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Los Angeles County Department of Coroner
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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Kenneth F. Martinez and Randy L. Tubbs, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by John Decker. Desktop publishing was performed by Ellen Blythe and Nichole Herbert.

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SUMMARY

On October 25, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request to conduct a health hazard evaluation (HHE) from the office of the Los Angeles County Department of Coroner. Specifically, the request was for NIOSH assistance in evaluating a pneumatic reciprocating saw equipped with local exhaust ventilation (LEV) used for cranial openings during forensic autopsies and examinations. The pneumatic saw was being evaluated by the coroner's office as an alternative to an electrically-driven reciprocating saw. The objective of the NIOSH evaluation was to determine if the alternative reciprocating saw (1) generates less tissue and bone fragment aerosol that could potentially challenge the breathing zone of the operating forensic technician, and (2) reduces the noise exposure to the technician and surrounding personnel.

A site visit was conducted by NIOSH investigators (including two industrial hygienists and a psychoacoustician) on December 13–14, 1995. The investigation was conducted in coordination with the Los Angeles County Health Department who simultaneously collected particulate air samples for microscopic analysis of bone and tissue fragments. The NIOSH investigation included real–time area and personal measurements of airborne particulates and spectral measurements of noise during the conduct of six autopsies (four autopsies for the noise evaluation).

Differences in peak concentrations of airborne particulates measured during autopsies, with and without the aide of local exhaust ventilation (LEV), indicate that LEV significantly reduces the aerosols produced by the reciprocating saws. No short-term, high concentrations of particulates were observed during autopsies utilizing the LEV system. Aerosol concentrations measured during the use of both saws, without LEV, were one to two orders of magnitude over baseline, and personal real–time air samples indicate that these aerosols were present in the breathing zone of the operating technician.

The noise measurements from the two types of reciprocating saws suggest that the noise levels do not exceed noise occupational exposure limits. Although levels approached 95 dB(A), during a 15–second period, the short amount of time which the physician or technician are subjected to the noise lowers the time–weighted average (TWA) exposure below all evaluation criteria. Even the most conservative exposure criteria of NIOSH and the American Conference of Governmental Industrial Hygienists (ACGIH®) allow exposure to 95 dB(A) for a total time of slightly less than one hour. The noise exposures last two minutes or less for each autopsy. It is unlikely that employees would perform 30 autopsies per day.

LEV applied at the cutting surface of reciprocating surgical saws can be an effective tool to reduce the risk of occupational exposure to blood, bone, and tissue aerosol fragments during autopsies which may be contaminated by infectious agents (e.g., *Mycobacterium tuberculosis*). However, the vacuum recovery system should be mechanically integrated with the activation of the reciprocating saw, eliminating the possibility of operator error. Noise levels generated by these surgical devices should not exceed the evaluation criteria for hazardous noise exposure given the short duration of their use.

Keywords: SIC 9221 (Police Protection) tuberculosis, HIV, coroner, bloodborne pathogen, noise, cranial saws

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INTRODUCTION

On October 25, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request to conduct a health hazard evaluation (HHE) from the office of the Los Angeles County Department of Coroner (LACDOC). Specifically, the request was for NIOSH assistance in evaluating a pneumatic reciprocating saw equipped with local exhaust ventilation (LEV) used for cranial openings during forensic autopsies and examinations. The pneumatic saw was being evaluated by the coroner's office as an alternative to the electrically-driven reciprocating saw. The objective of the NIOSH evaluation was to determine if the reciprocating saw (1) generates less tissue and bone fragment aerosol that could potentially challenge the breathing zone of the operating forensic technician, and (2) reduces the noise exposure to the technician and surrounding personnel.

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BACKGROUND

During the first six months of 1995, two active cases of tuberculosis (TB) and 10 tuberculin skin test (TST) conversions among employees were reported by the LACDOC. Additionally, in December 1995, one case of active disease was diagnosed in a general relief worker operating as a janitor for the building. An epidemiologic assessment concluded that a high risk of TB infection was evident for LACDOC employees.[1] Autopsy room workers were five times more likely to develop TB infection than other employees. Employee to employee transmission was ruled out in the outbreak. However, the possible transmission of disease from the cadaver to employees could not be ruled out.

The LACDOC building is concrete and glass construction and is approximately 27 years old. The overall ventilation systems were reported to be functioning at 75 percent of design capacity with many of the components in need of maintenance and repair.[1] Autopsies are primarily conducted in three rooms; the main rooms have table capacities for five and six simultaneous autopsies, while a smaller room has a capacity for three. The smaller of the three autopsy rooms was designated for cases suspected of human immunodeficiency virus (HIV) or TB infection. A test and balance of the ventilation systems serving the autopsy rooms indicated that the main autopsy room was under negative pressure (having approximately 20 air changes per hour [ACH]), whereas, the smaller autopsy room was under positive pressure. As a result, a separate exhaust system was installed in the small autopsy room to place it under negative pressure relative to the corridor, achieving a maximum air change rate of approximately 24 ACH.

In addition to the changes made to the ventilation system in the small autopsy room, in the first quarter of 1996, LACDOC initiated a study evaluating the implementation of a pneumatically driven reciprocating saw (Salam International Model 1100, Laguna Niguel, California) equipped with LEV to reduce occupational exposures to blood and other bodily fluids. If effective, the pneumatic saw would replace an electrically-driven saw (Stryker Model 810) then currently being used. The pneumatic saw operates at a speed of 19,000 cycles per minute (cycles/min), whereas, the electric saw operates at a speed of 17,000 cycles/min. The LEV on the pneumatic model consists of a hood and spray nozzle connected to an aqueous spray/vacuum extraction system. The aqueous spray/vacuum extraction system is physically located in adjacent space (i.e., the building garage) to the small autopsy room. The holding tank on the vacuum extraction system contains a 10 percent bleach solution to decontaminate incoming materials. Additionally, the exhaust on the vacuum extraction system is equipped with an internal high efficiency particulate air (HEPA) filter.

METHODS

Particulates

Real–time sampling for airborne particulates was conducted with three light–scattering instruments; the Grimm Model 1105 Dust Monitor (Labortechnik GmbH & CoKG, Ainring, Germany); the Met–One Model 227 Hand–Held Particle Counter (Met–One, Inc., Grants Pass, Oregon); and the Handheld Aerosol Monitor (HAM [PPM, Inc., Knoxville, Tennessee]). The Grimm Dust Monitor is a light scattering aerosol spectrometer designed for real–time particulate measurement with particle size discrimination. Eight channels collect count information for particle sizes greater than 0.75, 1, 2, 3.5, 5, 7.5, 10, and 15 micrometers (µm). The Met–One Particle Counter counts particles simultaneously using a solid state laser diode in two size ranges (0.3 and 1 µm were selected for this survey) at an operating flow rate of 2.8 liters per minute (lpm). The HAM uses near–forward scattering of infrared light with an instrument response designed to fit the respirable aerosol fraction. Data were collected during six autopsies to monitor the particulates generated by distinct events. The monitors probe inlets were mounted approximately 15 centimeters above the forehead of the decedent. For each autopsy, data were integrated for 1 second (sec) and stored sequentially on the Grimm data card over the entire time period. The collected particle count and size information was downloaded to a laptop computer following the completion of the autopsy. Start and stop times for significant autopsy events were recorded during each sample collection period.

Noise

Real–time area noise sampling was conducted with a Larson–Davis Laboratory Model 2800 Real–Time Analyzer equipped with Larson–Davis Laboratory Model 2559 ½" random incidence microphone. This instrument allows for the analysis of noise into its spectral components in a real–time mode. The one–third octave center frequency bands from 8 Hertz (Hz) to 16 kilohertz (kHz) were integrated for 15 seconds and stored sequentially in the analyzer over the time period necessary for the technician to open the skull for inspection by the pathologist. An attempt was made to only store samples which contained a full 15–seconds of sawing. If the technician turned off the saw before the sample was complete, the analyzer was reset and that sample discarded. The analyzer was mounted on a tripod placed at the right side of the autopsy table next to the cadaver's head with the microphone at approximately the level of the technician's ear while he was using the saw. Ambient noise levels in the room, while the saw was not in use, were also stored for each of the cadavers that were surveyed.

EVALUATION CRITERIA

The occupational hazards encountered by health care professionals are varied. These hazards include exposures to biologic, chemical, and physical agents, as well as ergonomic challenges posed by the manipulation and transport of patients. In 1988, NIOSH published a document that focused on protecting the safety and health of health care workers. NIOSH found that, compared to the civilian workforce, hospital workers have a greater percentage of workers' compensation claims for sprains and strains, infectious and parasitic diseases, dermatitis, hepatitis, mental disorders, eye diseases, influenza, and toxic hepatitis.[2] Probably the most occupationally unique and high risk hazards are posed by exposures to infectious agents. In some instances, the risk of occupationally acquired infections is of such concern that comprehensive, agent focused guidelines have been published by the Centers for Disease Control and Prevention (CDC).

Specifically, these guidelines have addressed occupational exposures to *Mycobacterium tuberculosis*, human immunodeficiency virus (HIV), and hepatitis B virus (HBV).[3,4] In 1991, OSHA published their final rule on occupational exposures to bloodborne pathogens.[5] The bloodborne pathogens rule is in part based on the concept of "universal precautions." Universal precautions are defined as the treatment of all human blood and certain human body fluids as if known to be infectious for human immunodeficiency virus (HIV), hepatitis B virus (HBV), and other bloodborne pathogens. In 1996, OSHA developed a directive for enforcement procedures and scheduling for occupational exposures to tuberculosis.[6]

Within the health care industry, certain sectors are known to present greater exposure risk potentials to both bloodborne pathogens and tubercle bacilli. During the conduct of autopsies, an increased risk to the pathologist and pathology technicians can result from unknown disease etiologies and potentially large infectious agent concentrations released during invasive procedures. The infectious diseases of special concern during autopsies (or more generally, infection hazards in the deceased) have included tuberculosis, hepatitis B and C virus, HIV, Creutzfeldt–Jacob disease, group A streptococcal infection, gastrointestinal organisms, and possibly meningitis and septicaemia (especially meningococcal).[7,8] Recent concerns about the increasing incidence of hantavirus pulmonary syndrome (HPS) have resulted in questions regarding the level of biosafety necessary to protect autopsy prosectors operating on decedents known to have been infected with hantavirus. Given the limited biosafety information regarding HPS and the serious consequences of infection, recommendations have been made to use biosafety level (BSL) 2 facilities and BSL 3 procedures and practices.[9] Tuberculosis has gained increasing attention as a significant exposure concern during the conduct of autopsies. Sugita et al. demonstrated an increased odds ratio (6.08–10.98) among pathologists and pathology technicians engaged in their current specialist work compared to control groups.[10] Recent case studies of outbreaks among autopsy personnel resulting from occupational exposures have been documented.[11,12,13]

Specific ventilation criteria for autopsy rooms, in which the decedent is suspected of having an infectious disease at the time of death, currently do not exist. However, the American Society for Heating, Refrigerating, and Air–Conditioning Engineers (ASHRAE) and the American Institute of Architects (AIA) have published ventilation specific guidelines for autopsy areas.[14,15] These guidelines recommend that autopsy areas be provided with at least 12 ACH. Additionally, ASHRAE recommends a minimum contribution of 2 outdoor ACHs; AIA does not have a provision for the introduction of outdoor air.

Noise

Noise–induced loss of hearing is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise–induced loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.[16] While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise–induced hearing loss is insidious. Typically, it begins to develop at 4000 or 6000 Hz (the hearing range is 20 Hz to 20000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist," have still higher frequency components.[17]

The A–weighted decibel [dB(A)] is the preferred unit for measuring sound levels to assess worker noise exposures. The dB(A) scale is weighted to approximate the sensory response of the human ear to sound frequencies near the threshold of hearing. The decibel unit is dimensionless, and represents the logarithmic relationship of the measured sound pressure level to an arbitrary reference sound pressure (20 micropascals, the normal threshold of human hearing at a frequency of 1000 Hz). Decibel units are used because of the very large range of sound pressure levels which are audible to the human ear. Because the dB(A) scale is logarithmic, increases of 3 dB(A), 10 dB(A), and 20 dB(A) represent a doubling, tenfold increase, and 100–fold increase of sound energy, respectively. It should be noted that noise exposures expressed in decibels cannot be averaged by taking the simple arithmetic mean.

The OSHA standard for occupational exposure to noise (29 CFR 1910.95) specifies a maximum PEL of 90 dB(A) for a duration of eight hours per day.[18] The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship, or exchange rate. This means that a person may be exposed to noise levels of 95 dB(A) for no more than 4 hours, to 100 dB(A) for 2 hours, etc. Conversely, up to 16 hours exposure to 85 dB(A) is allowed by this exchange rate. NIOSH, in its Criteria for a Recommended Standard, proposed a REL of 85 dB(A) for 8 hours, 5 dB less than the OSHA standard.[19] The NIOSH 1972 criteria document also used a 5 dB time/intensity trading relationship in calculating exposure limits. However, in 1995, NIOSH changed its official recommendation for an exchange rate of 5 dB to 3 dB.[20] ACGIH also changed its TLV in 1994 to a more protective 85 dB(A) for an 8–hour exposure, with the stipulation that a 3 dB exchange rate be used to calculate time–varying noise exposures.[21] Thus, a worker can be exposed to 85 dB(A) for 8 hours, but to no more than 88 dB(A) for 4 hours or 91 dB(A) for 2 hours.

The duration and sound level intensities can be combined in order to calculate a worker's daily noise dose according to the formula:

$$Dose = 100 \times (C_1 / T_1 + C_2 / T_2 + ... + C_n / T_n),$$

where C_n indicates the total time of exposure at a specific noise level and T_n indicates the reference duration for that level as given in Table G–16a of the OSHA noise regulation.[18] During any 24–hour period, a worker is allowed up to 100% of his daily noise dose. Doses greater than 100% are in excess of the OSHA PEL.

The OSHA regulation has an additional action level (AL) of 85 dB(A); an employer shall administer a continuing, effective hearing conservation program when the TWA value exceeds the AL. The program must include monitoring, employee notification, observation, audiometric testing, hearing protectors, training, and recordkeeping. All of these requirements are included in 29 CFR 1910.95, paragraphs (c) through (o).

Finally, the OSHA noise standard states that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dB(A), feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. However, in 1983, a compliance memorandum (CPL 2–2.35) directed OSHA compliance officers not to cite employers for lack of engineering controls until workers' TWA levels exceed 100 dB(A), so long as the company has an effective hearing conservation program in place. Even in TWA levels in excess of 100 dB(A), compliance officers are to use their discretion in issuing fines for lack of engineering controls.

RESULTS

Particulates

Figures 1, 3, 5, 8, 10, and 13 present graphical representations of the real–time data collected with the Met–One particle counter for the six monitored autopsies. Particle count measurements were made over the complete time period of each autopsy. Figures 8 and 10 depict data collected during the use of the electric saw without LEV. Figures 1, 3, 5, and

13 depict data collected during the use of the pneumatic saw with LEV. It is important to note that the time period for the use of the cranial saw for each monitored autopsy composed only a small portion of the entire procedure; on the order of one to two minutes. For all of the monitored autopsies, no distinctly observable effect is apparent for particles > 0.3 µm, but for particles > 1 µm, peaks are observable in Figures 2, 8, and 10. These peaks correspond to the use of the reciprocating saw on the cranial region of the decedent and range from one to two orders of magnitude above the baseline. Additionally, the lack of observable peaks for particles > 0.3 µm indicate that the diameters of particles generated by the use of the reciprocating saws predominate at > 1 µm. It is important to note that during the second autopsy (Figure 3), the exhaust flow for the LEV was inoperable (the technician was not aware that the switch for the unit was turned off) during the first half of the time period that the pneumatic saw was used. The peak observed in Figure 3 coincides with the inoperability of the LEV.

Figures 6, 9, 11, and 14 present the HAM real–time measurement results collected on the operating technician during the complete time period of each individual autopsy (due to instrument malfunction, data were only available for autopsies 3 through 6). Note that the results from the HAM are reported as concentration estimates of particulate load (i.e., milligrams per cubic meter of air) and cannot be quantitatively compared to the other aerosol measurements reported in total counts per volume of sampled air (i.e., particles per liter). However, observation of qualitative trends can be used to understand exposure points during each autopsy. Specifically, the peaks observed in the HAM graphical representations (i.e., Figures 9 and 11) correlate, in time, with the peaks observed in the Met–One data created by the use of the reciprocating saw.

Figures 2, 4, 7, 12, and 15 present graphical representations of the real–time data collected with the Grimm particle counter for five of the six monitored autopsies (due to instrument malfunction, data was not collected for autopsy 5). As with the other real–time measurements, attempts were made to collect data over the complete time period of each autopsy. Figure 12 depicts data collected during the use of the electric saw without LEV. Figures 2, 4, 7, and 15 depict data collected during the use of the pneumatic saw with LEV. For all of the monitored autopsies, minimal or reduced observable effects are apparent for particles > 0.75 µm, but for all remaining particle cut points, peaks are observable in Figures 2, 4, 12, and 15. These peaks correspond to the use of the reciprocating saw on the cranial region of the decedent. The most significant increases in relative concentrations occur for the cut points at 2, 2.5, and 3 µm. When the electric saw was applied, observable effects are noted for all particle size cut points (except for particles > 15 µm) ranging from one–half to two orders of magnitude above the baseline. As seen in the Met–One results, a peak is observed (Figure 4) which coincides with the inoperability of the LEV during the initial segment of the cranial cut.

Noise

Noise from the saws used on four cadavers was analyzed with three sets of samples with the pneumatic saw and one set with the electric saw. The cranial procedure took approximately 75 to 105 seconds to complete; therefore, five to seven individual spectral plots of 15–seconds duration were stored for analysis. Cases #1–3 had the technician operating the pneumatic saw and case #7's cranium was opened by two different electric saws because of a failure of the first saw during the procedure. Inspection of the individual spectral plots revealed a general pattern of higher noise exposures associated with the earlier cutting and lesser amounts of overall noise on successive samples. Specifically, for case #1, the noise levels went from 92.8 to 85.6 dB(A); case #2 levels ranged from 93.5 to 88.7 dB(A); case #3 levels were 94.8 to 88.6 dB(A); and case #7 ranged from 94.9 to 86.5 dB(A).

A comparison of the one–third octave band noise levels for the pneumatic and electric saws is presented in Figure 17. The spectra that are shown are average levels for the entire procedure of opening the cranium. The pneumatic saw data is from the five individual samples recorded on body #2 while the electric saw data represents both saws used on body #7 over the seven individual samples. The data show little difference in the noise emitted by the two types of saws. The peak energy level for the pneumatic saw was recorded at the 4 kHz third octave band while the maximum for the electric saw was at 5 kHz. The electric saw also had greater energy in the third octave bands higher than 5 kHz. The average overall noise energy was slightly higher for the electric saw on both the A–weighted scale and unweighted (sound pressure level [SPL]) scale. However, these differences of 1–2 dB are not generally perceptible to normal hearing listeners.

The fluid delivery and HEPA vacuum recovery system which supports the pneumatic saw were located in the garage area adjacent to the autopsy room. The garage area is accessible through a doorway which was closed during autopsy. LACDOC employees were seen in the opposite end of the garage while the system was in use. A spectral average of the noise coming from the system was measured at a distance of approximately four feet from the vacuum and at ear level of a standing person. The data (Figure 18) show that much of the noise energy is emitted at 500 to 4000 Hz, but that the overall levels are not in excess of any relevant criteria since the system is on only during the time when the saw is operational.

During the survey of the pneumatic saw, the technician seemed to not be totally familiar with this relatively new piece of equipment. The saw was designed so that the fluid delivery system and the vacuum recovery system could be operated independent of the saw blade. That is, a deliberate effort had to be made to turn on the vacuum and fluid systems before pressing the trigger which would activate the blade. During the first autopsy, all of the saw's systems were operating. However, during subsequent autopsies, the fluid and vacuum systems were inadvertently turned off on the initial cut into the skull on the second autopsy and the fluid delivery was off for the initial cut during the third autopsy. The noise samples for each of these three events are presented in Figure 19. The overall noise levels were lowest when the complete cutting system was in operation. The greatest effects of the fluid and vacuum systems on the noise can be seen in the higher frequency, third–octave bands at and above 4kHz.

DISCUSSION

Particulates

The real–time measurement data collected with the Met–One and Grimm instruments (reported as particles/liter [part/L]) were similar. The baseline readings for both instruments during the sampled autopsies (for particles > 1µm) were focused between 1000 and 2000 part/L. For the Grimm, data from autopsies 1 through 4 were collected as integrated one minute samples; the sample measurements for autopsies 5 and 6 were collected at six second intervals. All of the Met–One measurements were collected over 10 second intervals. The longer sample period for the earlier Grimm measurements may account for the lower comparative particle concentrations; longer sample periods result in a dampening of the peaks due to an averaging of all values over the entire sample period. Specifically, if the sample period includes numerous data points that approach the particle concentration baseline, the lower values will weight the average toward the baseline.

For all of the monitored autopsies, no distinctly observable effect is apparent for particles > 0.3 µm, as measured by the Met–One. This is consistent with the Grimm results which present smaller peak values (relative to the baseline) at the 0.75 µm cut–point compared to all other values at cut–points of 2, 2.5, and 3 µm over the same sample period. These reduced particle concentrations in the sub–micrometer size range indicate that a significant portion of the particles emitted by application of reciprocating saws are above 1 µm. This is contrary to previously published data which indicate median diameters in the sub–micrometer size range. Green and Yoshida (1990) measured (in the breathing zone of a pathology technician) the aerosols generated by the application of a reciprocating saw during five cranial autopsies.[22] The results of scanning/transmission electron microscopy indicated a median particle diameter of 0.37 µm. In a 1992 study investigating the generation of surgical aerosols as simulated on bovine tissue, Jewett *et al.* reported that most of the aerosols were below 4.2 µm with a peak occurring at 0.42 µm, as measured by a 10–stage, low–pressure cascade impactor.[23] However, in a follow–up investigation evaluating occupational exposures collected in the breathing zone (using personal cascade impactors with cut points at 0.52, 3.5, and 14.8 µm), Heinsohn and Jewett (1993) reported the detection of hemoglobin in a smaller percentage of the samples at a particle size of 0.52 µm (38% versus 90% detected at 14.7 µm).[24]

The particulate peaks observed during autopsies 2, 4, and 5 (Figures 3, 8, and 10 of the Met–One results and Figures 4 and 12 of the Grimm results) indicate that the application of LEV has a significant effect on reducing the aerosols produced by the reciprocating saws. Additionally, the peak observed during autopsy 2 (use of the pneumatic saw while the LEV was inoperable) confirms that the reduction in aerosol emission results from the LEV and not from the use of the pneumatic saw versus the electric saw. The aerosol concentrations observed from use of both saws without LEV can be one to two orders of magnitude over baseline. The peaks observed from the personal real–time air samples collected on the operating technician with the HAM (Figures 9 and 11 of the HAM results) indicate that aerosols generated by use of the unventilated reciprocating saws are capable of reaching the breathing zone of the worker.

The real–time instrumentation compared favorably with the filter cassette samples collected by the county health department. As shown in Figure 16, there is a consistent reduction in the concentration levels (reported as fragments [as determined by optical microscopy] per liter of air) between the application of the electric saw and the pneumatic saw equipped with LEV. The largest differential is observed for the right area sample and the personal breathing zone (PBZ) sample collected on the forensic technician. The PBZ sample collected on the pathologist exhibited the lowest differential margin; the pathologist did not use the reciprocating saw and was generally located opposite of and approximately three feet from the forensic technician. The dissimilar concentrations between the left and right area samples can be explained by the direction of air flow in the room. The auxiliary exhaust units were located in the ceiling nearer to the entry door of the room. This placement of the exhaust air vent would cause a pressure differential resulting in air movement from left to right across the operating table. Therefore, particles generated by the application of the reciprocating saw would drift to the right.

Noise

The noise data from the two types of reciprocating saws reveal that the noise levels should not exceed the evaluation criteria for hazardous noise exposure. Although levels can approach 95 dB(A), the greatest 15–second sample recorded during the evaluation, the short amount of time which the physician or technician are subjected to the noise lowers the TWA value below all the criteria. Even the most conservative exposure criteria of NIOSH and the ACGIH allow exposure to 95 dB(A) for a total time of slightly less than one hour.[20,21] The exposure times measured in the survey were on the order of two minutes or less for each autopsy. It is unlikely that employees would perform 30 autopsies per day.

NIOSH was given a training videotape produced by the Department of the Coroner which introduced the audience to the pneumatic saw. In the videotape, a comparison of the noise emitted by the pneumatic and electric saws was made with a microphone placed near the saws and the VU meter of the microphone's amplifier in camera view. The level of energy on the meter was obviously greater for the electric saw, which seems to be in conflict with the results found during the NIOSH evaluation. It is possible that the differences are due to the way in which the comparisons were made. In the Coroner's videotape, the saws were allowed to run at full power in free space, i.e., they were not doing any work. The NIOSH data were collected during actual sawing operations. The effect of putting a load on the saw when it was cutting into bone most likely changed the acoustical output of the tools. Also, a higher energy sound component (above 4 kHz) for the electric model may cause the two types of saws to sound different to the operator.

CONCLUSIONS

The health care industry poses unique occupational exposure concerns including exposure to pathogenic agents in blood and other fluids. HIV has been shown to remain viable in the cool aerosols generated by certain surgical tools.[25] In addition, researchers have demonstrated the ability of HIV to survive several hours to 16 days postmortem and has been detected several days outside of a host.[26,27] Due to the invasive nature of the procedures used in the operating theater and the aerosol–generating potential of specific surgical instruments (i.e., harmonic scalpels, electro–cautery knives, lasers, and reciprocating saws), there is an increased risk of exposure to aerosols that may contain infectious agents (i.e., *Mycobacterium tuberculosis*). These same risks are encountered during the conduct of autopsies. Additionally, during an autopsy, the HIV status of a decedent or the diagnosis of tuberculosis or other infectious diseases may not be known. Therefore, it is prudent to evaluate the risks prior to each case and employ appropriate control strategies to minimize the potential for occupational exposures.

The objective of this NIOSH investigation was to determine if the alternative reciprocating saw (1) generates less tissue and bone fragment aerosol that could potentially challenge the breathing zone of the operating forensic technician, and (2) reduces the noise exposure to the technician and surrounding personnel. Real-time, light-scattering instruments were used to monitor transient peaks of generated particles during the performance of autopsies. For the NIOSH data, no attempt was made to determine the exact contribution of blood and/or tissue fragments to the observed particle concentrations. However, it can be assumed that the generated aerosols are predominantly composed of constituents from the cadaver (i.e., tissue, bone, blood, and water). In contrast, the filter cassette samples collected by the county health department were analyzed for bone and tissue fragments.

The particulate peaks observed during three of the monitored autopsies conducted without the aide of LEV indicate that the application of LEV has a significant effect on reducing the aerosols produced by the reciprocating saws. Additionally, the peaks observed from the personal real–time air samples collected on the operating technician with the handheld aerosol monitor indicate that aerosols generated by use of the unventilated reciprocating saws are capable of reaching the breathing zone of the worker and are in the respirable size range. The noise data from the two types of reciprocating saws reveal that the noise levels should not exceed the evaluation criteria for hazardous noise exposure.

The extra bulkiness resulting from the extension of the pneumatic lines and the exhaust ventilation tubing created a number of ergonomic issues. Awkward postures imposed by the trailing lines resulted in a two–fold increase in the time to conduct the cranial cuts. The ergonomic implications could result in a lack of acceptance of the modified device among the professional forensic community.

The application of video recording equipment and the time synchronization of this equipment to the real–time instrumentation allowed the identification of peak concentrations not observable with the filter cassette data collected by the county health department. This information can be used to focus control strategies. For this investigation, the data from the real–time instrumentation indicated that aerosols are predominantly generated during the application of the reciprocating saw. Therefore, controls applied during the use of reciprocating saw will have the greatest impact on the generation of aerosols during the conduct of autopsies. Additionally, the collected data can be overlaid onto the video images to be subsequently used as training aids.

As observed during this investigation, operator error can result in occupational exposures to aerosols. Therefore, it is recommended that respirators continue to be applied under the current program to protect against inadvertent exposures to infectious aerosols During the time of the NIOSH investigation, county coroner department policies required the use of HEPA filtered particulate half-face respirators (at a minimum; hooded, powered air-purifying respirators were also available), double gloves, caps, gowns, and shoe coverings for autopsies conducted in the "high risk" room. For respirator use, OSHA requires a respiratory protection program that includes the following components: written standard operating procedures, user instruction and training, cleaning and disinfection, storage, inspection, surveillance of work area conditions, evaluation of respirator protection program, medical review, and use of certified respirators.[28]

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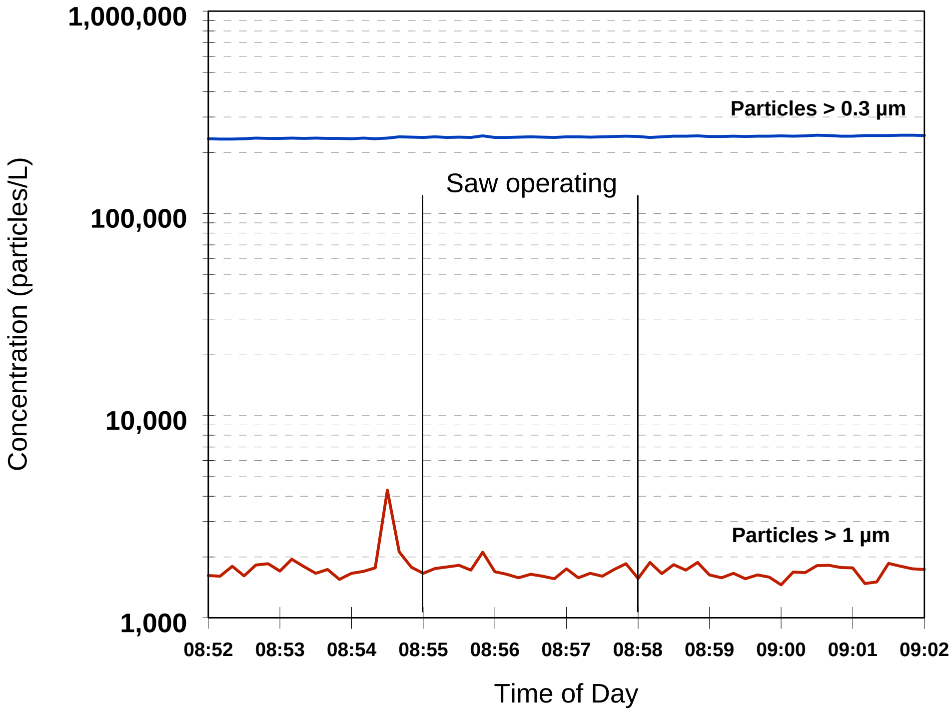

Figure 1. Met–One Results of Autopsy 1 (pneumatic saw with LEV)

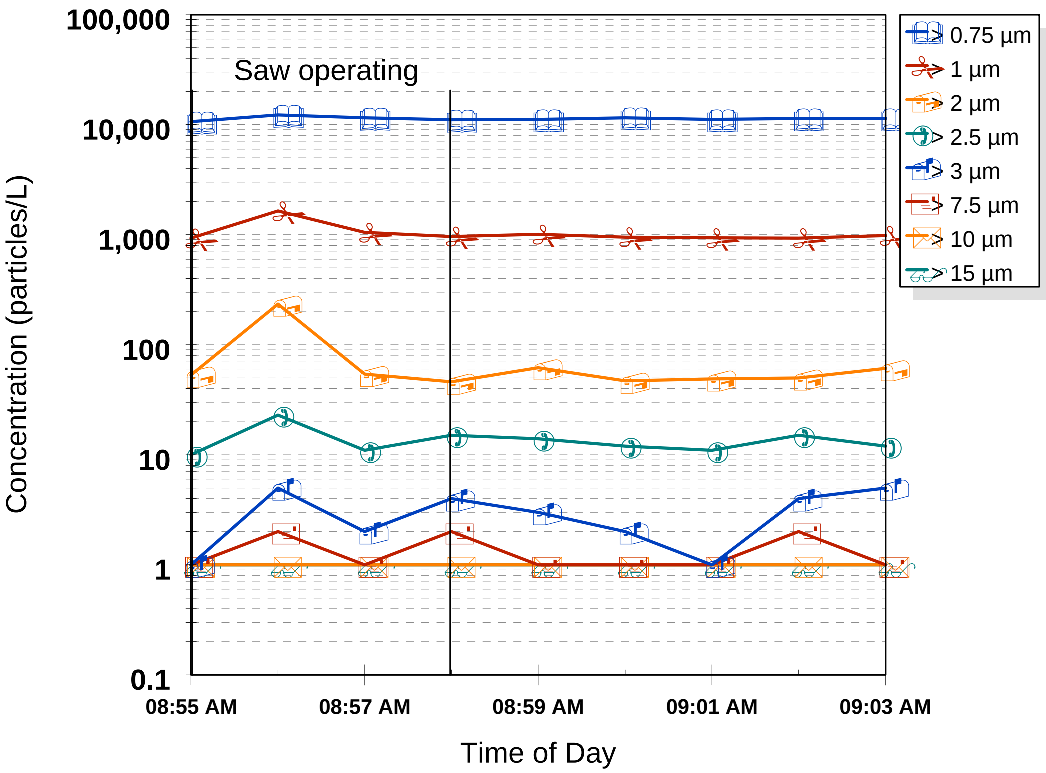

Figure 2. Grimm Results of Autopsy 1 (pneumatic saw with LEV)

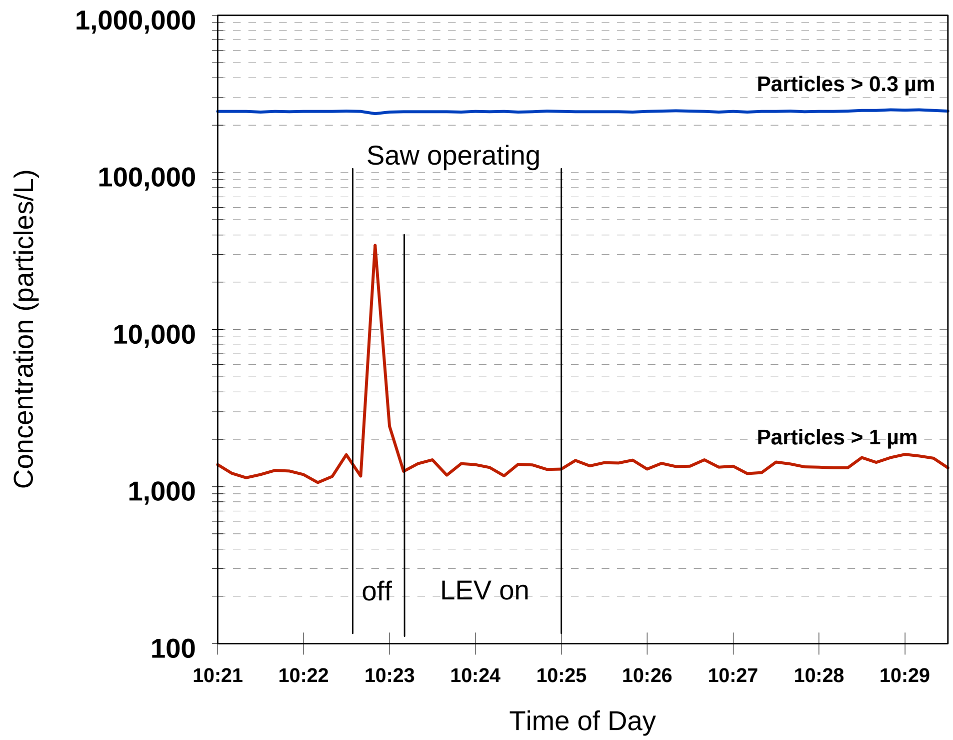

Figure 3. Met–One Results of Autopsy 2 (pneumatic saw with LEV)

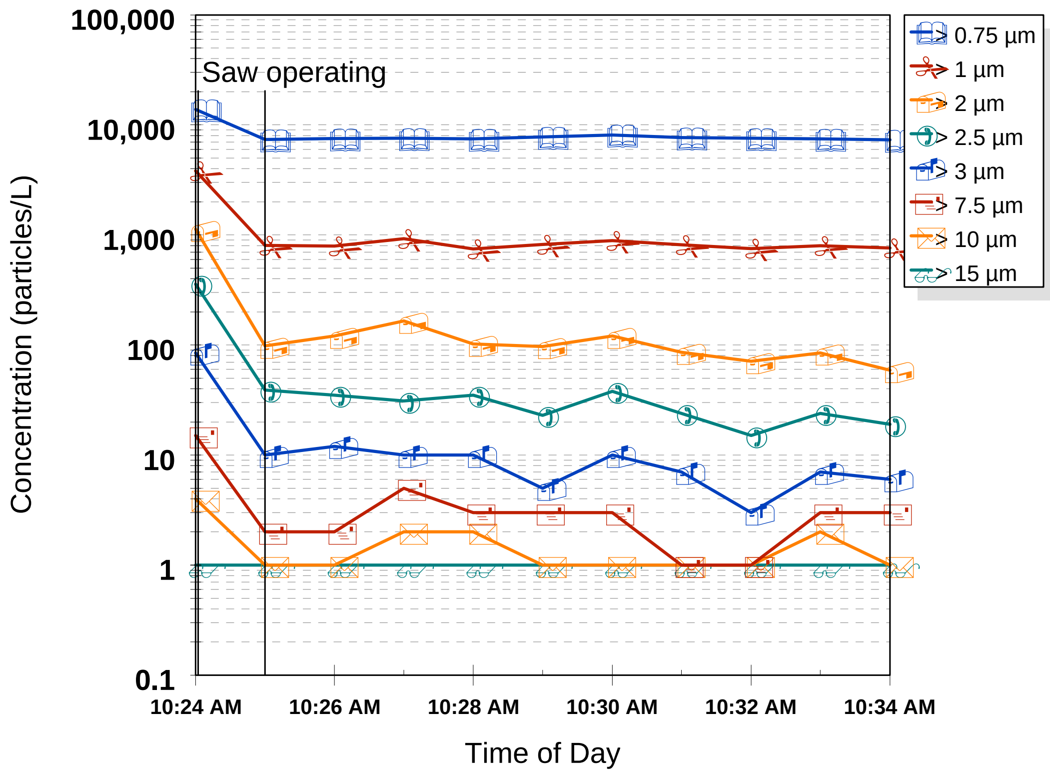

Figure 4. Grimm Results of Autopsy 2 (pneumatic saw with LEV)

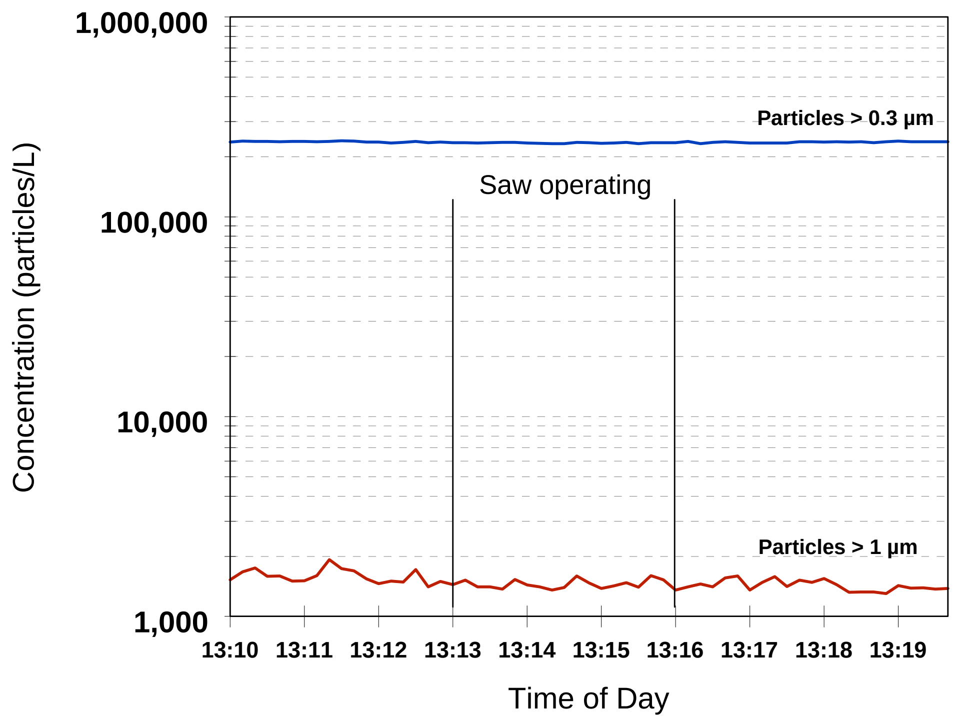

Figure 5. Met–One Results of Autopsy 3 (pneumatic saw with LEV)

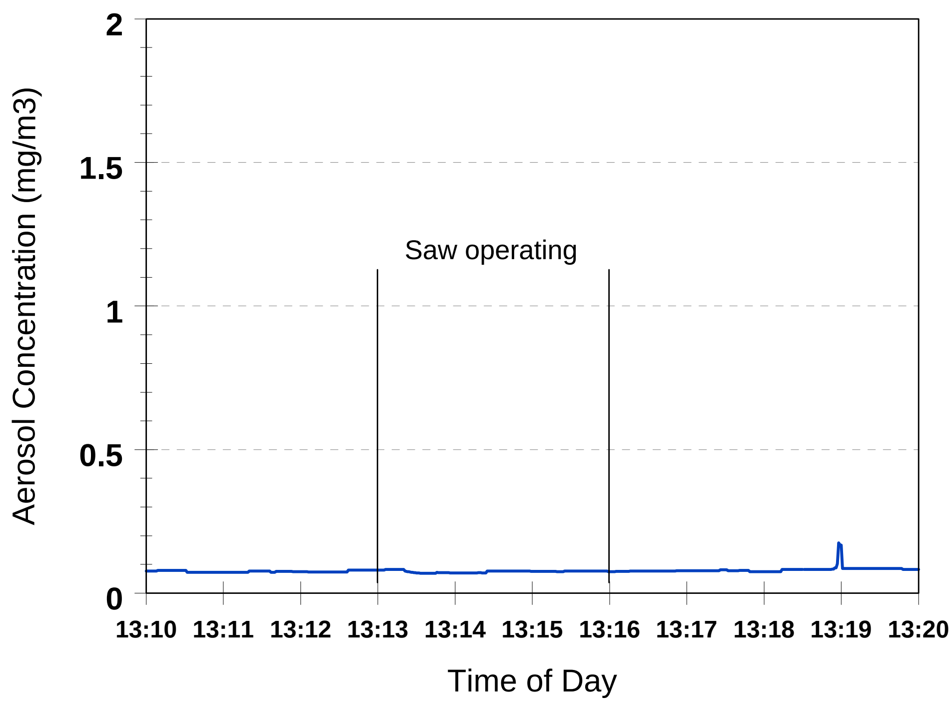

Figure 6. PBZ HAM Results of Autopsy 3 (pneumatic saw with LEV)

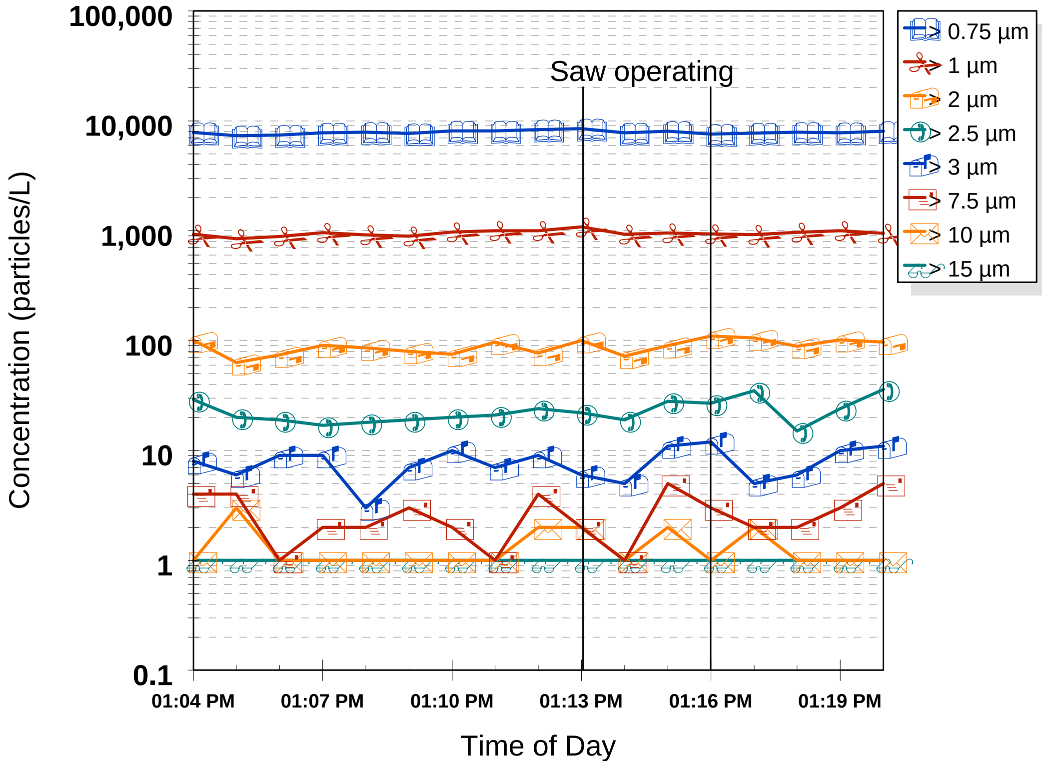

Figure 7. Grimm Results of Autopsy 3 (pneumatic saw with LEV)

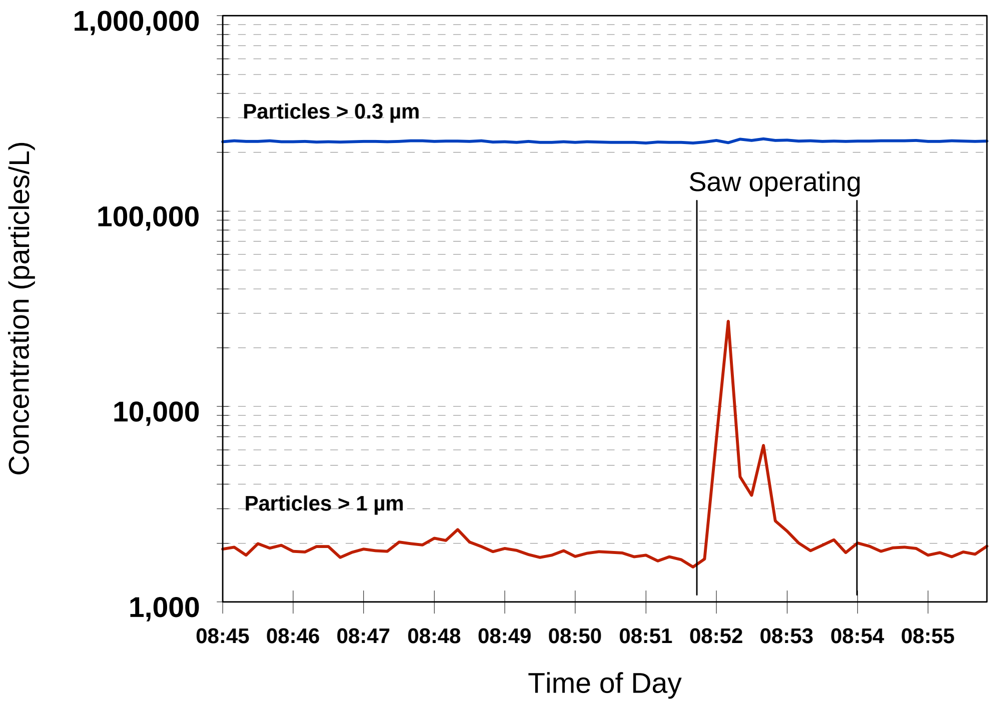

Figure 8. Met–One Results of Autopsy 4 (Electric saw)

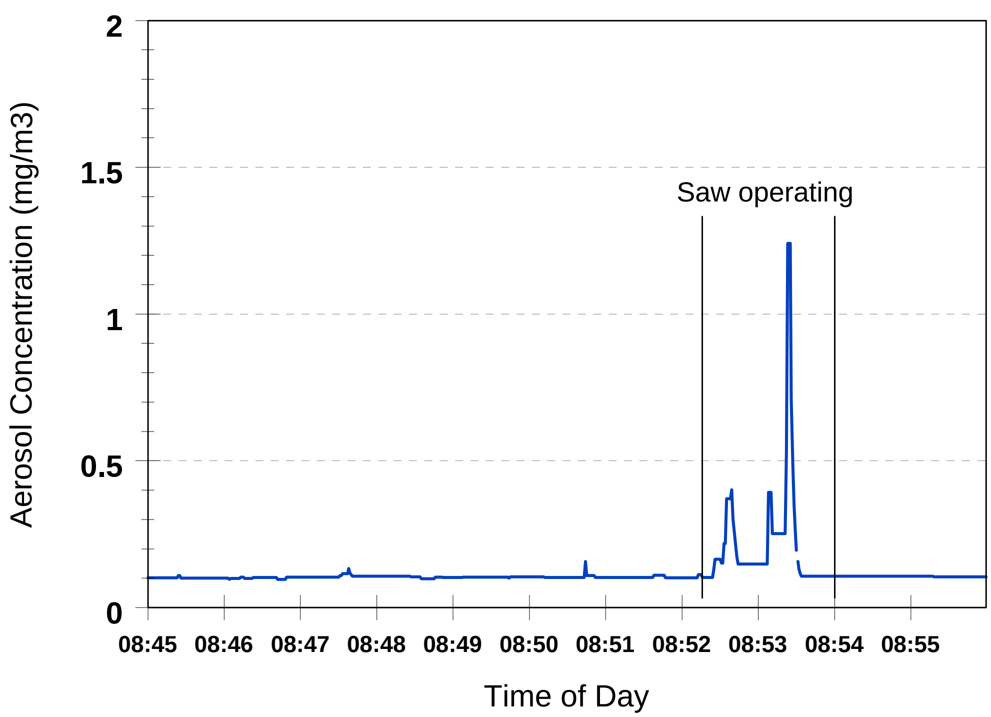

Figure 9. PBZ HAM Results of Autopsy 4 (Electric saw)

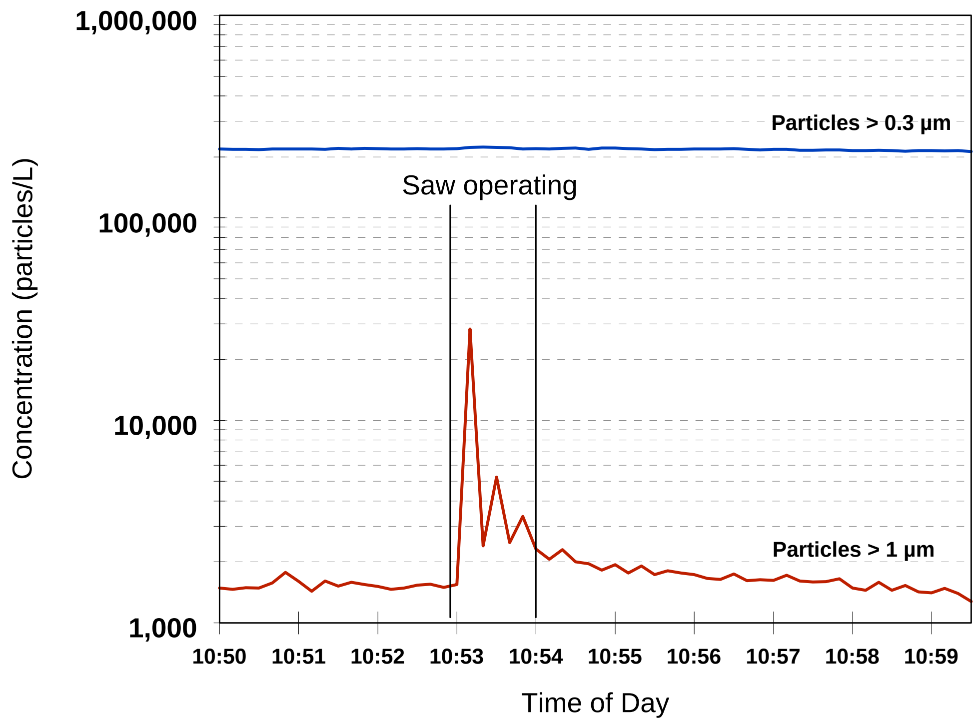

Figure 10. Met–One Results of Autopsy 5 (Electric saw)

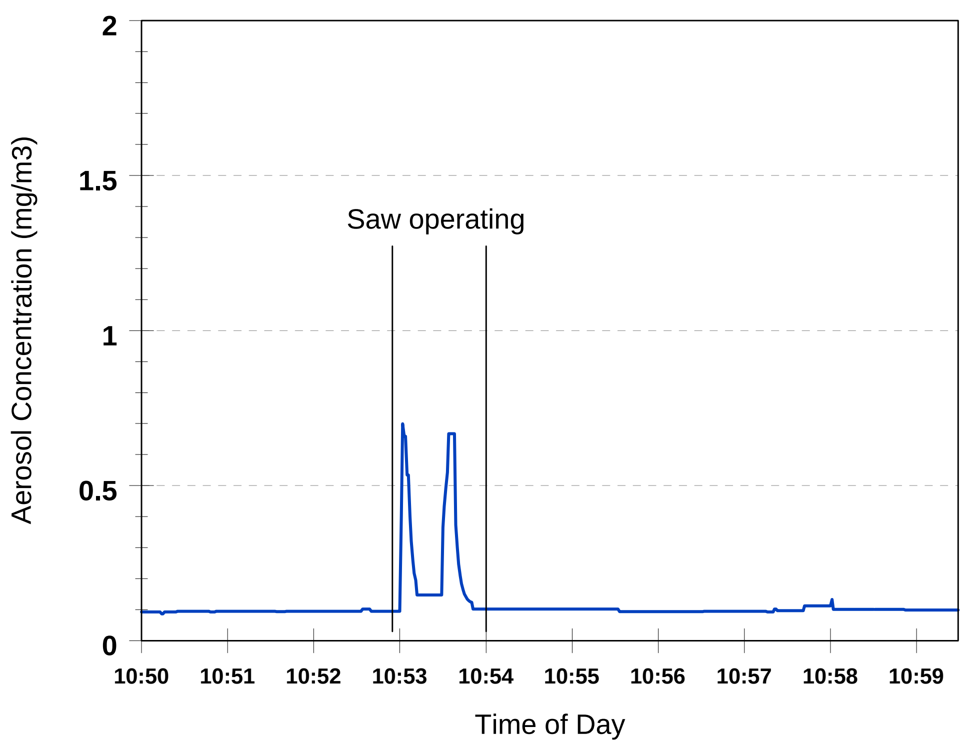

Figure 11. PBZ HAM Results of Autopsy 5 (Electric saw)

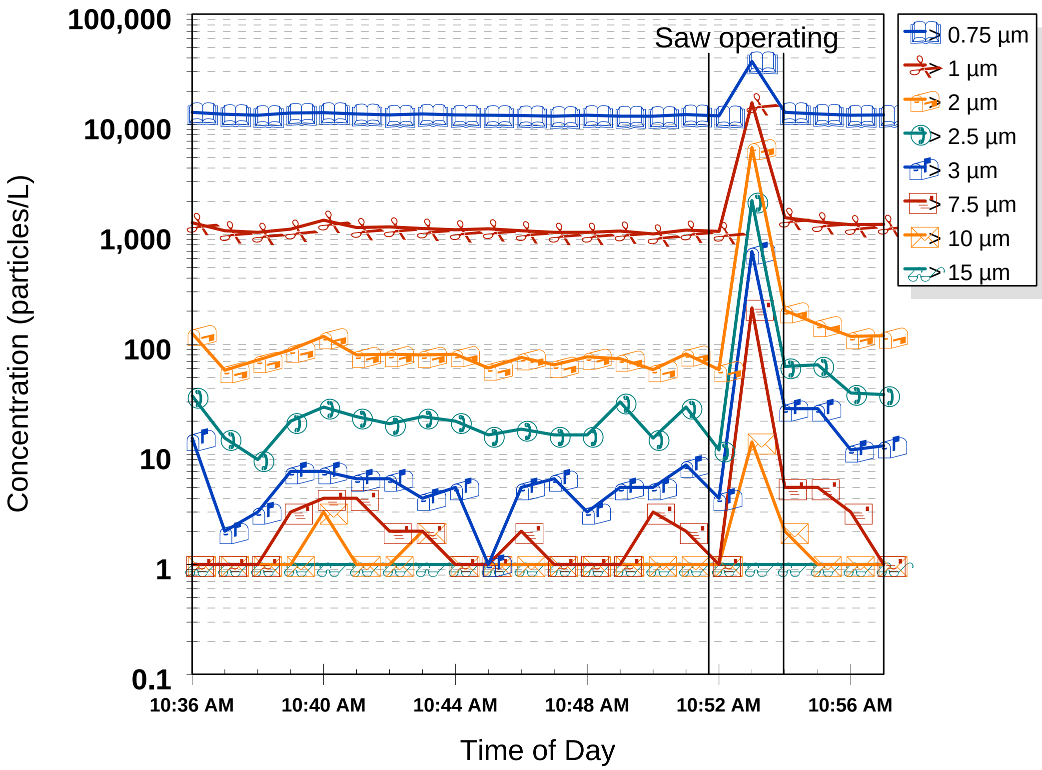

Figure 12. Met–One Results of Autopsy 5 (Electric saw)

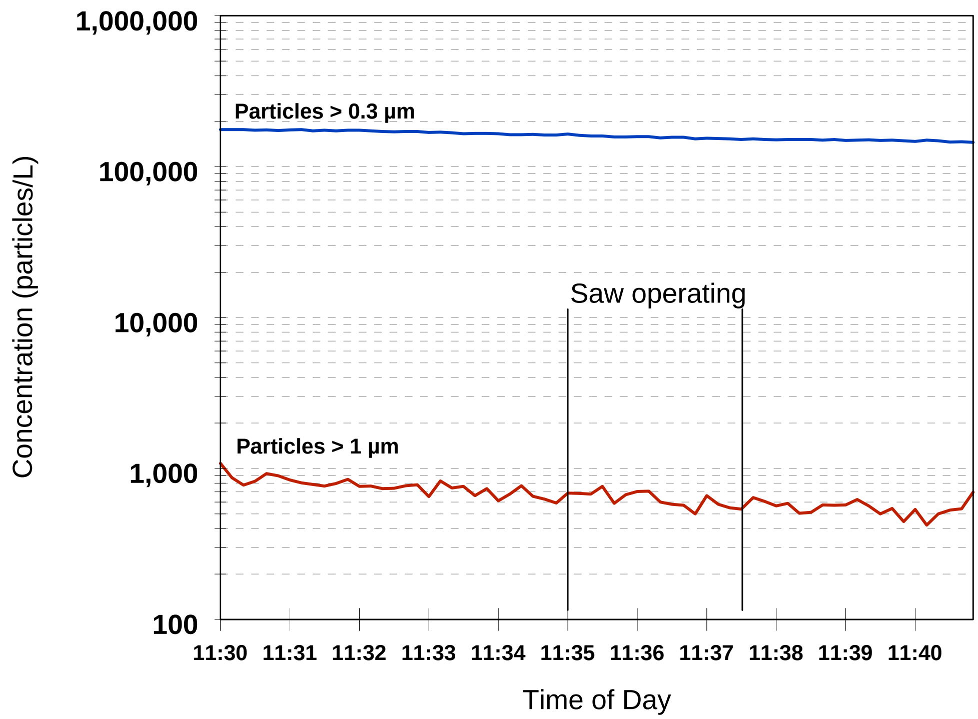

Figure 13. Met–One Results of Autopsy 6 (pneumatic saw with LEV)

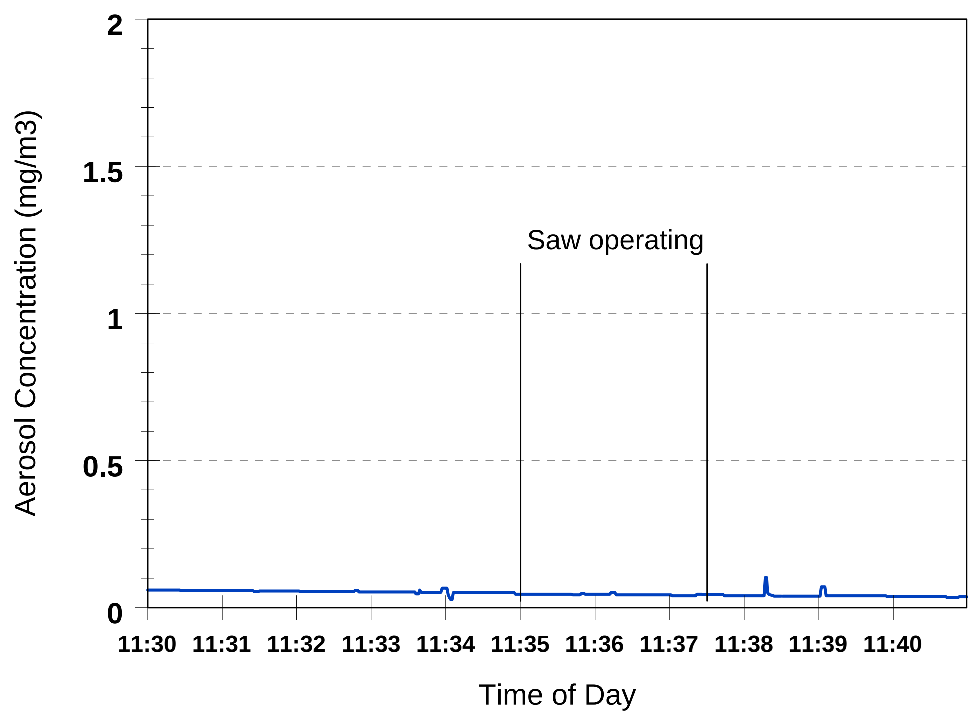

Figure 14. PBZ HAM Results of Autopsy 6 (pneumatic saw with LEV)

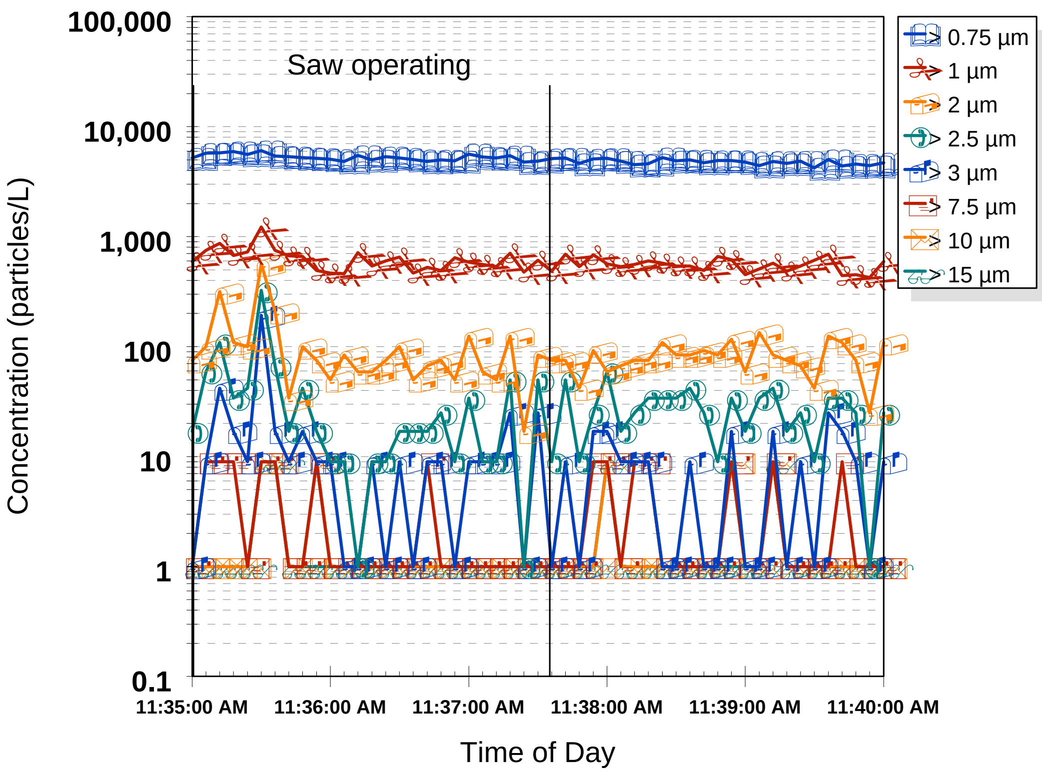

Figure 15. Met–One Results of Autopsy 6 (pneumatic saw with LEV)

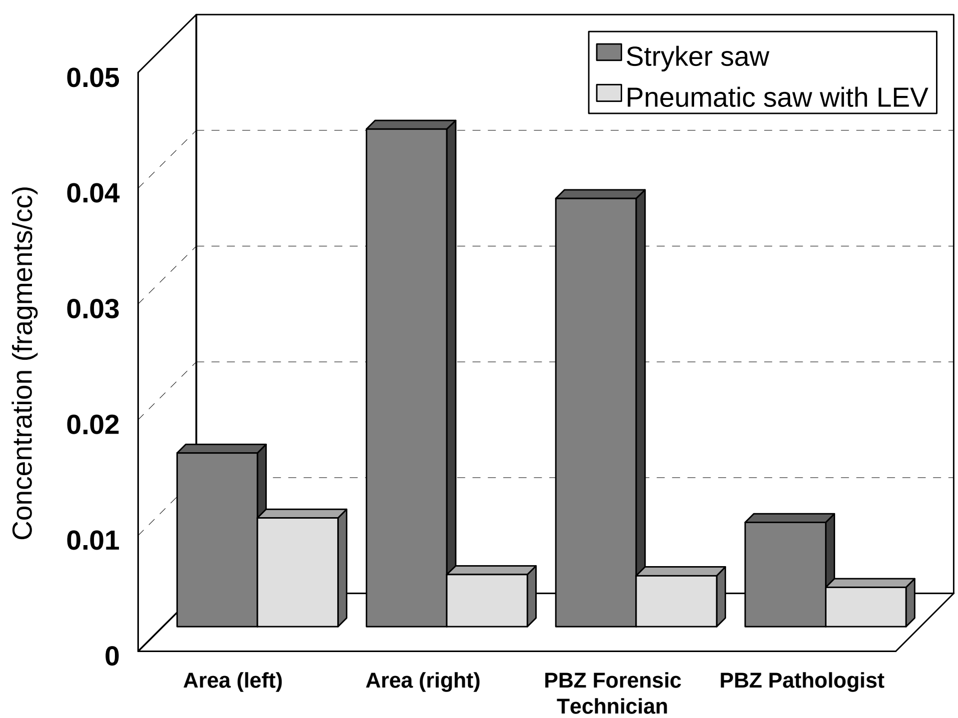

Figure 16. Filter Cassette Sampling Results Comparing Bone and Tissue Fragment Concentrations for Different Reciprocating Saws.

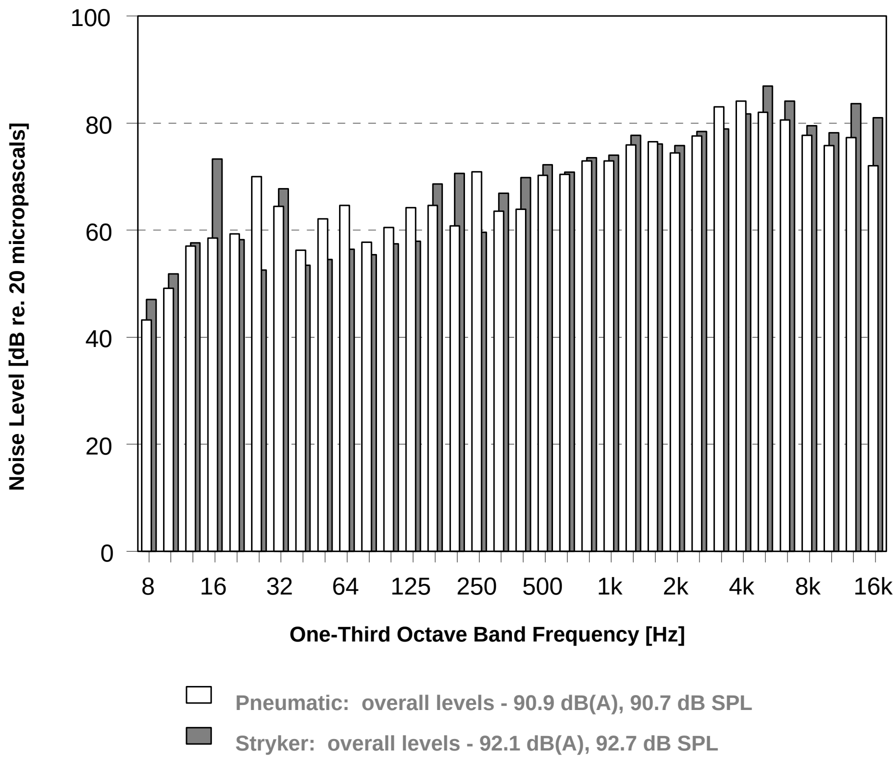

Figure 17. Noise Levels for Pneumatic versus Electric Saw

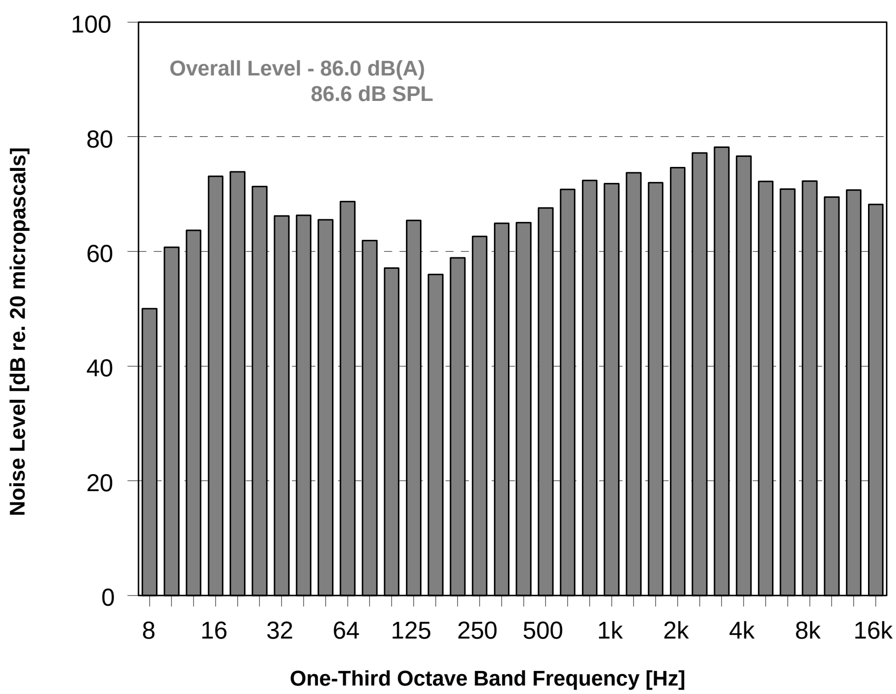

Figure 18. Noise Levels for HEPA Vacuum and Recovery System

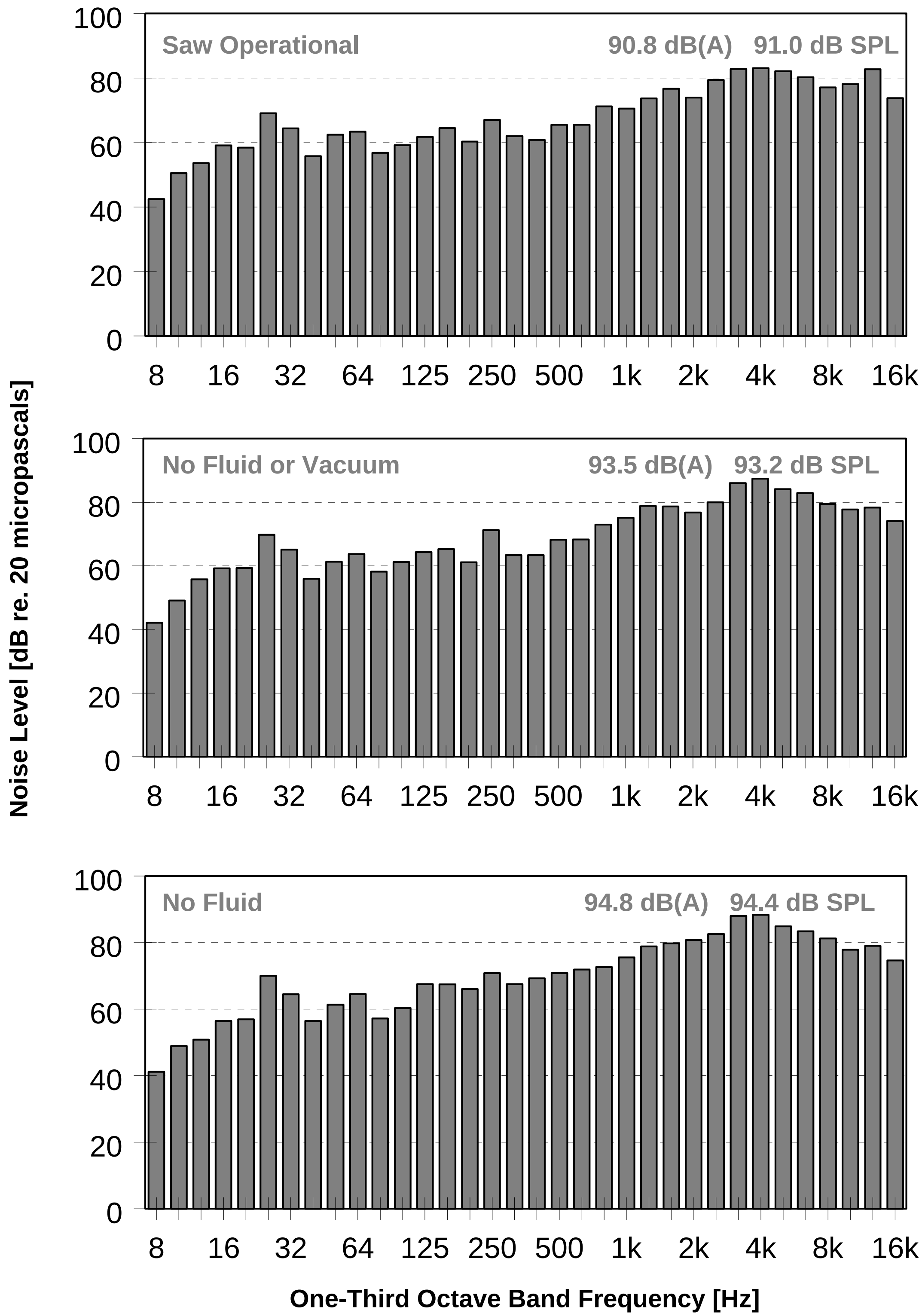

Figure 19. Noise Levels for First 15–second Pneumatic Saw Samples

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