



NIOSH HEALTH HAZARD EVALUATION REPORT

**HETA #2000-0402-3021
Inova Fairfax Hospital
Falls Church, Virginia**

November 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 Kristin Gwin and Rob McCleery. 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.

Copies of this report have been sent to employee and management representatives at Inova Fairfax Hospital and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. The report may be viewed and printed from the following internet address: <http://www.cdc.gov/niosh/hhe>. Copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161.

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 confidential employee request for a health hazard evaluation (HHE) at Inova Fairfax Hospital in Falls Church, Virginia. This request noted that employees had concerns regarding the health effects of exposure to 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 be present in the air.
- Levels of these compounds were below the relevant criteria for occupational exposure.
- Of the employees surveyed, 52% reported at least one symptom that they associated with surgical smoke exposure.
- Forty-two percent of employees described irritation of their eyes and upper respiratory tract after surgical smoke exposure.

- Sixty-seven percent of employees reported annoyance with the odor from the surgical smoke.

What Inova Fairfax 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 Inova Fairfax 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.



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 #2000-0402-3021



**Health Hazard Evaluation Report 2000-0402-3021
Inova Fairfax Hospital
Falls Church, Virginia
November 2006**

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SUMMARY

On August 21, 2000, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation at Inova Fairfax Hospital in Falls Church, Virginia. The request noted concerns from surgery department employees in regard to exposure to compounds found in surgical smoke and respiratory symptoms and headaches thought to be associated with such exposure.

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 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 compounds 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, greater than 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.

Table of Contents

Preface.....	ii
Acknowledgments and Availability of Report.....	ii
Highlights of Health Hazard Evaluation	iii
Summary.....	iv
Introduction.....	1
Background	1
Methods.....	1
Medical.....	1
Industrial Hygiene	1
Evaluation Criteria	3
Surgical Smoke.....	4
Volatile Organic Compounds.....	4
Benzene	4
Toluene.....	5
Xylene.....	5
Aldehydes.....	5
Formaldehyde.....	5
Acetaldehyde	6
Acrylaldehyde (Acrolein)	6
Polycyclic Aromatic Compounds.....	6
Cresols.....	7
Phenol.....	7
Hydrogen Cyanide	7
Carbon Monoxide	7
Particulates	7
Results	8
Medical.....	8
Industrial Hygiene	8
Discussion and Conclusions	9
Recommendations	10
References.....	10

INTRODUCTION

On August 21, 2000, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation (HHE) at Inova Fairfax Hospital in Falls Church, Virginia. The request noted concerns from surgery department employees in regard to exposure to chemical compounds in surgical smoke as well as reports of respiratory illness and headaches.

On March 8-9, 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 21-25, 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 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 Inova Fairfax Hospital management and employee representatives on December 14, 2001.

BACKGROUND

Inova Fairfax Hospital is a 753-bed regional medical center in Falls Church, Virginia, serving the Washington, DC metropolitan area. The hospital is a medical and nursing teaching hospital affiliated with the medical schools of Georgetown and George Washington

Universities and the Medical College of Virginia. Multiple operating room units exist at the hospital. The NIOSH investigators focused on a main surgical suite containing 14 operating rooms (ORs), including two specifically for urology procedures.

METHODS

Medical

A one-page self-administered questionnaire was distributed to 50 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 a variety of 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 22, 2001, sampling was performed during five procedures. These included a mastectomy, a cystoscopy-transurethral resection of the prostate (TURP), a prostatectomy, a body cast replacement for scoliosis, and a spinal fusion. On May 23, 2001,

five surgical procedures were sampled: a lumbar decompression, two lumbar laminectomies, a breast tissue expander insertion, and a thyroidectomy. Four surgical procedures were sampled on May 24, 2001. These included a cystoscopy-TURP, a small bowel resection, and two mastectomies.

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 connected 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 Analytic 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).

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, 14 area air samples and 27 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 the 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 4 μg total hydrocarbons/sample. The limits of quantitation (LOQ) were 1 μg benzene/sample, 1 μg toluene/sample, 8 μg xylene/sample, and 10 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 14 area air samples were collected for aldehydes. Analysis of the cartridges was performed according to NIOSH Method 2016 with modifications. The LODs were 0.02 μg formaldehyde/sample and 0.03 μg acetaldehyde/sample. The LOQs were 0.08 μg formaldehyde/sample and 0.1 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. The LOD for acrolein was 0.8 $\mu\text{g}/\text{sample}$; the LOQ was 3 $\mu\text{g}/\text{sample}$.

Fourteen area air samples were collected for polycyclic aromatic compounds 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 samples was conducted using fluorescence detection according to NIOSH Method 5800. The LOD and LOQ were 3 $\mu\text{g}/\text{sample}$ and 10 $\mu\text{g}/\text{sample}$, respectively.

Fourteen area air samples were collected 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 samples was conducted using gas chromatography with flame ionization detection according to NIOSH Method 2546. The LODs were 1 µg cresols/sample and 0.8 µg phenol/sample. The LOQs were 4 µg cresols/sample and 3 µg phenol/sample.

Fourteen area air samples were collected 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 the samples was conducted using spectrophotometry according to NIOSH Method 6010 with modifications. The LODs and LOQ were 0.2 µg/sample and 0.7 µg/sample, respectively.

Area air sampling was performed according to NMAM Method 6604 for carbon monoxide (CO) using the Biosystems Inc. ToxiUltra Gas Detector, a passive diffusion monitor, which recorded CO concentrations during each procedure. 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 increase 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 subtilis* and *Staphylococcus aureus*. Mycobacteria have also been isolated in smoke, including *Mycobacterium tuberculosis*.⁷ Human immunodeficiency virus (HIV) proviral DNA and intact viral DNA from the human papilloma virus have been found in plumes produced by lasers.^{8,9} Other biological materials collected from surgical smoke include intact and fragmented human cells and intact DNA.^{10,11} In addition to biological material, chemical by-products 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. 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.

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. NIOSH further recommends a 15-minute STEL of 1.0 ppm. 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 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. The OSHA PEL is 1 ppm for an 8-hour TWA with a 15-minute STEL of 5 ppm.¹⁶

Toluene

Toluene is a colorless, aromatic organic liquid containing a six-carbon ring (a benzene ring) with a methyl group (CH₃) 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. 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 up to a 10-hour TWA. NIOSH has also set a recommended STEL of 150 ppm for a 15-minute sampling period. The ACGIH TLV is 50 ppm for an 8-hour TWA, with a Notice of Intended Changes to 20 ppm. The OSHA PEL for toluene is 200 ppm for an 8-hour TWA.

Xylene

Xylene is a colorless, flammable organic liquid with a molecular structure consisting of a benzene ring with two methyl group (CH₃) 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, uncoordination, drowsiness, and unconsciousness.²¹ Previous studies have shown that concentrations from 60 to 350 ppm may cause giddiness, anorexia, and vomiting. 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, OSHA and NIOSH 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 suspected human carcinogen and has set a 10-hour REL of 0.016 ppm with a 15-minute ceiling limit of 0.1 ppm. 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.” ACGIH has set a ceiling limit of 0.3 ppm.

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, the 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. 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.

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 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 concentrations (TC_{LO}) for human responses to acrolein are 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. The OSHA PEL for acrolein is a TWA of 0.1 ppm. The NIOSH REL is also a TWA of 0.1 ppm, with a 15-minute STEL of 0.3 ppm. The ACGIH TLV of 0.1 ppm is a ceiling limit that should not be surpassed during the work shift.

Polycyclic Aromatic Compounds

Polycyclic aromatic compounds (PACs) refer to a set of cyclic organic compounds that includes 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. 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. 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. Repeated or prolonged exposure may cause gastrointestinal disturbances (vomiting, loss of appetite), nervous disorders, headache, dizziness, and dermatitis. The odor of cresol is recognized at concentrations as low as 5 ppm. The ACGIH TLV was set at 5 ppm to prevent irritation. The NIOSH REL is a TWA of 2.3 ppm. The OSHA PEL is a TWA of 5 ppm.

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. 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. 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. Little monitoring data for airborne cyanides in the ambient environment is available.

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

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. The NIOSH REL for carbon monoxide is 35 ppm for a 10-hour TWA. NIOSH also recommends a ceiling limit of 200 ppm that should not be exceeded at any time during the workday. The OSHA PEL for carbon monoxide is 50 ppm for an 8-hour TWA. The ACGIH TLV for carbon monoxide is 25 ppm as an 8-hour TWA.

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

Thirty-three employees completed the questionnaire, a participation rate of approximately 66%. The participants included 21 surgical nurses (63.6%), 10 surgical technicians (30.3%), and 2 nurse anesthetists (6.0%). The average age of the participants was 41.9 years. The average time spent working in ORs at Inova Fairfax Hospital was 9.9 years, and average total time working in ORs during their careers was 14.7 years.

Seventeen participants (51.5%) reported on the questionnaire 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 4 weeks: 8 individuals (24.2%) reported eye irritation, 6 (18.2%) reported burning of nose or throat, 7 (21.2%) reported headache, 8 (24.2%) reported coughing, and 1 (3.0%) reported nasal congestion or runny nose. Six employees (18.2%) reported that they had been diagnosed with asthma by a physician and 8 (24.2%) developed asthma or asthma-like symptoms after they began working in ORs. (Asthma-like

symptoms were defined as having two or more of the following symptoms: wheeze, shortness of breath, chest tightness, and coughing attacks.) Among these individuals, two never smoked cigarettes, five were former smokers, and one was a current smoker.

A total of 22 participants (66.7%) reported annoyance with the odor from the surgical smoke.

Twelve participants (36.4%) 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 generally reported more symptoms than participants who worked 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 certain procedures ranged from non-detectable to 0.017 ppm. However, area and PBZ samples taken during a body-cast replacement procedure where no electrocautery knife was used and no surgical smoke was produced revealed a concentration of 0.010 ppm.

Acetaldehyde concentrations ranged from non-detectable to 0.014 ppm for the procedures sampled. These measured TWA exposure levels are considerably lower than the OSHA PEL of 200 ppm. NIOSH recommends keeping levels of acetaldehyde to the lowest feasible concentration.

Toluene concentrations in the air ranged from 0.03 ppm to 0.46 ppm. The TWA concentrations during the procedures sampled were well below all applicable exposure limits, including the 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 Dust Monitor was used to record the levels of airborne particulates in the operating room environment during various surgical procedures. Figures 1 through 8 present graphical representations of the real-time data collected with the Grimm particle counter over the complete period of each surgical procedure. Overall, the highest peaks were recorded during the lumbar decompression and cystoscopy-TURP. Very few 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. The geometric mean concentrations of particles less than 10 μm ranged from 0.7 $\mu\text{g}/\text{m}^3$ to 21 $\mu\text{g}/\text{m}^3$ depending on the surgical procedure, as described in Figures 1-8.

DISCUSSION AND CONCLUSIONS

Results from the questionnaire show that many employees associate exposure to surgical smoke with at least one or more health symptoms (eye and upper respiratory tract irritation, in particular) that they have experienced at work. Even more complain of the smell or odor of the smoke. Generally, individuals who had more concentrated exposure to surgical smoke reported more symptoms, although many individuals with less exposure also reported irritative symptoms. The development of symptoms after beginning work in ORs and subsequent exposure to surgical smoke is important as it suggests a potential causative factor. Despite this anecdotal information, it is unclear whether these symptoms were necessarily related to surgical smoke exposure.

The industrial hygiene results found quantifiable airborne concentrations of formaldehyde, acetaldehyde, and toluene. No quantifiable substances other than those were found in the ORs. The measurable compounds were also documented to be present in control

(background) samples taken in an OR where a procedure without any smoke production was occurring (i.e., body cast replacement). 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 increases during use of the electrocautery unit. Oftentimes, spikes in concentration were seen before (or at the very beginning of) the operation as well as 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 operating room may be a potential factor in these spikes. 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 to chemical compounds 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 surgical 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 and LEV as close as possible to the point of smoke production.

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

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**Table 1. Personal breathing zone and area air sampling results, by surgical procedure
May 22, 2001 Inova Fairfax Hospital
HETA 2000-0402-3021**

Procedure	Worker or Location Sampled	Formaldehyde Concentration (ppm)*	Acetaldehyde Concentration (ppm)	Toluene Concentration (ppm)
<i>mastectomy</i>	assistant surgeon	0.005	0.003	--**
<i>mastectomy</i>	scrub nurse	0.005	0.002	--
<i>mastectomy</i>	area sample	0.003	0.001	0.24
<i>mastectomy</i>	surgeon	--	--	0.17
<i>mastectomy</i>	circulating nurse	--	--	0.05
<i>cystoscopy-TURP</i>	nurse anesthetist	0.004	0.001	--
<i>cystoscopy-TURP</i>	assistant surgeon	0.006	0.001	--
<i>cystoscopy-TURP</i>	area sample	0.004	0.001	0.20
<i>cystoscopy-TURP</i>	circulating nurse	--	--	0.18
<i>cystoscopy-TURP</i>	surgeon	--	--	0.20
<i>prostatectomy</i>	nurse anesthetist	0.004	0.002	--
<i>prostatectomy</i>	circulating nurse	0.005	0.002	--
<i>prostatectomy</i>	area sample	0.005	0.002	0.14
<i>prostatectomy</i>	scrub nurse	--	--	0.08
<i>prostatectomy</i>	surgeon	--	--	0.16
<i>body cast replacement</i>	circulating nurse	0.010	0.003	--
<i>body cast replacement</i>	assistant surgeon	0.010	0.004	--
<i>body cast replacement</i>	area sample	0.010	0.004	0.20
<i>body cast replacement</i>	surgeon	--	--	0.14
<i>spinal fusion</i>	scrub nurse	0.010	0.006	--
<i>spinal fusion</i>	area sample	0.010	0.005	0.09
<i>spinal fusion</i>	circulating nurse	--	--	0.12
<i>spinal fusion</i>	assistant surgeon	--	--	0.12
	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
May 23, 2001 Inova Fairfax Hospital
HETA 2000-0402-3021**

Procedure	Worker or Location Sampled	Formaldehyde Concentration (ppm)*	Acetaldehyde Concentration (ppm)	Toluene Concentration (ppm)
<i>lumbar decompression</i>	circulating nurse	0.003	0.001	--**
<i>lumbar decompression</i>	scrub nurse	ND [^]	ND	--
<i>lumbar decompression</i>	area sample	0.003	0.001	0.41
<i>lumbar decompression</i>	nurse anesthetist	--	--	0.44
<i>lumbar decompression</i>	assistant surgeon	--	--	0.46
<i>lumbar laminectomy</i>	scrub nurse	0.004	0.001	--
<i>lumbar laminectomy</i>	circulating nurse	0.002	0.001	--
<i>lumbar laminectomy</i>	area sample	0.002	0.001	0.40
<i>lumbar laminectomy</i>	surgeon	--	--	0.27
<i>lumbar laminectomy</i>	nurse anesthetist	--	--	0.27
<i>breast tissue expander</i>	nurse anesthetist	0.004	0.004	--
<i>breast tissue expander</i>	scrub nurse	0.004	0.003	--
<i>breast tissue expander</i>	area sample	0.004	0.003	0.17
<i>breast tissue expander</i>	circulating nurse	--	--	0.11
<i>breast tissue expander</i>	surgeon	--	--	0.19
<i>lumbar laminectomy</i>	nurse anesthetist	0.003	0.001	--
<i>lumbar laminectomy</i>	area sample	0.003	0.001	0.21
<i>lumbar laminectomy</i>	circulating nurse	--	--	0.19
<i>lumbar laminectomy</i>	scrub nurse	--	--	0.22
<i>thyroidectomy</i>	assistant surgeon	0.004	0.002	--
<i>thyroidectomy</i>	area sample	0.003	0.001	0.15
<i>thyroidectomy</i>	circulating nurse	--	--	0.16
<i>thyroidectomy</i>	surgeon	--	--	0.09
	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

[^] ND = a result of non-detected for that sample taken

[†] C = a ceiling exposure limit recommended not to be exceeded during any part of the working shift

[‡] LFC = lowest feasible concentration

**Table 3. Personal breathing zone and area air sampling results, by surgical procedure
May 24, 2001 Inova Fairfax Hospital
HETA 2000-0402-3021**

Procedure	Worker or Location Sampled	Formaldehyde Concentration (ppm)*	Acetaldehyde Concentration (ppm)	Toluene Concentration (ppm)
<i>cysto-TURP</i>	circulating nurse	0.015	0.002	--**
<i>cysto-TURP</i>	nurse anesthetist	0.005	0.002	--
<i>cysto-TURP</i>	area sample	0.005	0.002	0.03
<i>cysto-TURP</i>	assistant surgeon	--	--	0.20
<i>cysto-TURP</i>	surgeon	--	--	0.18
<i>small bowel resection</i>	assistant surgeon	0.006	0.002	--
<i>small bowel resection</i>	scrub nurse	0.006	0.002	--
<i>small bowel resection</i>	area sample	0.005	0.002	0.10
<i>small bowel resection</i>	circulating nurse	--	--	0.14
<i>small bowel resection</i>	surgeon	--	--	0.14
<i>mastectomy</i>	nurse anesthetist	0.005	0.002	--
<i>mastectomy</i>	attending surgeon	0.013	0.014	--
<i>mastectomy</i>	area sample	0.004	0.002	0.07
<i>mastectomy</i>	plastic surgeon	--	--	0.06
<i>mastectomy</i>	circulating nurse	--	--	0.11
<i>biopsy and mastectomy</i>	surgeon	0.017	0.002	--
<i>biopsy and mastectomy</i>	circulating nurse	0.006	0.002	--
<i>biopsy and mastectomy</i>	area sample	0.005	0.002	0.16
<i>biopsy and mastectomy</i>	nurse anesthetist	--	--	0.18
<i>biopsy and mastectomy</i>	scrub nurse	--	--	0.13
	NIOSH REL	0.016	LFC‡	100
	OSHA PEL	0.750	200	200
	ACGIH TLV	(C† 0.30)	(C 25)	50

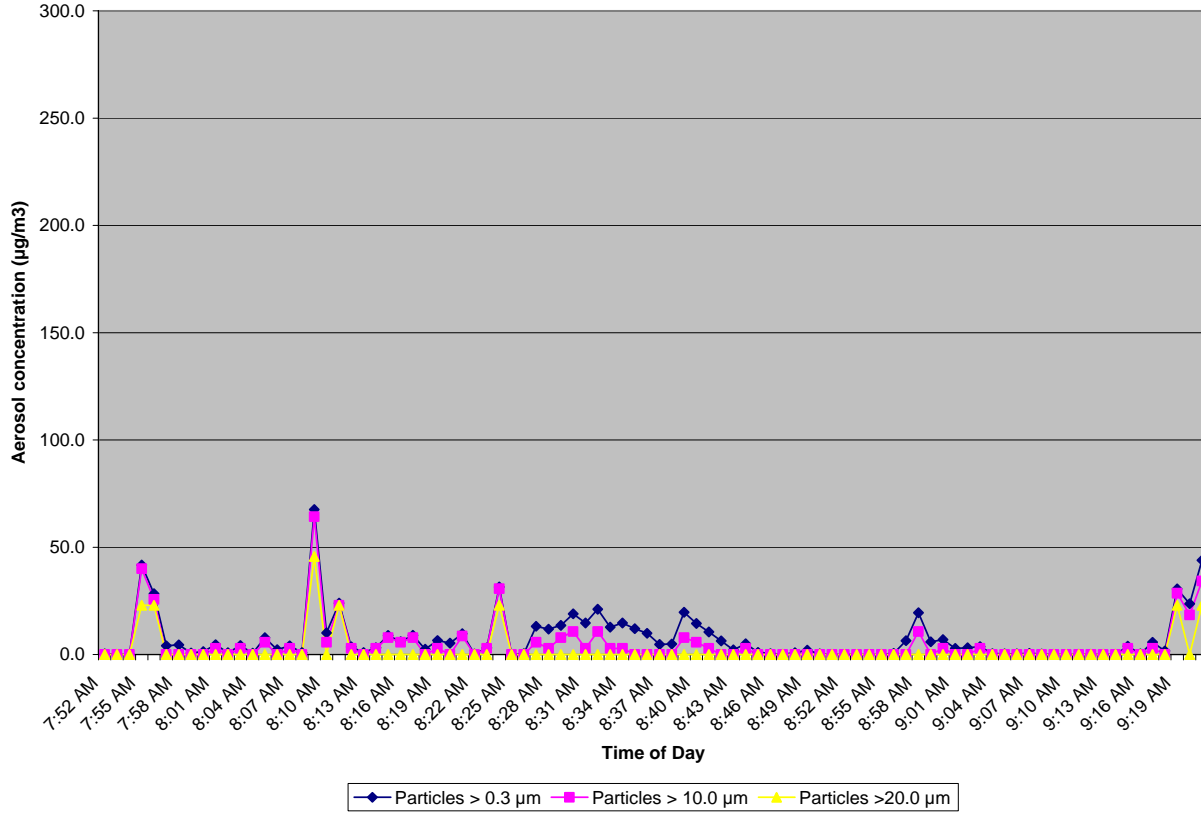
* ppm = parts per million

** 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, mastectomy
 May 22, 2001 Inova Fairfax Hospital
 HETA 2000-0402-3021**



Times of note:

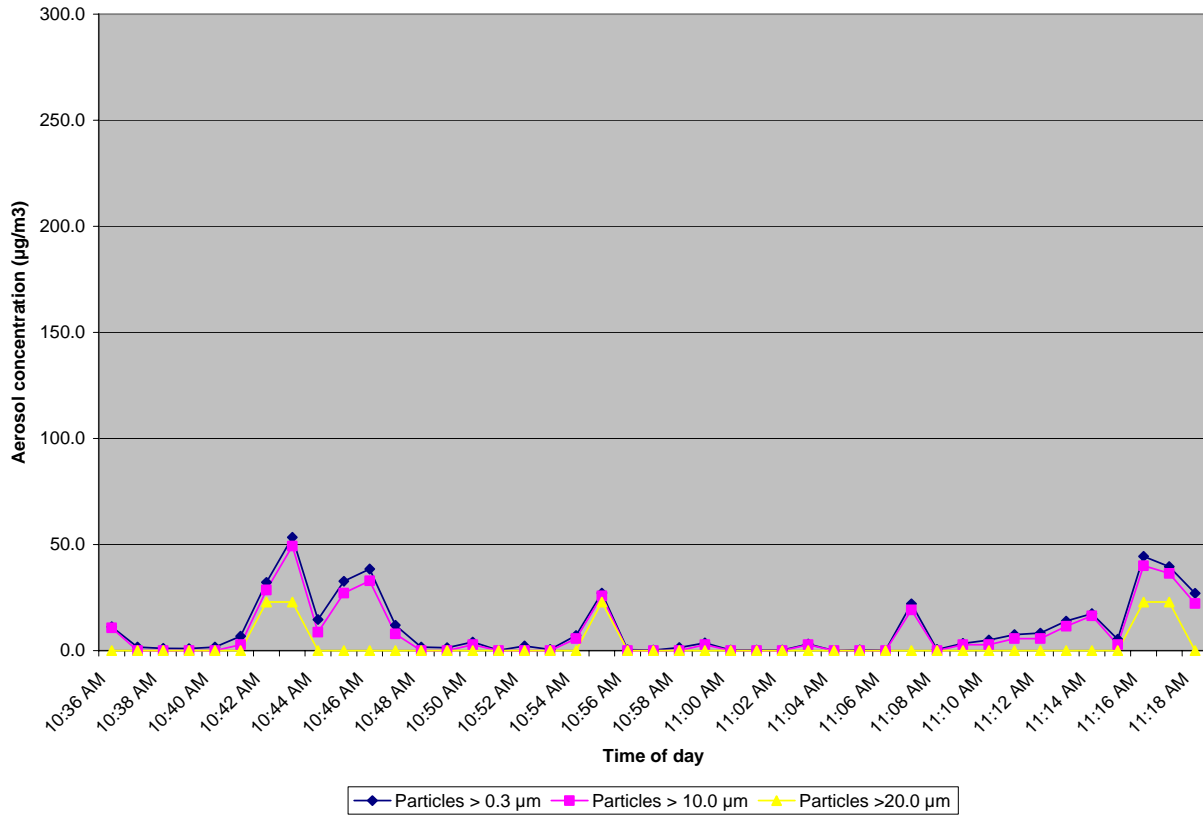
8:13 AM Surgeon enters OR

9:13 AM Surgeon leaves OR

Geometric mean concentration of particles less than 10 μm : 1.3 $\mu\text{g}/\text{m}^3$

Geometric standard deviation: 4.3

**Figure 2. Particulate concentrations, TURP
 May 22, 2001 Inova Fairfax Hospital
 HETA 2000-0402-3021**



Times of note:

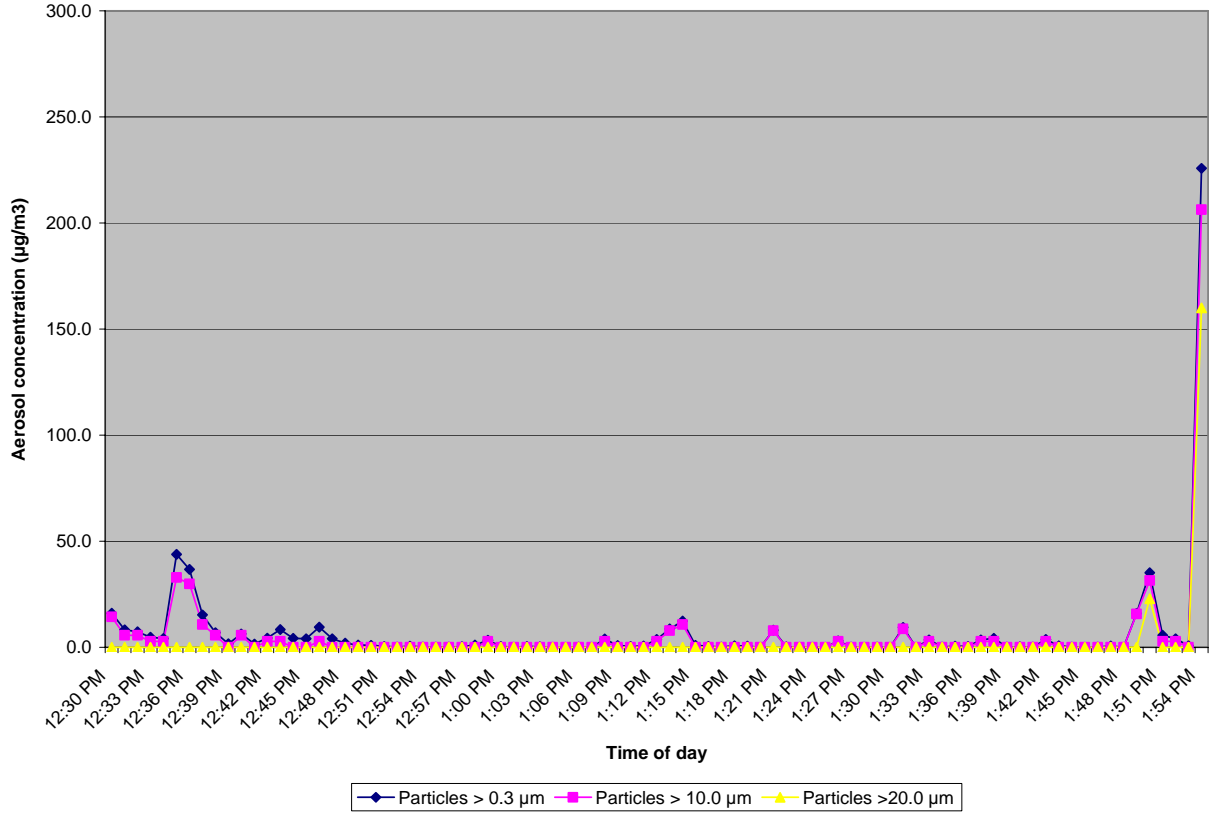
10:43 AM Surgeon enters OR

11:18 AM Surgeon leaves OR

Geometric mean concentration of particles less than 10 µm: 1.2 µg/m³

Geometric standard deviation: 3.1

**Figure 3. Particulate concentrations, Prostatectomy
 May 22, 2001 Inova Fairfax Hospital
 HETA 2000-0402-3021**



Times of note:

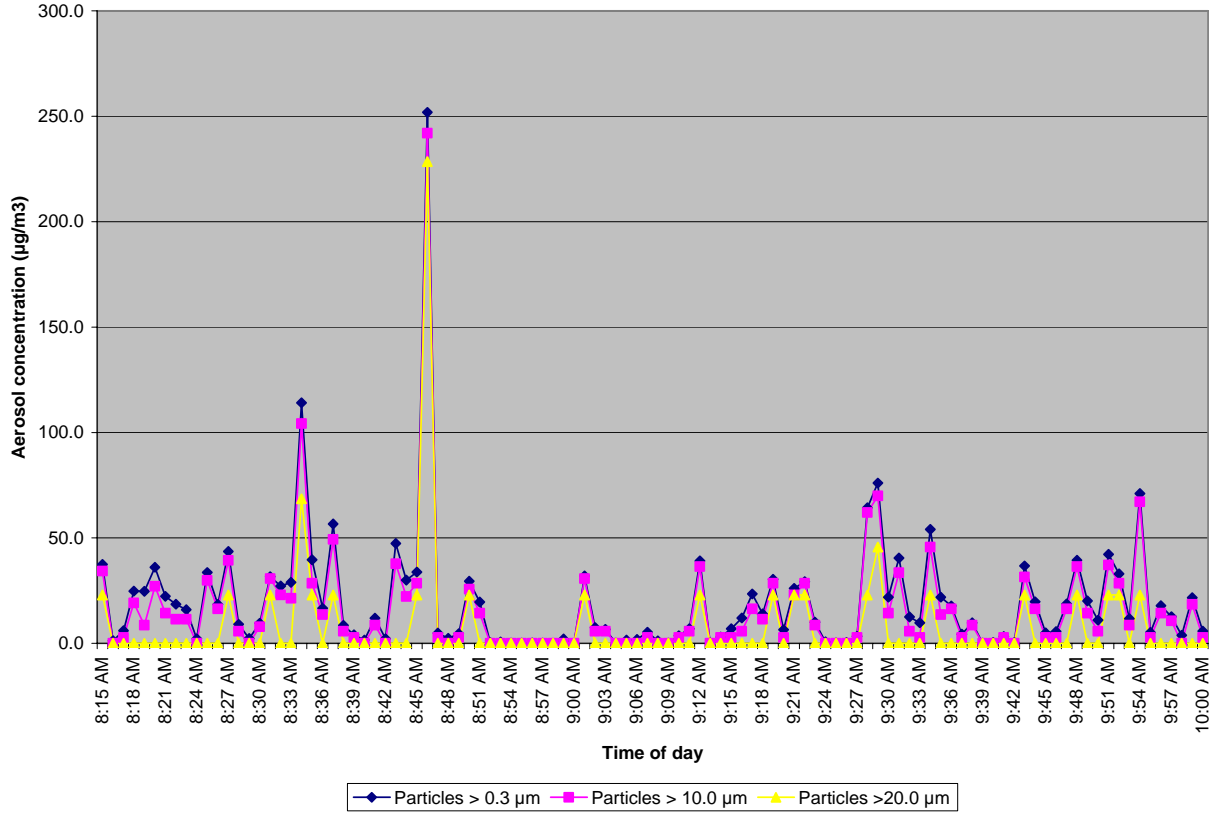
12:35 PM Surgeon enters OR

1:45 PM Surgeon leaves OR

Geometric mean concentration of particles less than 10 µm: 0.7 µg/m³

Geometric standard deviation: 3.3

**Figure 4. Particulate concentrations, Lumbar decompression
 May 23, 2001 Inova Fairfax Hospital
 HETA 2000-0402-3021**



Times of note:

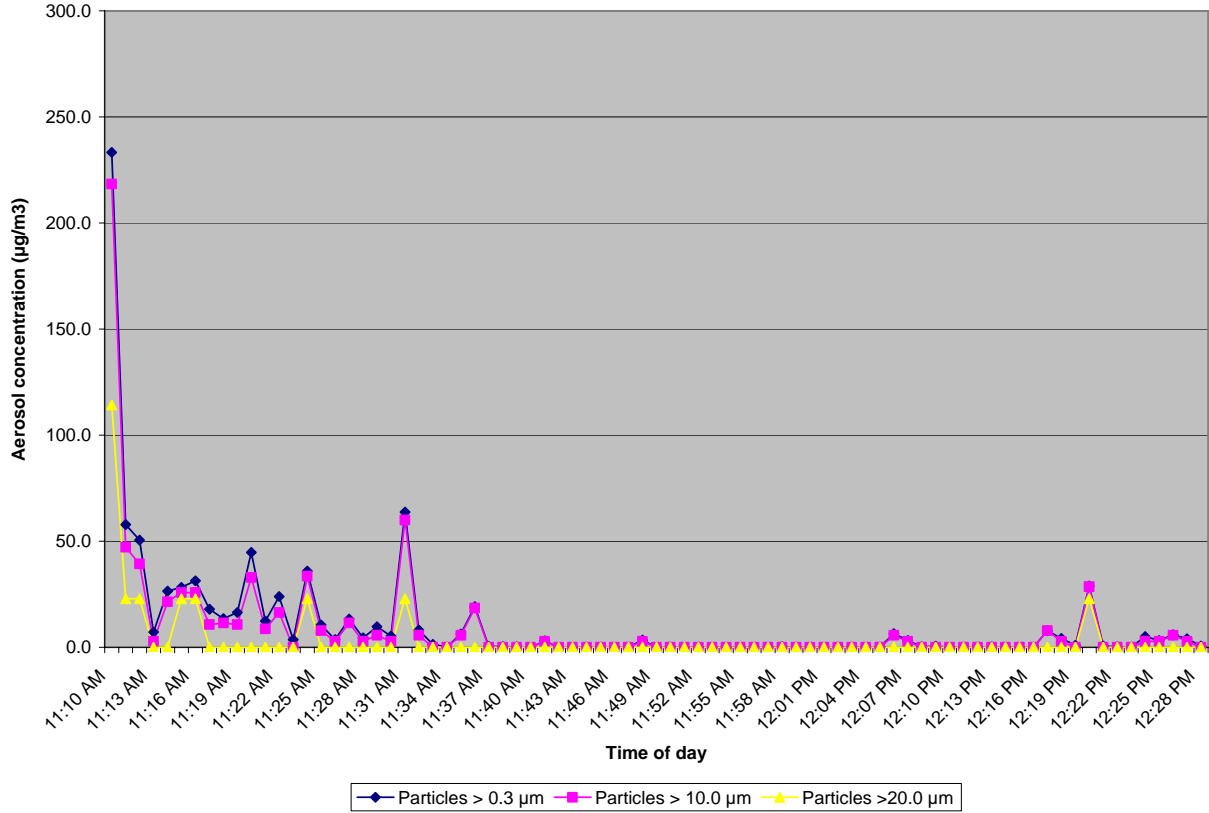
8:33 AM Surgeon enters OR

9:53 AM Surgeon leaves OR

Geometric mean concentration of particles less than 10 µm: 2.0 µg/m³

Geometric standard deviation: 3.3

**Figure 5. Particulate concentrations, Lumbar laminectomy
 May 23, 2001 Inova Fairfax Hospital
 HETA 2000-0402-3021**

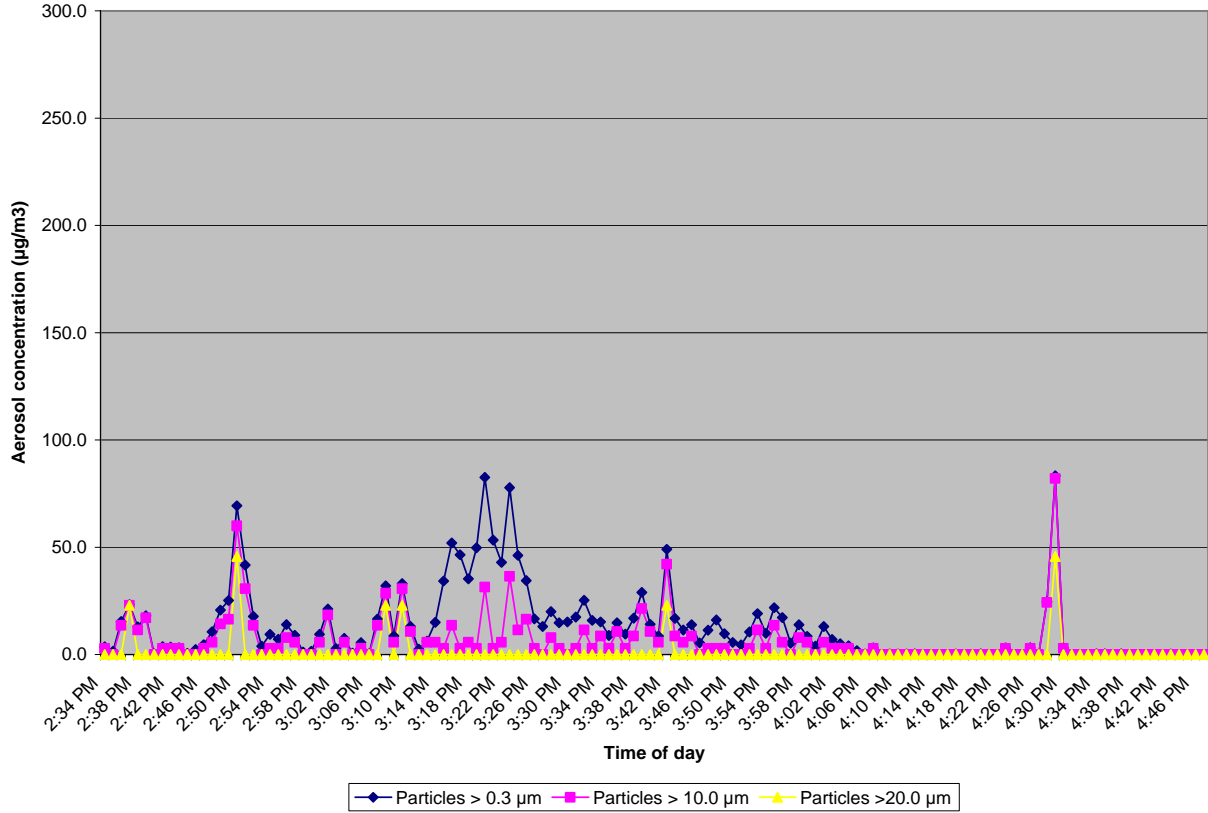


Times of note:

- 11:13 AM Surgeon enters OR
- 12:25 PM Surgeon leaves OR

Geometric mean concentration of particles less than 10 µm: 0.8 µg/m³
 Geometric standard deviation: 4.1

**Figure 6. Particulate concentrations, Breast tissue expander insertion
 May 23, 2001 Inova Fairfax Hospital
 HETA 2000-0402-3021**

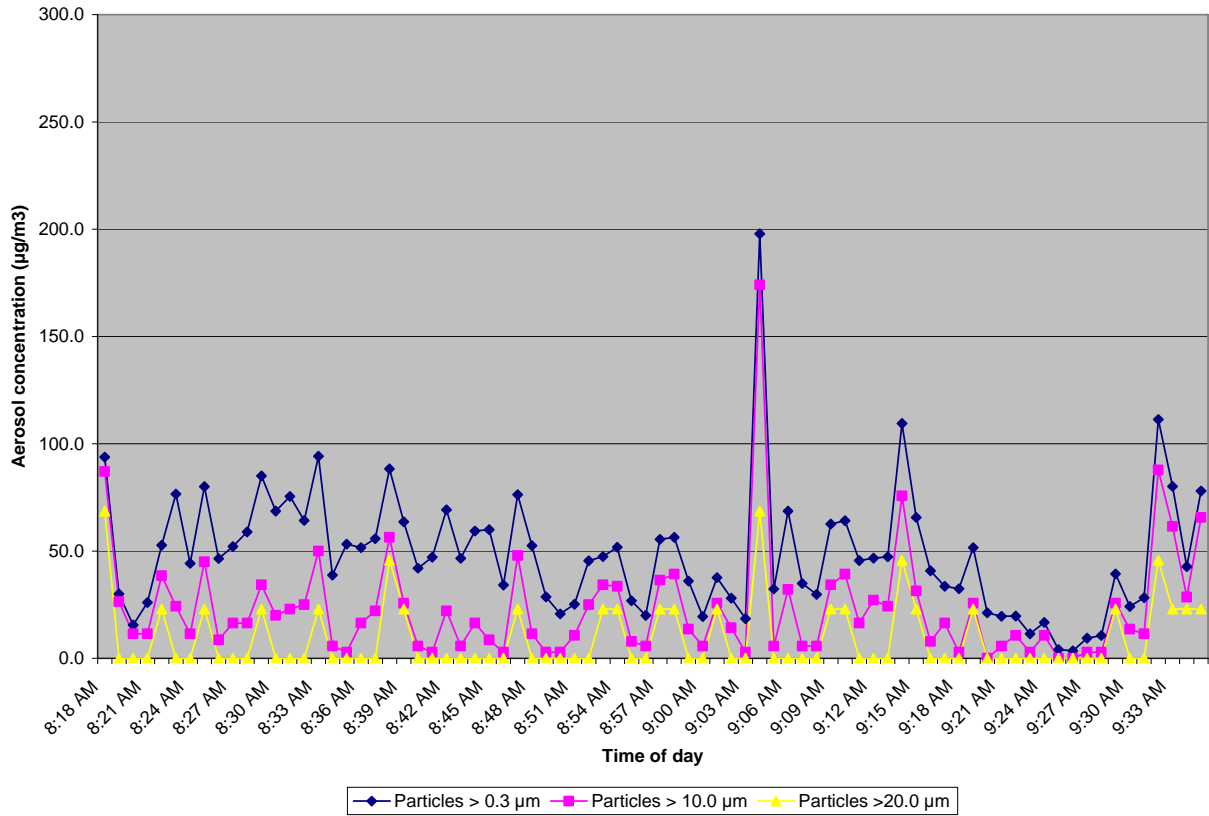


Times of note

- 3:02 PM Surgeon enters OR
- 4:45 PM Surgeon leaves OR

Geometric mean concentration of particles less than 10 μm : 2.1 $\mu\text{g}/\text{m}^3$
 Geometric standard deviation: 5.4

**Figure 7. Particulate concentrations, Cystoscopy-TURP
 May 24, 2001 Inova Fairfax Hospital
 HETA 2000-0402-3021**

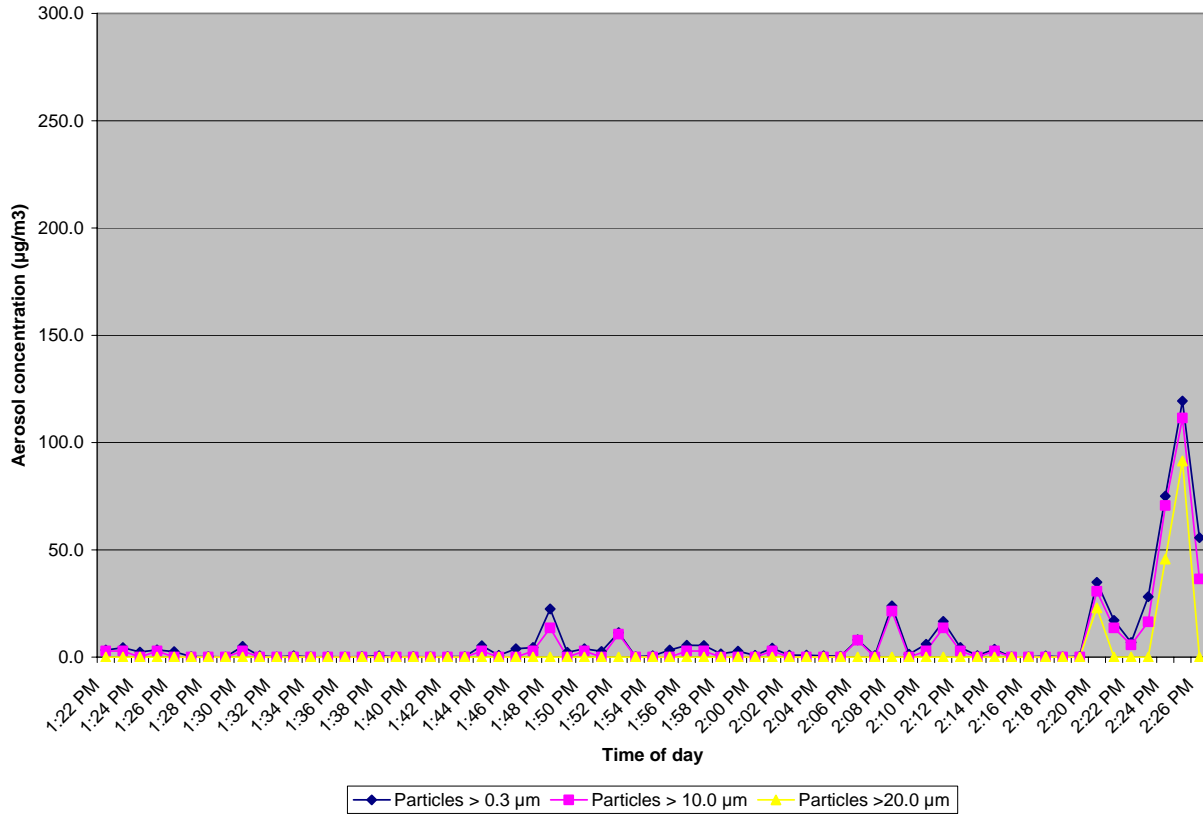


Times of note:

- 8:47 AM Surgeon enters OR
- 9:33 AM Surgeon leaves OR

Geometric mean concentration of particles less than 10 µm: 21 µg/m³
 Geometric standard deviation: 2.0

**Figure 8. Particulate concentrations, Mastectomy
 May 24, 2001 Inova Fairfax Hospital
 HETA 2000-0402-3021**



Times of note:

1:24 PM Surgeon enters OR

2:26 PM Surgeon leaves OR

Geometric mean concentration of particles less than 10 µm: 0.8 µg/m³

Geometric standard deviation: 3.8

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



HC11

Control of Smoke From Laser/Electric Surgical Procedures



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.



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 \(1-800-356-4674\)](tel:1-800-35-NIOSH)

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

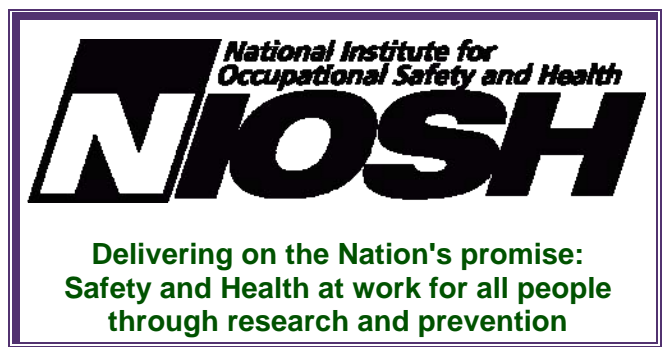
The principal contributor to this HAZARD CONTROLS is C. Eugene Moss, Division of Surveillance, Hazard Evaluations and Field Studies. Assistance was provided by the Education and Information Division, NIOSH.

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