 0.7 µg/sample.

Area air sampling was performed according to NIOSH Method 6604 for carbon monoxide (CO) using the Biosystems Inc. ToxiUltra Gas Detector, a passive diffusion monitor, which recorded CO concentrations during each procedure.[1] One reading was taken every 30 seconds by each monitor. The recorded measurements were then downloaded to a computer. The monitor measures CO concentrations from 0-500 parts per million (ppm), and had been calibrated prior to the site visit according to the manufacturer's specifications.

A Grimm Model 1108 real-time Dust Monitor (Grimm Technologies, Inc., Douglasville, GA) was used to perform real-time area sampling for the levels of airborne particulates in the operating room environment during various surgical procedures. The Grimm Dust Monitor is a light-scattering aerosol spectrometer designed for real-time particulate measurement with particle size discrimination. Data was collected over the entire time period during the selected procedures. For each, the data was integrated for 1 minute and stored sequentially on the Grimm data card over the entire sampling period. The collected information was downloaded to a laptop computer following the completion of the sampling day.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[3] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®)

Threshold Limit Values (TLVs®),[4] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[5] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Surgical Smoke

Surgical smoke or plume is created when energy is delivered to intact cells during surgery. When energy from a laser or electrosurgical unit is delivered to a cell, energy in the form of heat is released. This heat vaporizes the intracellular fluid, increasing the pressure inside the cell, and eventually causing rupture of the cell membrane. After the membrane bursts, a plume of smoke is released into the atmosphere of the OR. At the same time, the intense heat chars the protein and other organic material within the cell and causes thermal death of the adjacent cells. The charring of cells releases material such as carbonized cell fragments and hydrocarbons.[6]

Compared to electrosurgery, thermal lasers vaporize tissue very rapidly, causing an explosive effect. This explosive tissue response causes rapid generation of odors and thick plumes of smoke. Electrosurgical energy causes hemostasis and dissection more slowly, and the tissue response is not as explosive. The amount of surgical smoke may vary with: 1) the type of surgical procedure, 2) the target tissue, 3) surgical technique, 4) duration of application of thermal or mechanical energy, and 5) the instrument used to vaporize the tissue.

All personnel who work in ORs are exposed to surgical smoke to some degree, but the extent of the exposure can be highly variable. Surgeons and others standing at the operating table generally have a more concentrated exposure to smoke during procedures, but scrub nurses, circulating nurses, and surgical technicians may also have exposures. Surgical smoke is known to produce odors and limit the view of the surgical field.

Surgical smoke has potential biological and chemical components. Viable bacteria have been cultured from surgical smoke. These bacteria include *Bacillus subtillis* and *Staphylococcus aureus*. Mycobacteria have also been isolated in smoke, including *Mycobacterium tuberculosis*.[7] Human immunodeficiency virus (HIV) pro-viral DNA and intact viral DNA from the human papilloma virus have been found in plumes produced by lasers.[8,9] Other biological material collected from surgical smoke included intact and fragmented human cells and intact DNA.[10,11] In addition to biological material, chemical components have also been found in the surgical smoke, including various volatile organic compounds, polycyclic aromatic compounds, aldehydes, cresols, phenol, hydrogen cyanide, and carbon monoxide.

Volatile Organic Compounds

Volatile organic compounds (VOCs) describe a large class of chemicals that are organic (i.e., contain carbon) and have a sufficiently high vapor pressure to allow some of the compound to exist in the gaseous state at room temperature. Typically, these compounds are emitted in varying concentrations from numerous indoor sources including, but not limited to, carpeting, fabrics, adhesives, solvents, paints, cleaners, waxes, cigarettes, and combustion sources.

Benzene

Benzene is an aromatic organic hydrocarbon containing a six-carbon ring with alternating double bonds. Acute inhalation exposure to high concentrations of benzene can cause drowsiness, fatigue, nausea, vertigo, narcosis, and other symptoms of central nervous system (CNS) depression as noted with excessive exposure to other aromatic hydrocarbons.[4,12,13] However, the most remarkable health effects associated with benzene exposure are chronic effects due to repeated exposure to low concentrations over many years.[13]

Benzene is classified by the International Agency for Research on Cancer (IARC) as a known human carcinogen and has been associated with irreversible bone marrow injury and the development of hematopoietic toxicity, including aplastic anemia and leukemia in humans.[14,15] NIOSH classifies benzene as a human carcinogen, and recommends controlling occupational exposures to prevent employees from being exposed to concentrations greater than 0.1 ppm, determined as a TWA concentration for up to a 10-hour work shift in a 40-hour work week.[3] NIOSH further recommends a 15-minute STEL of 1.0 ppm.[3] Although NIOSH has established these guidelines which should not be exceeded, the Institute still urges reducing exposures to the "lowest feasible concentration" because it is not possible to establish thresholds for carcinogens that will protect 100% of the population. The OSHA PEL is 1 ppm for an 8-hour TWA with a 15-minute STEL of 5 ppm.[16] The current ACGIH TLV is 0.5 ppm for an 8-hour TWA with a 15-minute STEL of 2.5 ppm, and is noted as a confirmed human carcinogen.[4]

Toluene

Toluene is a colorless, aromatic organic liquid containing a six-carbon ring (a benzene ring) with a methyl group (CH_3) substitution. Inhalation and skin absorption are the major occupational routes of entry. Toluene can cause acute irritation of the eyes, respiratory tract, and skin.[17]

The main effects reported with excessive (inhalation) exposure to toluene are CNS depression and neurotoxicity.[17] Studies have shown that subjects exposed to 100 ppm of toluene for 6 hours complained of eye and nose irritation, and in some cases, headache, dizziness, and a feeling of intoxication (narcosis).[18,19,20] No symptoms were noted below 100 ppm in these studies.

The NIOSH REL for toluene is 100 ppm for a 10-hour TWA.[3] NIOSH has also set a recommended STEL of 150 ppm for a 15-minute sampling period.[3] The OSHA PEL for toluene is 200 ppm for an 8-hour TWA.[5] The ACGIH TLV is 50 ppm for an 8-hour TWA, with a Notice of Intended Changes to 20 ppm.[4]

Xylene

Xylene is a colorless, flammable organic liquid with a molecular structure consisting of a benzene ring with two methyl group (CH_3) substitutions. The vapor of xylene has irritant effects on the skin and mucous membranes, including the eyes and respiratory tract. This irritation may cause itching, redness, inflammation, and discomfort.

Acute xylene inhalation exposure may cause headache, dizziness, incoordination, drowsiness, and unconsciousness.[21] Previous studies have shown that concentrations from 60 to 350 ppm may cause giddiness, anorexia, and vomiting.[21] At high concentrations, exposure to xylene has a narcotic effect on the CNS, and minor reversible effects on the liver and kidneys.[21,22]

The current OSHA PEL, NIOSH REL, and ACGIH TLV for xylene are 100 ppm over an 8-10-hour TWA.[3,4,5] In addition, NIOSH and ACGIH have published STELs for xylene of 150 ppm averaged over 15 minutes.[3,4]

Aldehydes

Formaldehyde

Formaldehyde, a colorless gas with a strong odor, is a constituent of tobacco smoke and of combustion gases. Formaldehyde levels in ambient air can result from diverse sources such as automobile exhaust, combustion processes, and may also be released from foam plastics, carbonless copy paper, particle board, and plywood. Exposure can occur through inhalation and skin absorption. Symptoms of exposure to low concentrations of formaldehyde may include irritation of the eyes, throat, and nose; headaches; nausea; nasal congestion; asthma; and skin rashes. It is often difficult to ascribe specific health effects to specific concentrations of formaldehyde because people vary in their subjective responses and complaints. For example, irritative symptoms may occur in people exposed to formaldehyde at concentrations below 0.1 ppm, but more typically they begin at exposures of 1.0 ppm and greater. However, some children or elderly persons, those with pre-existing allergies or respiratory disease, and persons who have become sensitized from prior exposure may have symptoms from exposure to concentrations of formaldehyde between 0.05 and 0.10 ppm. Cases of formaldehyde-induced asthma and bronchial hyperreactivity developed specially to formaldehyde are uncommon.[23]

NIOSH has identified formaldehyde as a potential human carcinogen and has set a REL of 0.016 ppm with a 15-minute ceiling limit of 0.1 ppm.[3] The OSHA PEL is 0.75 ppm as an 8-hour TWA and 2 ppm as a STEL.[24] ACGIH has designated formaldehyde as a suspected human carcinogen and therefore, recommends that "worker exposure by all routes should be carefully controlled to levels as low as possible below the TLV."[4] ACGIH has set a ceiling limit of 0.3 ppm.[4]

Acetaldehyde

Acetaldehyde is an irritant of the eyes and mucous membranes. Human volunteers exposed to 50 ppm for 15 minutes experienced mild eye irritation. Sensitive subjects complained of mild upper respiratory irritation even after 15 minutes exposure at 25 ppm. In 1985, IARC concluded that "there is sufficient evidence for the carcinogenicity of acetaldehyde to experimental animals" and "inadequate evidence for the carcinogenicity of acetaldehyde in humans," which for the purpose of the OSHA Hazard Communications Standard would classify acetaldehyde as category 2B carcinogen.[25] The Environmental Protection Agency (EPA) considers acetaldehyde a probable human carcinogen.[26] NIOSH currently considers acetaldehyde a potential occupational carcinogen, and recommends keeping levels of acetaldehyde to the lowest feasible concentration.[3] The OSHA PEL for an 8-hour TWA is 200 ppm (360 milligrams per cubic meter [mg/m^3]).[5] The ACGIH has set a ceiling limit of 25 ppm.[4]

Acrylaldehyde (Acrolein)

Acrolein is a severe eye and respiratory system irritant. The principal site of chemical effects is the mucous membranes of the upper respiratory tract. Acrolein has a vasopressor effect (i.e., causes a rise in blood pressure) that has been observed in animals at exposure levels of 10 to 5029 mg/m^3 (4.4 to 2200 ppm) for one minute. The unsaturated nature of the compound results in an eye irritancy potential 2.5 times greater than that of formaldehyde. At acrolein concentrations of 0.5 to 1.0 ppm, the irritant potential increases to four or five times that of formaldehyde at the same concentrations. The lowest published toxic concentration (TC_{LO}) for human responses to acrolein is 0.2 ppm (eye irritation threshold) and 0.6 ppm (respiratory response threshold). The human odor threshold is 0.33 to 0.4 ppm. Acrolein is a major contributor to the irritant properties of cigarette smoke.[23] The OSHA PEL for acrolein is a TWA of 0.1 ppm.[5] The NIOSH REL is also a TWA of 0.1 ppm, with a 15-minute STEL of 0.3 ppm.[3] The ACGIH TLV of 0.1 ppm is a ceiling limit that should not be surpassed during the work shift.[4]

Polycyclic Aromatic Compounds

Polycyclic aromatic compounds (PACs) refer to a set of cyclic organic compounds that include polynuclear aromatic hydrocarbons (PAHs), and also compounds that may have sulfur, nitrogen, or oxygen in the ring structure, and alkyl-substituted cyclics. NIOSH investigators have hypothesized that PACs with 2 to 3 rings (referred to as low-molecular-weight PACs) may be associated with more irritative effects, while the 4- to 7-ring PACs (termed high-molecular-weight PACs) may have more carcinogenic and/or mutagenic effects.[1] It is not currently possible to definitively distinguish between these two PAC groups analytically; however, using two different spectrofluorometric detector wavelengths (360 nanometer [nm] and 400 nm) allows the detector to be more sensitive to PACs based on ring number.[1] No occupational exposure criteria have been established for total PACs or PAHs.

Cresols

Cresol occurs in three isomers, all of which can cause CNS disorders, gastroenteric disturbances; dermatitis; and damage to liver, kidneys, or lungs. Exposure occurs through skin contact, ingestion and inhalation. In addition, inhalation of particulate cresol as an aerosol is possible.[27] Toxic manifestations that may develop within 20 to 30 minutes after absorption include eye irritation, conjunctivitis, headache, dizziness, dimness of vision, tinnitus (ringing in the ears), irregular and rapid respiration, weak pulse, dyspnea (shortness of breath), and profound muscular weakness, occasionally followed by mental confusion.[27] Repeated or prolonged exposure may cause gastrointestinal disturbances (vomiting, loss of appetite), nervous disorders, headache, dizziness, and dermatitis.[27] The odor of cresol is recognized at concentrations as low as 5 ppm. The ACGIH TLV was set at 5 ppm to prevent irritation.[4] The NIOSH REL is a TWA of 2.3 ppm.[3] The OSHA PEL is a TWA of 5 ppm.[5]

Phenol

Phenol is an irritant of the eyes, mucous membranes, and skin. The skin is a route of entry for the vapor and liquid phases. Symptoms of chronic phenol poisoning may include difficulty in swallowing, diarrhea, vomiting, lack of appetite, headache, fainting, dizziness, dark urine, mental disturbances, and possibly a skin rash.[12] The NIOSH REL, ACGIH TLV, and OSHA PEL for phenol are 5 ppm as a TWA.[3,4,5]

Hydrogen Cyanide

The general population may be exposed to cyanides from a variety of sources, including inhalation of contaminated air, ingestion of contaminated drinking water or cyanide-containing food, and the metabolism of certain drugs.[28] Cyanide is found in low levels in the tissues of healthy people as a result of normal metabolism, eating of cyanide-containing foods, and cigarette smoking.[29] However, an average daily intake of cyanide from these sources has not been estimated.[30]

The single largest source of airborne cyanides in the ambient environment is vehicle exhaust.[28] Other atmospheric sources include emissions from chemical processing industries, iron and steel mills, metallurgical industries, metal plating and finishing industries, petroleum refineries, municipal waste incinerators, and cigarette smoke. Smokers are known to have higher levels of cyanide in the blood and are at increased risk of cyanide's nervous system effects.[28] Little monitoring data for airborne cyanides in the ambient environment is available.

NIOSH has set a 15-minute STEL of 4.7 ppm.[3] ACGIH has set a ceiling limit of 4.7 ppm for hydrogen cyanide.[4] The OSHA PEL is set at 10 ppm.[5]

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials. CO combines with hemoglobin and interferes with the oxygen-carrying capacity of blood. Symptoms include headache, drowsiness, dizziness, nausea, vomiting, collapse, myocardial ischemia, and death.[12] The NIOSH REL for carbon monoxide is 35 ppm for a 10-hour TWA.[3] NIOSH also recommends a ceiling limit of 200 ppm that should not be exceeded at any time during the workday.[3] The OSHA PEL for carbon monoxide is 50 ppm for an 8-hour TWA.[5] The ACGIH TLV for carbon monoxide is 25 ppm as an 8-hour TWA.[4]

Particulates

Health problems associated with various particulate exposures are influenced by four critical factors: the type of particulate involved, the length of exposure, the concentration of airborne particulates in the breathing zone of the workers, and the size of the particulates present in the breathing zone.[31] Particulate size is the main factor that influences deposition in the respiratory system. Large particulates (> 5 micrometers [µm] in diameter) are likely to lodge on the walls of the nasal cavity or pharynx during inspiration; medium particles (1 µm to 5 µm in diameter) are likely to settle out in the trachea, bronchi, or bronchioles as the air velocity decreases in the smaller passageways; and small particles (< 1 µm in diameter) typically move by diffusion into the alveoli.[32] No exposure criteria exist for exposure to particulates in surgical smoke. Comparison of surgical smoke particulate levels to the established criteria for particulates not otherwise regulated (PNOR) would be inappropriate as the criteria cover only biologically inert or nuisance dust, which may not be the case for particulates from this type of exposure.

RESULTS

Medical

Forty-eight employees completed the questionnaire, a participation rate of approximately 80%. The participants included 30 surgical nurses (62.5%), 12 surgical technicians (25.0%), and 6 in the "other" category (including physicians, nurse anesthetist, nurse managers) (12.5%). The average age of the participants was 41.7 years. The average time spent working in ORs at Morton Plant Hospital was 8.5 years, and average total time working in ORs during their careers was 12.8 years.

Twenty-one participants (43.7%) reported at least one symptom that they associated with surgical smoke exposure. The participants reported the following symptoms after exposure to surgical smoke in the previous four weeks: five individuals (10.4%) reported eye irritation, six (12.5%) reported burning of nose or throat, eight (16.7%) reported headache, five (10.4%) reported cough, and six (12.5%) reported nasal symptoms. Three employees (6.3%) reported that they have been diagnosed by a physician as having asthma and one (2.1%) developed asthma or asthma-like symptoms after they began working in operating rooms. (Asthma-like symptoms were defined as having 2 or more of the following symptoms: wheeze, shortness of breath, chest tightness, and coughing attacks.) The individual that developed asthma-like symptoms never smoked cigarettes.

A total of 28 participants (58.3%) reported annoyance with the odor from the surgical smoke.

Fourteen participants (29.2%) responded that they spent more than 50% of their time in the OR scrubbed in. Participants who spent more than 50% of their time scrubbed in and near the surgical field reported more symptoms than participants who generally work farther away from the surgical field.

Industrial Hygiene

Of all the compounds sampled including VOCs, aldehydes, PACs, cresols, phenol, hydrogen cyanide, and CO, only formaldehyde, acetaldehyde, and toluene returned quantifiable results above the analytical limits of detection. Results for these three compounds are listed in Tables 1, 2, and 3 by date, surgical procedure, and worker or location sampled.

Formaldehyde concentrations in the air during the procedures sampled ranged from non-detectable to 0.009 ppm. A background sample taken outside a closed-door OR revealed a level of 0.008 ppm, while a background sample taken inside an empty OR where no procedure was occurring returned a result of 0.002 ppm. NIOSH has set an REL for formaldehyde of 0.016 ppm as a TWA for up to a 10-hour workday during a 40-hour workweek. The TWA exposure levels measured during the procedures sampled would still be below both the OSHA PEL of 0.75 ppm and the NIOSH REL of 0.016 ppm.

Acetaldehyde concentrations ranged from non-detectable to 0.014 ppm for the procedures sampled. A background sample taken outside a closed-door OR revealed a level of 0.008 ppm, while a background sample taken inside an empty OR where no procedure was occurring returned a result of 0.004 ppm. These measured TWA exposure levels are considerably lower than the OSHA PEL of 200 ppm. NIOSH recommends that levels of acetaldehyde be kept to the lowest feasible concentration.

Toluene concentrations in the air ranged from 0.01 ppm to 0.72 ppm. A background sample taken inside an empty OR where no procedure was occurring returned a result of 0.05 ppm. The TWA concentrations during the procedures sampled were well below all applicable exposure limits, including the NIOSH REL of 100 ppm, the OSHA PEL of 200 ppm, and the ACGIH TLV of 50 ppm.

A Grimm Model 1108 real-time Particulate Monitor was used to record the levels of airborne particulates in the operating room environment during various surgical procedures. Figures 1 through 6 present graphical representations of the real-time data collected with the Grimm particle counter over the complete period of each surgical procedure. The highest peaks were recorded during the two mastectomies. Very little of the total particulates were in the smallest measured size ranges, submicrometer to 10 µm, which would reach the deepest regions of an individual's respiratory tract where gas exchange occurs. Geometric mean concentrations of particles less than 10 µm ranged from 1.3 µg/m^3 to 9.9 µg/m^3, depending upon the surgical procedure.

DISCUSSION AND CONCLUSIONS

Almost half of the individuals who completed the questionnaire reported at least one symptom they associated with surgical smoke. A majority of the participants were bothered by the odor of the smoke. Approximately 33% complained of irritation of their eyes and upper respiratory tract after surgical smoke exposure. Generally, individuals who had more concentrated exposure to surgical smoke reported more symptoms, although many individuals with less exposure also reported irritative symptoms. Only one individual reported asthma-like symptoms after beginning work in ORs. It is unclear whether these symptoms were related to surgical smoke exposure. However, if these symptoms persist, they would warrant individual medical follow-up.

The industrial hygiene results found quantifiable airborne concentrations of the compounds formaldehyde, acetaldehyde, and toluene. No quantifiable substances other than those were found in the ORs. However, these were also documented to be present in control (background) air samples taken in the hallway outside of an OR and in an empty OR where no procedures were occurring, although at lower levels. A variety of products and materials in the indoor environment can be sources of VOCs, therefore it is possible that surgical smoke may not be the sole or primary source of the exposures to these VOCs.

Concentrations of particulates in the air during surgical procedures did not show recognizable patterns of spikes during use of the electrocautery unit. Oftentimes, spikes in concentration were seen before (or at the very beginning of) the operation and at the end (or after) the surgery was completed, coinciding with the arrival or departure of the surgeon. Therefore, increased staff movements in and around the OR may be a factor. Local exhaust ventilation (LEV) was not used during these procedures.

A majority of those surveyed reported annoyance with the odor from the surgical smoke. It has been shown that low-level odors, specifically VOCs, can cause irritation of certain sensory receptors at concentrations around their odor threshold (the molecular concentration at which the human nose can detect a chemical). These sensory receptors are part of the trigeminal nerve and are located on the cornea, and in the nose and throat. Irritation of these sensory receptors can result in sneezing, nasal stuffiness, rhinorrhea (runny nose), facial pain, eye irritation, watery eyes, headache, sinus congestion, cough, throat irritation, and wheezing.[33] Exposure to sensory irritants can, in susceptible individuals, trigger airway hyperreactivity resulting in asthma attacks, cough, chest tightness, and shortness of breath.[34,35,36] Regarding the odors and symptoms of eye irritation, burning of nose or throat, headache, coughing, and nasal symptoms reported among the employees, there is evidence in the medical literature that these types of symptoms can be produced by exposure to VOCs that activate sensory receptors in the nervous system. The activation and amplification of these sensory receptors can occur from exposure to extremely low molecular concentrations of airborne chemicals, concentrations that are difficult or impossible to measure with currently available testing techniques. These odors may have played a role in many of the irritant symptoms experienced by the OR employees. Individuals with a history of atopy (allergies) may be particularly vulnerable to the effects of odors.

Although exposures above the permitted or recommended limits were not identified, low concentrations of the compounds found in surgical smoke may be sufficient to cause irritative effects on the eyes and mucuous membranes, especially for sensitive individuals. Although not studied in this evaluation, past NIOSH research has also shown the possibility of mutagenic airborne particulates being present in surgical smoke.[37] Additionally, the symptom questionnaire found that most employees surveyed found the odor associated with surgical smoke annoying and/or objectionable. Although not a hazardous condition, such a factor has a significant impact on the quality of worklife for many of the employees at the facility. For these reasons, controls for capturing the surgical smoke should be evaluated and implemented.

RECOMMENDATIONS

1) Implement engineering controls during procedures where surgical smoke is produced. See Appendix A for NIOSH recommendations on controls for electric/laser surgical procedures. As described, recommended ventilation techniques include a combination of general room ventilation and LEV positioned as close as possible to the point of smoke production.

2) Encourage employees to continue to report instances of health symptoms thought to be associated with exposure to surgical smoke to the hospital's occupational health staff.

REFERENCES

1. NIOSH [2006]. NIOSH manual of analytical methods (NMAM®). 4th ed. Schlecht PC, O'Connor PF, eds. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 94–113 (August, 1994); 1st Supplement Publication 96–135, 2nd Supplement Publication 98–119; 3rd Supplement 2003–154. [http://www.cdc.gov/niosh/nmam/]

2. OSHA [1993]. OSHA analytical methods manual, 2nd ed. U.S. Department of Labor, Occupational Safety and Health Administration; Salt Lake Technical Center; Salt Lake City, UT. [http://www.osha.gov/dts/sltc/methods/index.html]

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

4. ACGIH® [2006]. 2006 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

5. CFR [2003]. 29 CFR 1910.1000. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

6. Wenig BL, Stenson KM, Wenig BM, Tracey D [1993]. Effects of plume produced by the Nd:YAG laser and electrocautery on the respiratory system. Lasers Surg Med 13:242-245.

7. Walker B [1990]. High efficiency filtration removes hazards from laser surgery. Br J Theatre Nurs 27(6):10-12.

8. Baggish M [1991]. Presence of human immunodeficiency virus DNA in laser smoke. Laser Surg Med 11:197-203.

9. Garden JM, O'Banion MK, Shelnitz LS, Pinski KS, Bakus AD, Reichmann ME, Sundberg JP [1988]. Papillomavirus in the vapor of carbon dioxide laser-treated verrucae. JAMA 259(8):1199-1202.

10. Winstin C [1994]. The effects of smoke plume generated during laser and electrosurgical procedures. Minim Invasive Surg Nurs 8:99-102.

11. DesCoteaux JG, Picard E, Poulin EC, Baril M [1996]. Preliminary study of electrocautery smoke particles produced in vitro and during laproscopic procedures. Surg Endo 10:152-158.

12. Hathaway GJ, Proctor NH [2004]. Proctor and Hughes' Chemical hazards of the workplace. 5th ed. Hoboken, NJ: John Wiley and Sons.

13. NIOSH [1974]. Criteria for a recommended standard: occupational exposure to benzene. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 74-137.

14. WHO [1989]. IARC monographs on the evaluation of carcinogenic risks to humans: occupational exposures to the petroleum refining; crude oil and major petroleum fuels. World Health Organization 45:159-201. 1-8 March 1988.

15. NTP [1991]. Sixth annual report on carcinogens: 1991 summary. Research Triangle Park, NC: U.S. Department of Health and Human Services, National Toxicology Program.

16. CFR [2006]. 29 CFR 1910.1028. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

17. NIOSH [1973]. Criteria for a recommended standard: occupational exposure to toluene. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 73-11023.

18. WHO [1981]. Recommended health-based limits in occupational exposure to select organic solvents. Geneva: World Health Organization, Technical Report Series No. 664.

19. Benignus VA [1981]. Health effects of toluene: a review. Neurotoxicology 2:567-568.

20. Anderson I, Lundqvist GR, Molhave L, Pedersen OF, Proctor DF, Vaeth M, Wyon DP [1983]. Human response to controlled levels of toluene in six-hour exposures. Scand J Work Environ Health 9:405-418.

21. NIOSH [1975]. Criteria for a recommended standard: occupational exposure to xylene. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 75-168.

22. NIOSH [1977]. Occupational diseases: a guide to their recognition. Cincinnati,OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77-181.

23. NRC [1981]. Formaldehyde and other aldehydes. National Academy Press. Washington, D.C. Committee on Aldehydes, National Research Council.

24. CFR [2003]. 29 CFR 1910.1048. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

25. IARC [1985]. Allyl compounds, aldehyde, epoxides and peroxides. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Volume 36. Lyon, France: World Health Organization, International Agency for Research on Cancer.

26. EPA [1988]. Integrated risk information system (IRIS): Risk estimate for carcinogenicity for acetaldehyde. Cincinnati, OH: U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office.

27. NIOSH [1978]. Criteria for a recommended standard: occupational exposure to cresol. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 78-l33.

28. ATSDR [1991]. Case studies in environmental medicine: cyanide toxicity. Atlanta, GA: U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry.

29. Baselt RC [1988]. Biological monitoring methods for industrial chemicals. PSG Publishing Company, Inc., Littleton, Massachusetts.

30. ATSDR [1995]. Draft toxicological profile for cyanide. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry.

31. Plog B, Niland J, Quinlan P [1996]. Fundamentals of industrial hygiene, 4th ed., National Safety Council, Itasca, Illinois.

32. Stine K, Brown T [1996]. Principles of toxicology, Lewis Publishers, CRC Press, Inc. Boca Raton, Florida.

33. Sullivan JB, Kreiger GR, eds. [2001]. Clinical environmental health and toxic exposures. 2nd ed. Philadelphia: Lippincott Williams & Wilkins, pp. 394-396.

34. Cain W, Cometto-Muniz J [1995]. Irritation and odor as indicators of indoor pollution. Occup Med State of the Art Reviews 10(1):133-145.

35. Damgard G [1991]. Mechanisms of activation of the sensory irritant receptor by airborne chemicals. Toxicology 21(3):183-208.

36. Cometto-Muniz J, Cain W [1990]. Thresholds for odor and nasal pungency. Physiol Behav 48:719-725.

37. NIOSH [1988]. Hazard Evaluation and Technical Assistance Report: Bryn Mawr Hospital, Bryn Mawr, Pennsylvania. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Report no. 85-126-1932.

Table 1. Personal breathing zone and area air sampling results, by surgical procedure
HETA 2001-0066-3019 Morton Plant Hospital
May 8, 2001

Procedure	Worker or Location Sampled	Formaldehyde Concentration (ppm)*	Acetaldehyde Concentration (ppm)	Toluene Concentration (ppm)
colostomy	scrub nurse	0.005	0.009	--**
colostomy	circulating nurse	0.004	0.010	--
colostomy	area sample	0.004	0.009	0.19
colostomy	surgeon	--	--	0.22
colostomy	nurse anesthetist	--	--	0.13
laparoscopic cholecystectomy	scrub nurse	0.004	0.010	--
laparoscopic cholecystectomy	circulating nurse	0.006	0.012	--
laparoscopic cholecystectomy	surgeon	--	--	0.72
laparoscopic cholecystectomy	nurse anesthetist	--	--	0.49
laparoscopic cholecystectomy	area sample	--	--	0.32
left carotid endarterectomy	scrub nurse	0.006	0.014	--
left carotid endarterectomy	circulating nurse	0.005	0.012	--
left carotid endarterectomy	area sample	0.003	0.013	0.27
left carotid endarterectomy	surgeon	--	--	0.16
left carotid endarterectomy	nurse anesthetist	--	--	0.18
total hip replacement	surgeon	0.005	0.011	--
total hip replacement	circulating nurse	0.005	0.011	--
total hip replacement	area sample	0.004	0.011	0.17
total hip replacement	surgeon	--	--	0.11
total knee replacement	surgeon	0.006	0.010	--
total knee replacement	circulating nurse	0.005	0.010	--
total knee replacement	area sample	0.005	0.009	0.20
total knee replacement	surgeon	--	--	0.21
	NIOSH REL	**0.016**	**LFC‡**	**100**
	OSHA PEL	**0.750**	**200**	**200**
	ACGIH TLV	**(C† 0.30)**	**(C 25)**	**50**

* ppm = parts per million
** dashed lines = a sample was not taken on that individual for a specific compound
† C = a ceiling exposure limit recommended not to be exceeded during any part of the working shift
‡ LFC = lowest feasible concentration

Table 2. Personal breathing zone and area air sampling results, by surgical procedure
HETA 2001-0066-3019 Morton Plant Hospital
May 9, 2001

Procedure	Worker or Location Sampled	Formaldehyde Concentration (ppm)*	Acetaldehyde Concentration (ppm)	Toluene Concentration (ppm)
cystoscopy-TURP	surgeon	0.007	0.011	--**
cystoscopy-TURP	circulating nurse	0.006	0.010	--
cystoscopy-TURP	area sample	0.008	0.011	0.04
cystoscopy-TURP	scrub nurse	--	--	0.17
cystoscopy-TURP	nurse anesthetist	--	--	0.13
mastectomy	scrub nurse	ND^	ND	--
mastectomy	circulating nurse	0.005	0.010	--
mastectomy	area sample	ND	ND	0.05
mastectomy	surgeon	--	--	0.07
mastectomy	nurse anesthetist	--	--	0.05
mastectomy	scrub nurse	0.005	0.004	--
mastectomy	circulating nurse	0.005	0.004	--
mastectomy	area sample	0.004	0.003	0.04
mastectomy	surgeon	--	--	0.05
triple bypass	surgeon	0.008	0.006	--
triple bypass	circulating nurse	0.008	0.005	--
triple bypass	area sample	0.006	0.005	0.01
triple bypass	asst. surgeon	--	--	0.01
	NIOSH REL	**0.016**	**LFC‡**	**100**
	OSHA PEL	**0.750**	**200**	**200**
	ACGIH TLV	**(C† 0.30)**	**(C 25)**	**50**

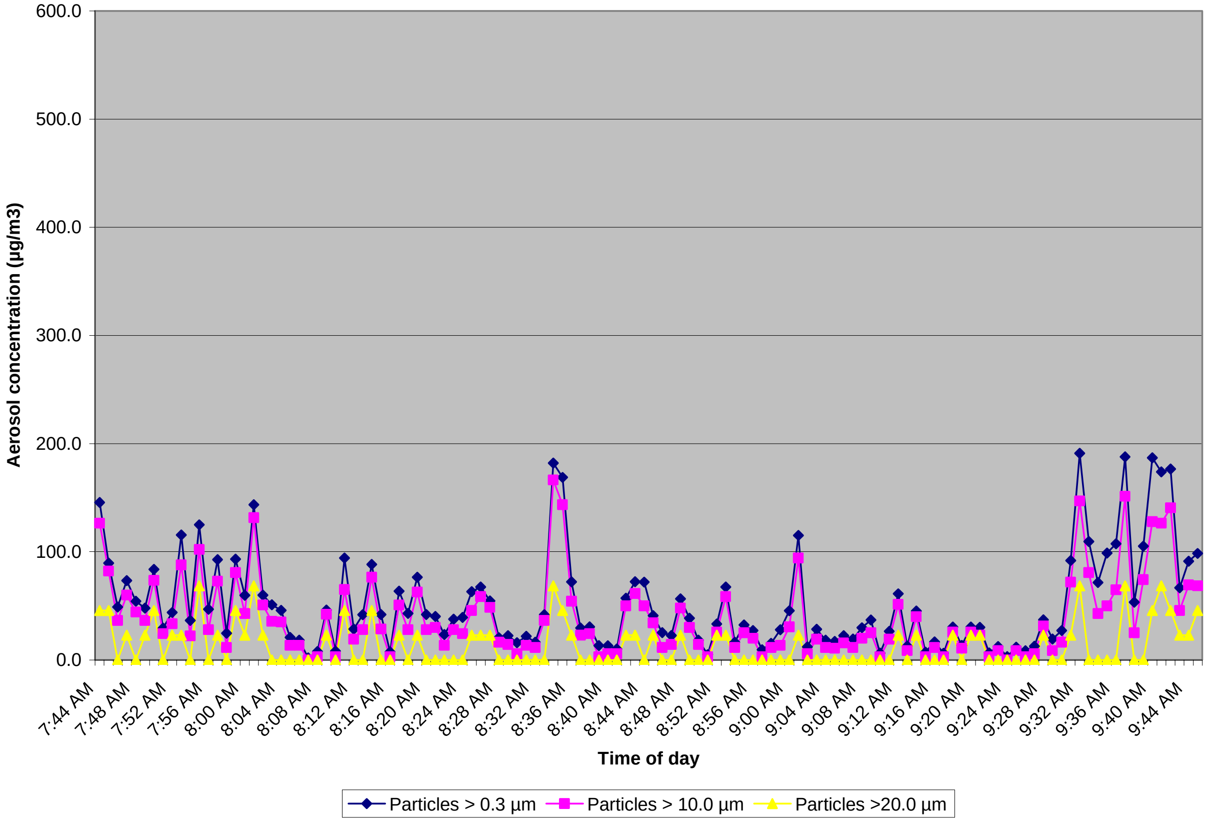
* ppm = parts per million
** dashed lines = a sample was not taken on that individual for a specific compound
† C = a ceiling exposure limit recommended not to be exceeded during any part of the working shift
‡ LFC = lowest feasible concentration
^ ND = non-detect

Table 3. Personal breathing zone and area air sampling results, by surgical procedure
HETA 2001-0066-3019 Morton Plant Hospital
May 10, 2001

Procedure	Worker or Location Sampled	Formaldehyde Concentration (ppm)*	Acetaldehyde Concentration (ppm)	Toluene Concentration (ppm)
takedown colostomy	scrub nurse	0.004	0.012	--**
takedown colostomy	area sample	0.003	0.012	0.04
takedown colostomy	surgeon	--	--	0.06
takedown colostomy	nurse anesthetist	--	--	0.03
shoulder Bankhart repair	nurse anesthetist	0.005	0.008	--
shoulder Bankhart repair	area sample	0.005	0.008	0.09
shoulder Bankhart repair	circulating nurse	--	--	0.05
total hip replacement	surgeon	0.006	0.008	--
total hip replacement	nurse anesthetist	0.006	0.009	--
total hip replacement	area sample	0.005	0.009	0.09
total hip replacement	scrub nurse	--	--	0.04
total hip replacement	circulating nurse	--	--	0.09
anal fistula	surgeon	0.005	0.005	--
anal fistula	area sample	0.003	0.004	0.17
anal fistula	asst. surgeon	--	--	0.22
anal fistula	circulating nurse	--	--	0.12
excision lipoma right hip	surgeon	0.009	0.009	--
excision lipoma right hip	area sample	0.006	0.006	0.27
excision lipoma right hip	asst. surgeon	--	--	0.24
excision lipoma right hip	circulating nurse	--	--	0.38
left thyroid lobectomy	surgeon	0.006	0.008	--
left thyroid lobectomy	area sample	0.003	0.007	0.14
left thyroid lobectomy	scrub nurse	--	--	0.04
left thyroid lobectomy	circulating nurse	--	--	0.04
background	Outside of OR	0.008	0.008	--
background	In Empty OR	0.002	0.004	0.05
	NIOSH REL	**0.016**	**LFC[‡]**	**100**
	OSHA PEL	**0.750**	**200**	**200**
	ACGIH TLV	**(C[†] 0.30)**	**(C 25)**	**50**

* ppm = parts per million
** dashed lines = a sample was not taken on that individual for a specific compound
[†] C = a ceiling exposure limit recommended not to be exceeded during any part of the working shift
[‡] LFC = lowest feasible concentration

Figure 1. Particulate concentrations, Cystoscopy-T.U.R.P.
HETA 2001-0066-3019 Morton Plant Hospital
May 9, 2001

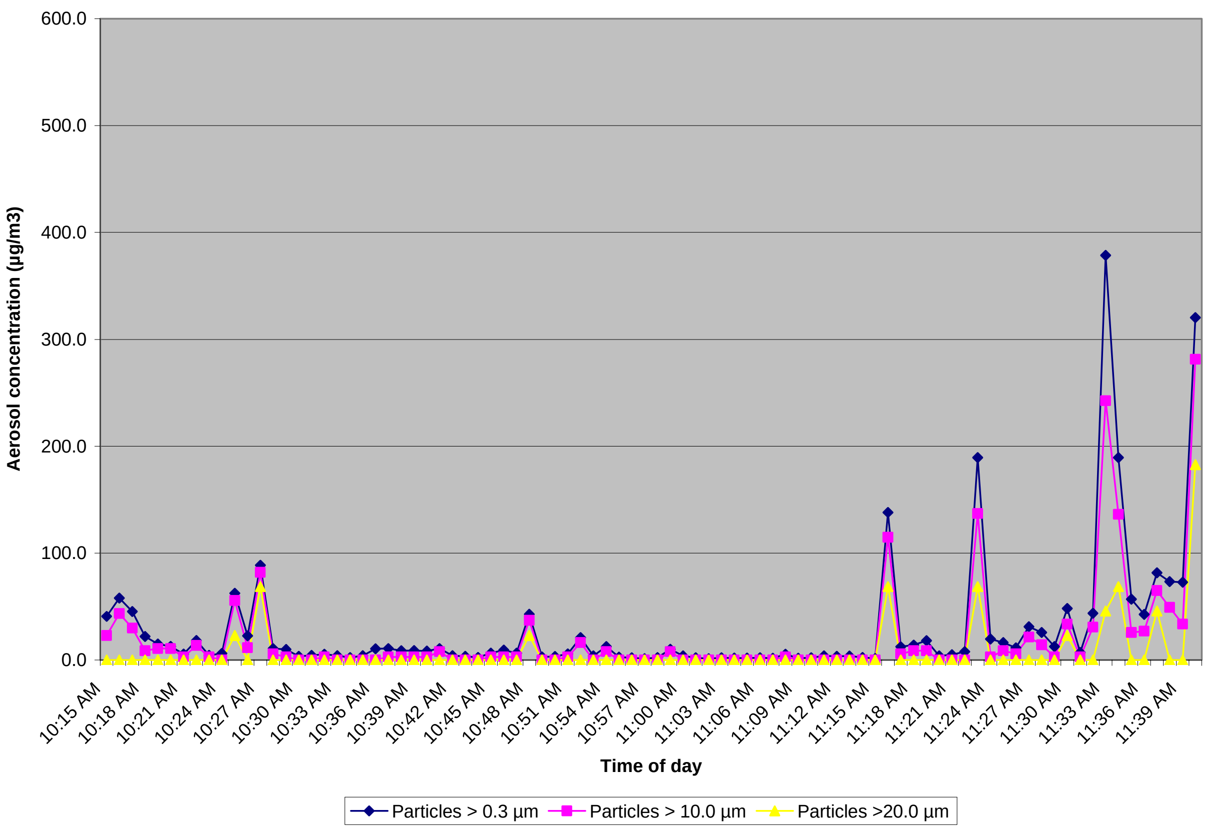


Times of note:

8:00 AM Surgeon enters OR to begin surgery
9:25 AM Surgeon leaves OR after surgery

Geometric mean concentration of particles less than 10 µm: 9.9 µg/m^3
Geometric standard deviation: 2.0

Figure 2. Particulate concentrations, Mastectomy 1
HETA 2001-0066-3019 Morton Plant Hospital
May 9, 2001

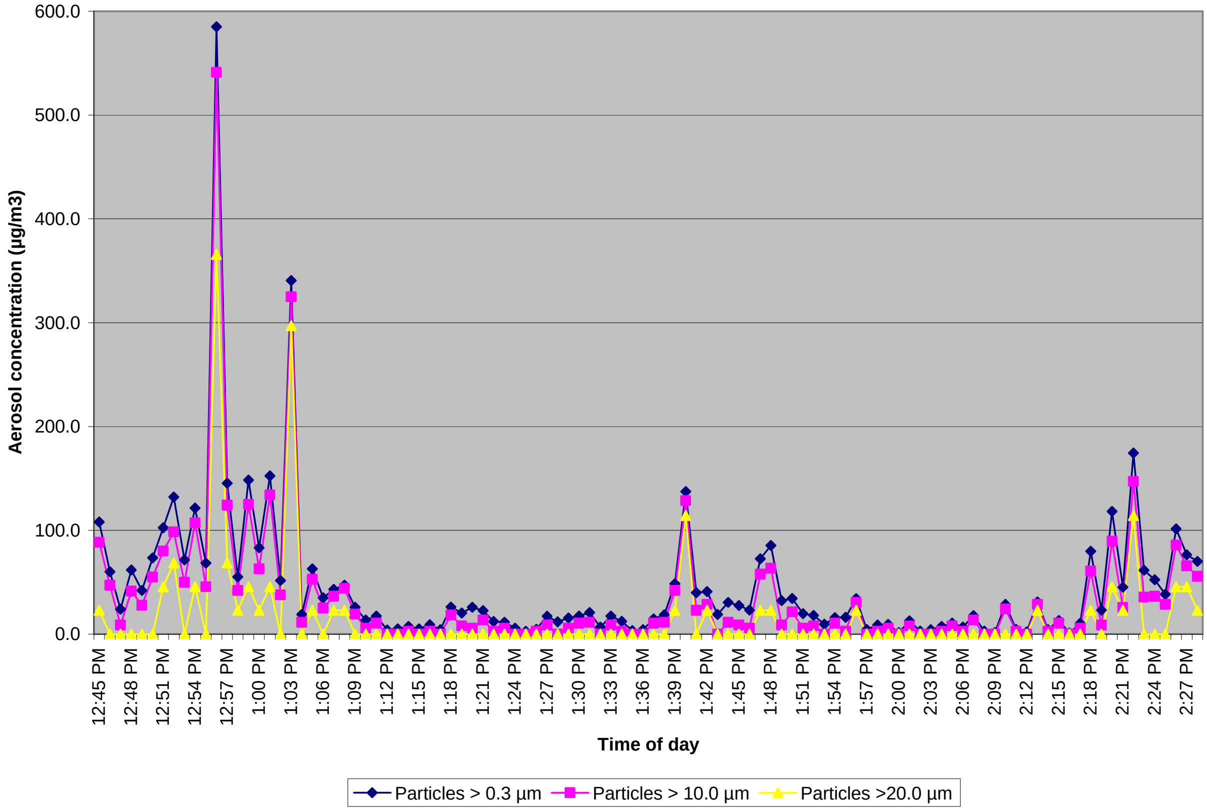


Times of note:

10:20 AM Surgeon enters OR to begin surgery
11:23 AM Surgeon leaves OR after surgery

Geometric mean concentration of particles less than 10 µm: 5.5 µg/m^3
Geometric standard deviation: 2.6

Figure 3. Particulate concentrations, Mastectomy 2
HETA 2001-0066-3019 Morton Plant Hospital
May 9, 2001

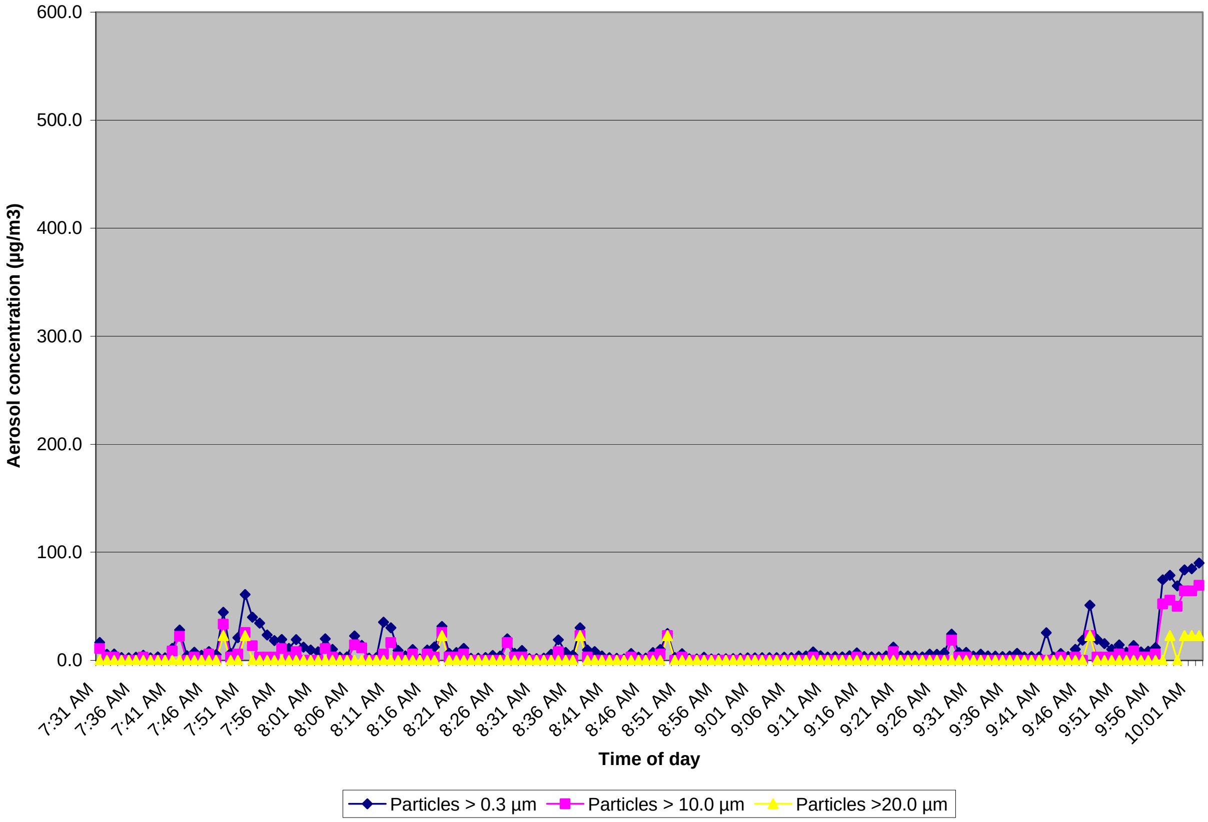


Times of note:

12:53 PM Surgeon enters OR to begin surgery
2:06 PM Surgeon leaves OR after surgery

Geometric mean concentration of particles less than 10 µm: 8.4µg/m^3
Geometric standard deviation: 2.2

Figure 4. Particulate concentrations, Takedown Colostomy
HETA 2001-0066-3019 Morton Plant Hospital
May 10, 2001

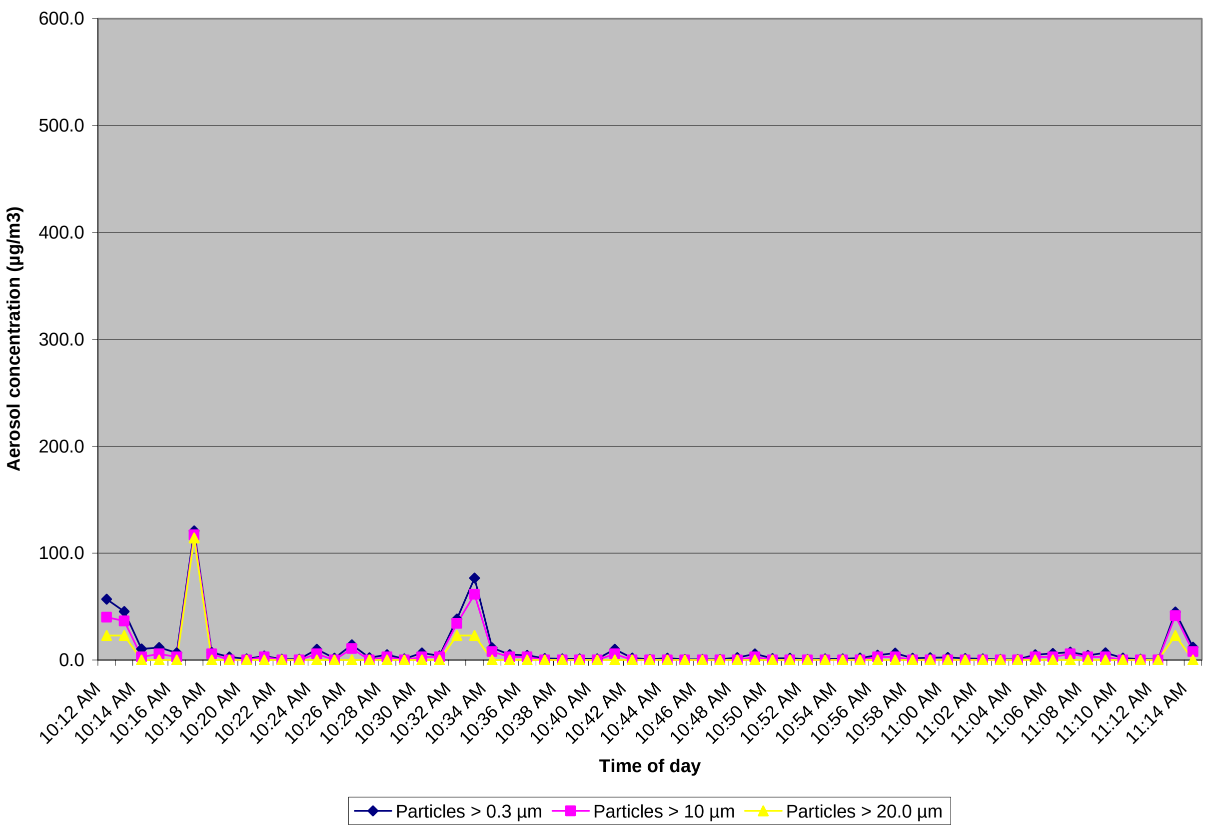


Times of note:

7:36 AM Surgeon enters OR to begin surgery
9:46 AM Surgeon leaves OR after surgery

Geometric mean concentration of particles less than 10 µm: 4.7 µg/m^3
Geometric standard deviation: 2.1

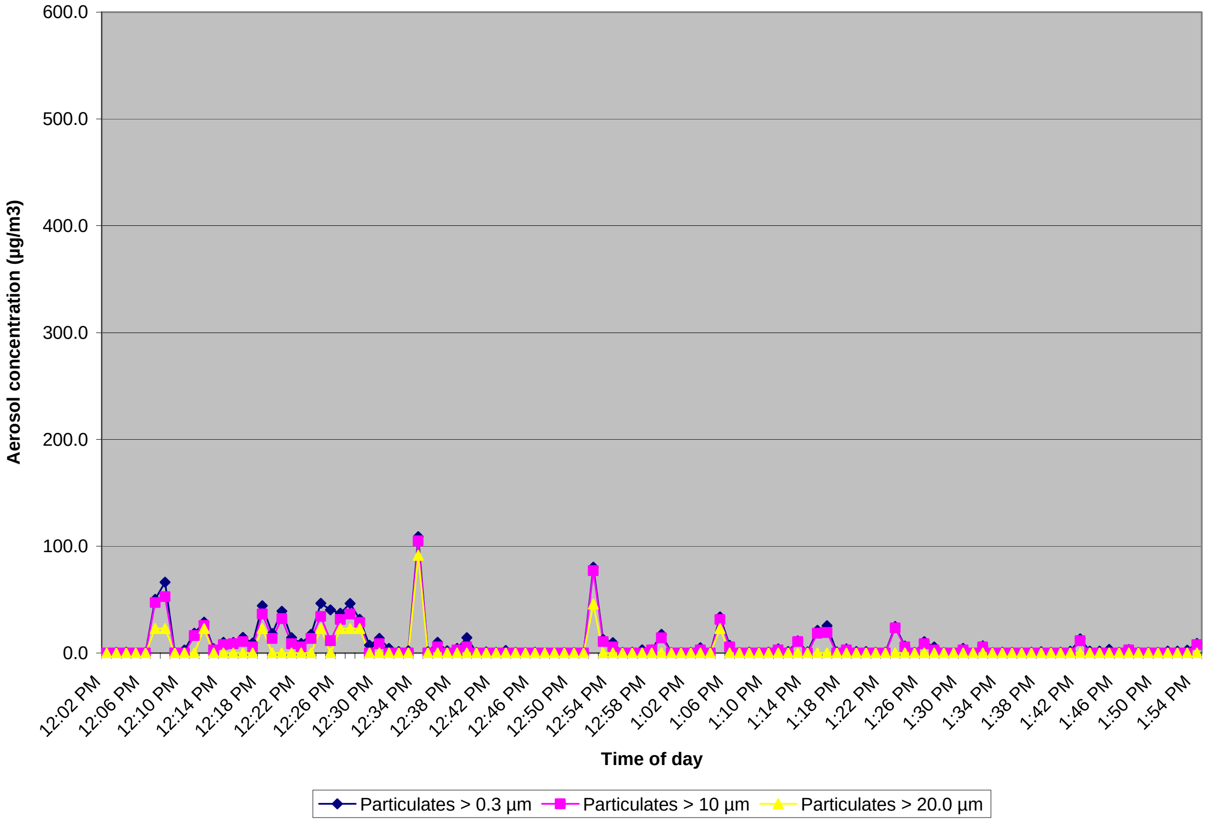
Figure 5. Particulate concentrations, Shoulder Bankhart Repair
HETA 2001-0066-3019 Morton Plant Hospital
May 10, 2001



Times of note:
10:16 AM Surgeon enters OR to begin surgery
11:12 AM Surgeon leaves OR after surgery

Geometric mean concentration of particles less than 10 µm: 1.8 µg/m^3
Geometric standard deviation: 2.3

Figure 6. Particulate concentrations, Total Hip Replacement
HETA 2001-0066-3019 Morton Plant Hospital
May 10, 2001



Times of note:

12:18 PM Surgeon enters OR to begin surgery
1:46 PM Surgeon leaves OR after surgery

Geometric mean concentration of particles less than 10 µm: 1.3 µg/m^3
Geometric standard deviation: 2.9

Appendix A. NIOSH Hazard Control Document: Control of Smoke from Laser/Electric Surgical Procedures

NIOSH HAZARD CONTROLS

HC11

Control of Smoke From Laser/Electric Surgical Procedures

HAZARD

During surgical procedures using a laser or electrosurgical unit, the thermal destruction of tissue creates a smoke byproduct. Research studies have confirmed that this smoke plume can contain toxic gases and vapors such as benzene, hydrogen cyanide, and formaldehyde, bioaerosols, dead and live cellular material (including blood fragments), and viruses. At high concentrations the smoke causes ocular and upper respiratory tract irritation in health care personnel, and creates visual problems for the surgeon. The smoke has unpleasant odors and has been shown to have mutagenic potential.

CONTROLS

NIOSH research has shown airborne contaminants generated by these surgical devices can be effectively controlled. Two methods of control are recommended:

- **VENTILATION**

  Recommended ventilation techniques include a combination of general room and local exhaust ventilation (LEV). General room ventilation is not by itself sufficient to capture contaminants generated at the source. The two major LEV approaches used to reduce surgical smoke levels for health care personnel are portable smoke evacuators and room suction systems.

  Smoke evacuators contain a suction unit (vacuum pump), filter, hose, and an inlet nozzle. The smoke evacuator should have high efficiency in airborne particle reduction and should be used in accordance with the manufacturer's recommendations to achieve maximum efficiency. A capture velocity of about 100 to 150 feet per minute at the inlet nozzle is generally recommended. It is also important to choose a filter that is effective in collecting the contaminants. A High Efficiency Particulate Air (HEPA) filter or equivalent is recommended for trapping particulates. Various filtering and cleaning processes also exist which remove or inactivate airborne gases and vapors. The various filters and absorbers used in smoke evacuators require monitoring and replacement on a regular basis and are considered a possible biohazard requiring proper disposal.

  Room suction systems can pull at a much lower rate and were designed primarily to capture liquids rather than particulate or gases. If these systems are used to capture generated smoke, users must install appropriate filters in the line, insure that the line is cleared, and that filters are disposed properly. Generally speaking, the use of smoke evacuators are more effective than room suction systems to control the generated smoke from nonendoscopic laser/electric surgical procedures.

• **WORK PRACTICES**

The smoke evacuator or room suction hose nozzle inlet must be kept within 2 inches of the surgical site to effectively capture airborne contaminants generated by these surgical devices. The smoke evacuator should be ON (activated) at all times when airborne particles are produced during all surgical or other procedures. At the completion of the procedure all tubing, filters, and absorbers must be considered infectious waste and be disposed appropriately. New filters and tubing should be installed on the smoke evacuator for each procedure. While there are many commercially available smoke evacuator systems to select from, all of these LEV systems must be regularly inspected and maintained to prevent possible leaks. Users shall also utilize control measures such as "universal precautions," as required by the OSHA Blood-Borne Pathogen standard.

For More Information

To obtain more information about controlling this hazard, or for information on other occupational health and safety issues, call the National Institute for Occupational Safety and Health (NIOSH)* at: 1-800-35-NIOSH (1-800-356-4674)

The following reports on this topic are available free upon request from NIOSH:

- Evaluation of a Smoke Evacuator Used for Laser Surgery, Lasers Surg Med 9:276 281 (1989)
- NIOSH Health Hazard Evaluation and Technical Assistance Reports, HETA 85-126-1932 (1988) and HETA 88-101-2008 (1990).

NIOSH is the Federal agency responsible for conducting research and making recommendations for preventing work-related illness and injuries. HAZARD CONTROLS are based on research studies that show reduced worker exposure to hazardous agents or activities.

Acknowledgments

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