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Roudebush Veterans Administration Medical Center
Indianapolis, Indiana

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PREFACE

The Hazard Evaluations and Technical Assistance Branch of 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 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 employer 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.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Calvin K. Cook of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by John Palassis, Education and Information Division. Desktop publishing by Ellen Blythe.

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Health Hazard Evaluation Report 96–0129–2615
Roudebush Veterans Administration Medical Center
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SUMMARY

In April 1996, the National Institute for Occupational Safety and Health (NIOSH) received a Health Hazard Evaluation (HHE) request from employees in the Pathology Laboratory at the Roudebush Veterans Administration Medical Center located in Indianapolis, Indiana. The request concerned laboratory workers who reported sporadic symptoms of eye and upper airway irritation believed to be associated to their work environment. Thermal comfort problems within the laboratory were also reported. NIOSH investigators conducted an initial indoor environmental quality (IEQ) investigation of the laboratory on June 12–13, 1996. During this initial site visit a series of real–time measurements were made for carbon dioxide (CO_2), temperature, and relative humidity (RH). The Chemical Hygiene Plan, Material Safety Data Sheets (MSDSs), and all manufacturers' information for laboratory and office equipment were reviewed to identify potential sources of machine emissions (i.e., ozone from laser printers). The heating, ventilating, and air–conditioning (HVAC) system was evaluated for deficiencies and potential entrainment of outdoor contaminant sources on the roof. On June 24, 1996, a return visit was made to perform air monitoring for particulates.

Carbon dioxide concentrations ranged up to 450 parts per million (ppm), below the 800 ppm guideline used by NIOSH investigators for indoor environments. Temperature and RH were not within the American Society of Heating, Ventilating and Air–Conditioning Engineer's (ASHRAE) thermal comfort guidelines for optimal and acceptable ranges for building occupants. Anemometer measurements of supply–air diffusers determined that air velocities were nearly five times greater than the American National Standards Institute's (ANSI) laboratory criteria for air velocities near fume hoods.

Because settled particles were observed on surfaces of workstations, equipment, and exhaust diffusers, a follow–up visit was made to sample for airborne particulates. Respirable particulate concentrations ranged up to 0.04 milligrams per cubic meter (mg/m^3), below the Environmental Protection Agency's (EPA) ambient air quality standard of 0.150 mg/m^3. Microscopic analyses of vacuum samples revealed a spectrum of particles such as cellulose (paper particles), synthetic fibers, gypsum, halite (salt), insect parts, rodent hair, glass fibers, quartz, and calcite.

Although airborne respirable particulate concentrations were low, settled particulates were observed throughout the laboratory which could contribute to worker health complaints of eye and upper respiratory irritation. Ventilation deficiencies were identified that caused thermal comfort problems. Recommendations were provided to: (1) reduce excess particulates by improving housekeeping and the ventilation air filtration system, and (2) resolve thermal comfort problems by modifying supply–air diffusers and adjusting RH.

Keywords: SIC 8071 (Medical Laboratories), indoor environmental quality, IEQ, sick building syndrome, eye irritation, upper airway irritation, dust, particulates, thermal comfort, HVAC, gypsum, ventilation, relative humidity.

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INTRODUCTION

In April 1996, the National Institute for Occupational Safety and Health (NIOSH) received a Health Hazard Evaluation (HHE) request from a group of Pathology Laboratory employees at the Veterans Administration Medical Center concerning health complaints of eye and upper–airway irritation they believed to be associated to their work environment. In response to the request, NIOSH industrial hygienists conducted an indoor environmental quality (IEQ) investigation of the work environment to determine the cause of employee health complaints. On June 12–13, 1996, an initial site visit was made to perform environmental monitoring and to inspect the facility's heating, ventilating, and air–conditioning (HVAC) system. On June 24, 1996, a follow–up visit was made to collect bulk samples of surface dust and perform air sampling for particulates.

BACKGROUND

Facility Description

The VA Medical Center is a six–story hospital located in an urban/commercial setting. Since 1987, the Medical Center has been a *smoke free* work environment. The 8,200 square foot Pathology Laboratory is located on the second floor adjacent to administrative offices and an Immunology Laboratory. The Pathology Laboratory consists of Hematology, Chemistry, Special Chemistry, and Blood Bank areas with no defining boundaries. The staff includes medical technologists and technicians who generally work 8 hours each day performing routine pathology analyses on biological specimens. Shortly after the laboratory was constructed and first occupied in August 1994, workers reported symptoms of eye and upper respiratory irritation they believed to be related to their work environment. In an effort to improve the air quality, two portable air cleaners were located at workstations of employees who experienced symptoms.

Ventilation Information

The HVAC needs of the Pathology and Immunology laboratories are served by a single–ducted, constant volume system with the *design* airflow rate capacity of 28,540 cubic feet per minute (cfm), and an *actual* airflow rate capacity of 28,554 cfm. The last testing and balancing of the HVAC system occurred after the laboratory was constructed. Ventilation (the induction of outdoor air) is afforded by an air–handling unit (AHU) numbered AC–33 located in a mechanical room on the third floor. The air intake for the AHUs located on the third floor, faces west of the building and has a pneumatically controlled damper to provide 100% outdoor air with no recirculation. Heating is provided by steam coils (using ethylene glycol) inside the AHU. Cooling was provided by chilled water coils located at a centralized physical plant. The air filtration system consists of prefilters with an efficiency of 30% and final filters with an efficiency of 85%. Prefilters were changed every two months while primary filters were changed every six months. The HVAC system also has the capacity of humidifying and dehumidifying to maintain a 45% humidity level in the laboratories. An auxiliary exhaust unit (manually controlled by an On/Off switch in the Hematology area of the laboratory) was used to create negative pressure in the laboratory. Exhaust for biological safety cabinets and exhaust hoods present in the laboratory was ducted to the roof (the exhaust stacks serving laboratory hoods extended 5–6 feet above the adjacent roof line). General maintenance on the HVAC system is performed every six months. Chlorine packets were present in the water condensate pan during the evaluation to control growth of microorganisms.

EVALUATION METHODS

On June 12 –13, 1996, the initial site visit included a series of measurements for carbon dioxide (CO_2), temperature, and relative humidity (RH). The HVAC system serving the Pathology Laboratory was evaluated with respect to its maintenance and performance. The inspection focused on the general

cleanliness of the AHU and the location of potential air contaminant sources (i.e., emission stacks) on the roof that might entrain into the air intake. Ventilation measurements were made to determine volumetric and velocity airflow at each supply and exhaust diffusers in the laboratory. The Chemical Hygiene Plan, Material Safety Data Sheets (MSDS) and all manufacturers' information for office and laboratory equipment were reviewed to identify potential sources of machine emissions (i.e., ozone from laser printers). On June 24, 1996, area air sampling was performed for particulates and vacuum bulk samples were collected to characterize the settled particulates on work surfaces and equipment.

The following information describes the instrumentation and sampling and analyses used to measure environmental factors during the investigation.

Respirable Particulates: Airborne respirable particulate concentrations were measured using the following two methods: (1) direct reading instrumentation, and (2) gravimetric analysis of a filter sample. Real–time respirable particulate concentrations were measured by using a GCA Environmental Instruments Model RAM–1 monitor. This portable, battery–operated instrument assesses changes in airborne particle concentrations via an infrared detector, centered on a wavelength of 940 nanometers (nm). At a flowrate of 2 Liters per minute (Lpm), indoor air first passes through a cyclone preselector, then through a detection cell, operating on a 0–2 milligrams per cubic meter (mg/m^3) range with a 32–second time constant that yields a minimum detectable concentration (MDC) of 0.001 mg/m^3.

Six area air samples for total particulates were collected in the Hematology and Chemistry areas of the lab for a period of about 5 ½ hours. In accordance with NIOSH sampling and analytical method 0500[(1)], air samples were collected on pre–weighed polyvinyl chloride (PVC) filters using sampling pumps calibrated at a flowrate of 3 Lpm. Samples were analyzed gravimetrically with a limit of detection (LOD) of 0.02 mg per filter. Field blanks were blindly submitted for quality assurance.

Five vacuum samples for surface particulates were collected from workstations, laboratory equipment, and window sills. After grinding and thorough mixing to ensure homogeneity, portions of each bulk sample were qualitatively analyzed by polarized light microscopy (PLM) at magnifications of 100, 200 and 400X. This analysis was performed to determine the composition of settled particulates.

Carbon Dioxide (CO_2): Real–time CO_2 concentrations were measured using a Gastech Model RI–411A portable CO_2 meter. This portable, battery–operated instrument monitors CO_2 (range 0 to 4975 parts per million [ppm]) by non–dispersive infrared absorption with a sensitivity of 25 ppm. Instrument zeroing and calibration were performed before and after use.

Temperature and Relative Humidity: Real–time temperature and relative humidity (RH) measurements were made using a Vaisala, Model HM 34, battery–operated meter. This meter is capable of providing direct readings for dry–bulb temperature and RH ranging from –4 to 140°F and 0 to 100%, respectively. Instrument calibration is performed monthly using primary standards.

Ventilation Inspection and Measurements: A Shortridge® Flow Hood model MN 86BP was used to determine the volumetric air flow of each ceiling supply and exhaust diffusers in the laboratory. Air velocity measurements of supply–air diffusers were made at occupant level (6 feet above the floor) using a hot–wire anemometer. Ventilation smoke tubes were used to evaluate air flow patterns at laboratory entrances to determine whether the laboratory was under positive or negative pressure with respect to adjacent areas.

EVALUATION CRITERIA

General

A number of published studies have reported a high prevalence of symptoms among occupants of office buildings.[2–6] NIOSH investigators have completed more than 1500 investigations of the indoor environment in a wide variety of settings. The majority of these investigations have been conducted since 1979.

The symptoms reported by building occupants have been diverse and usually not suggestive of any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, unusual fatigue, varying degrees of itching or burning eyes, irritations of the skin, nasal congestion, dry or irritated throats, and other respiratory irritations. Typically, the workplace environment has been implicated because workers report that their symptoms lessen or resolve when they leave the building.

Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building–related occupant complaints.[7,8] Among these factors are imprecisely defined characteristics of HVAC systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.[2–5] Reports are not conclusive as to whether increases of outdoor air above currently recommended amounts are beneficial.[9] The American Society of Heating, Ventilating and Air–Conditioning Engineers (ASHRAE) suggests outdoor air requirements for laboratories of 20 cubic feet per meter (cfm) per person. However, rates lower than this amount appear to increase the rates of complaints and symptoms in some studies.[10,11] Design, maintenance, and operation of HVAC systems are critical to their proper functioning and provision of healthy and thermally comfortable indoor environments. Indoor environmental pollutants can arise from either outdoor or indoor sources.[12]

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related to the occurrence of symptoms than the measurement of any indoor contaminant or condition.[13] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[14,15]

Less often, an illness may be found to be specifically related to something in the building environment. Some examples of potentially building–related illnesses are allergic rhinitis, allergic asthma, hypersensitivity pneumonitis, Legionnaires' disease, Pontiac fever, carbon monoxide poisoning, and reaction to boiler corrosion inhibitors. The first three conditions can be caused by various microorganisms or other organic material. Legionnaires' disease and Pontiac fever are caused by *Legionella* bacteria. Sources of carbon monoxide include vehicle exhaust and inadequately ventilated kerosene heaters or other fuel–burning appliances. Exposure to boiler additives can occur if boiler steam is used for humidification or is released by accident.

Problems that NIOSH investigators have found in the non–industrial indoor environment have included poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals from office furnishings, machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and outside air pollutants; comfort problems due to improper temperature and relative humidity conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job–related psychosocial stressors. In most cases, however, no cause of the reported health effects could be determined.

Standards for industrial environments are established, however, none exists specifically for the non–industrial indoor environments. NIOSH, the Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards or recommended

limits for occupational exposures.[16–18] With few exceptions, pollutant concentrations observed in the office work environment fall well below these published occupational standards or recommended exposure limits. The ASHRAE has published recommended building ventilation design criteria and thermal comfort guidelines.[19,20] The ACGIH has also developed a manual of guidelines for approaching investigations of building–related symptoms that might be caused by airborne living organisms or their effluents.[21]

Measurement of indoor environmental contaminants has rarely proved to be helpful, in the general case, in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proven relationship between a contaminant and a building–related illness. However, measuring ventilation and comfort indicators such as CO_2, temperature, and relative humidity are useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems.

Particulates, not otherwise classified

Often the chemical composition of the airborne particulate does not have an established occupational health exposure criterion. It has been the convention to apply a generic exposure criterion in such cases. Formerly referred to as nuisance dust, the preferred terminology for the non–specific particulate ACGIH Threshold Limit Value (TLV®) criterion is now *"particulates, not otherwise classified (n.o.c.),"* [or *"not otherwise regulated"* (n.o.r.) for the OSHA permissible exposure limit (PEL)].

Dust particles smaller than 2.5 micrometers (μm) in diameter are generally associated with combustion source emissions. The greatest contributor to indoor dust is environmental tobacco smoke (ETS). In buildings where tobacco smoking is not allowed, respirable dust levels are influenced by outdoor particle concentrations and minor contributions from other indoor sources. In buildings with oil, gas, or kerosene heating systems, increased dust concentrations associated with the heating sources may not be important. Respirable particles, defined as those less than 10 μm in diameter (PM_{10}), are a combined result of combustion, soil, and mechanical dust generators. When indoor combustion sources are not present, indoor particle concentrations generally fall well below the Environmental Protection Agency's (EPA) ambient PM_{10} standard of 0.15 mg/m^3 averaged over a 24–hour period.[22] NIOSH has used this ambient criteria to evaluate particulate concentrations in non–industrial environments.

Carbon Dioxide

Carbon dioxide is a normal constituent of exhaled breath and, if monitored, can be used as a screening technique to evaluate whether adequate quantities of outside air are being introduced into an occupied space. ASHRAE's most recently published ventilation standard, ASHRAE 62–1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for laboratories and office spaces.[19] Maintaining the recommended ASHRAE outdoor air supply rates when the outdoor air is of good quality, and there are no significant indoor emission sources, should provide for acceptable indoor air quality.

Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300–350 ppm). Carbon dioxide concentration is used as an indicator of the adequacy of outside air supplied to occupied areas. When indoor CO_2 concentrations exceed 800 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected.[23] Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased. It is important to note that CO_2 is not an effective indicator of ventilation adequacy if the ventilated area is not occupied at its usual level.

Temperature and Relative

Humidity

Temperature and RH measurements are often collected as part of an indoor environmental quality investigation because these parameters affect the perception of comfort in an indoor environment. The perception of thermal comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperature.[24] Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. The American National Standards Institute (ANSI)/ASHRAE Standard 55–1992 specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally acceptable.[20] Assuming slow air movement and 50% RH, the operative temperatures recommended by ASHRAE range from 68–74°F in the winter, and from 74–79°F in the summer. The difference between the two is largely due to seasonal clothing selection. In separate documents, ASHRAE also recommends that RH be maintained between 30 and 60% RH.[24,25] Excessive humidities can support the growth of microorganisms, some of which may be pathogenic or allergenic.

RESULTS AND OBSERVATIONS

According to the microscopic analyses, the five bulk settled particulate samples consisted of cellulose (paper), synthetic fibers, paint pigments, glass fibers, rodent hair, insect parts, halite (salt), calcite, and quartz (all listed in order of decreasing abundance). Although the six gravimetrically–analyzed air samples for particulates revealed concentrations below the MDC of 0.02 mg/m^3, qualitative analyses detected particles of halite, paint pigments, gypsum, cellulose synthetic fibers, calcite, and quartz (listed in order of decreasing abundance). Direct–reading measurements of suspended particulates revealed concentrations in the range of 0.02 to 0.04 mg/m^3, below EPA's ambient PM_{10} of 0.15 mg/m^3.[1] Carbon dioxide concentrations were measured up to 450 ppm, well within the recommended guideline of 800 ppm for indoor environments. Temperature measurements ranged from 70°F to 73°F, and RH measurements ranged from 59% to 68%. In combination, temperature and RH were not within ASHRAE's thermal comfort guidelines for optimal and acceptable ranges for building occupants.

A visual inspection of the AHU housing showed no signs of standing water, visible microbial growth, debris or damaged insulation. Although air filters showed some signs of dust, they were not excessively soiled. Outdoor air dampers were fully opened and in operable condition. The mechanical room that housed the AHU appeared clean and had no signs of chemical storage. An inspection of the outdoor air intakes identified no sources of entrainment within 50 feet such as exhaust stacks or loading docks. Roof exhaust stacks serving laboratory hoods were extended 5–6 feet above the adjacent roof line. Many HVAC designers feel 10 to 15 feet will provide enough height to breach the recirculation cavity on most roofs.[26] In this case, however, the height of stacks did not appear to be an issue because the air intakes for the laboratory and other areas of the building were located more than 50 feet away on the third–floor level, west of the building. Prevailing winds typically come from the west and southwest directions, allowing little chance for re–entrainment of stack exhausts.

According to the American National Standard Institute laboratory ventilation standard Z9.5–1992,[27] supply–air velocities at 6 feet in height above the floor should be less than half (preferable a) the face velocity of the exhaust hoods. For instance, exhaust hoods in the Pathology laboratory all have face velocities of about 100 feet per minute (fpm). Therefore, the required supply air velocities should be no more than 50 fpm, preferable 33 fpm when measured 6 feet above the floor. This standard

[1] The EPA air quality standard for particulates of 0.15 mg/m^3 was established based on a sampling period of 24 hours.

was established to prevent supply air from creating cross drafts that affect the efficacy of exhaust hoods. In the case of this survey, supply air velocities of nearly five times more than hood face velocities are likely to create cross drafts at hoods. When a supply–air diffuser creates a cross draft with a velocity greater than an exhaust hood's face velocity, a pressure difference is created that may cause contaminants to escape from the hood. This may explain why workers occasionally smelled chemical odors.

The design of the laboratory's ventilation system was intended to provide a negative pressure with respect to other areas of the hospital. The use of the auxiliary exhaust fan was essentially responsible for creating this negative pressure. Workers reported turning off the auxiliary exhaust on occasions when drafts at the entrance of the Lab Receiving area created thermal discomfort (too cold, drafty). When the auxiliary system was turned–off, an imbalance in the ventilation system was created that resulted in positive pressure at the entrance points, particularly at the Lab Receiving area.

DISCUSSION AND CONCLUSIONS

Considering laboratory workers had experienced no episodes of eye or upper airway irritation prior to occupying the newly constructed Pathology Laboratory, NIOSH investigators suspected gypsum dust exposure as a potential cause of workers' health complaints. Gypsum, commonly found in wallboard construction, is hygroscopic (having an affinity to water) and known to act as a drying agent to the eyes and upper airway, thus prompting irritation.[28] Gypsum particles were identified on each of the air samples collected during the follow–up visit, but were not identified in the bulk samples. It is speculated that less loading on air filters allowed easier identification of individual particles during analyses.

Although real–time measurements and integrated sampling results gave no indication of a particulate problem within the laboratory during the NIOSH investigation, other factors were identified that indicate the contrary. Visible particulates were observed on nearly all ceiling exhaust diffusers and laboratory analytical equipment. Most air filters for laboratory instruments, especially those of the portable air cleaners, appeared to be heavily soiled with particulates. These are signs of either inadequate air filtration or insufficient housekeeping. In addition to providing a more healthful work environment, it is good practice to maintain the laboratory free of excess dust and dirt that may pose contamination to biological specimens or analytical reagents.

Although not presented as an issue initially, discussions with workers revealed their displeasure of the thermal comfort problems (too cold) at workstations directly below slot supply–air diffusers where high velocity air was measured. This is conceivable since the slot diffusers were emitting high velocities of air (up to 480 fpm) into the occupant space, thus causing drafts or a cooling effect on workers. It is theorized that high velocity air created turbulence in the occupant zone that helped settled particulates become airborne, thus resulting in worker inhalation exposure.

According to employee reports, a window located in the Chemistry area of the laboratory was prone to leak during heavy rainfall. This window also has had a history of leaking antifreeze from an unidentified source on the next level above. Although employees reported no health complaints associated with these leaks, they did express concern about the potential for contamination of biological specimens at chemistry workstations.

Prior to the completion of this HHE final report, a NIOSH investigator made a follow–up telephone call to hospital management to report analytical results. It was learned that after the follow–up site visit management had implemented the preliminary recommendations offered by NIOSH during the closing meeting. Preliminary recommendations

included a thorough cleaning of the laboratory to remove accumulated dust on surfaces and equipment, as well as correcting ventilation deficiencies. Since these remedial actions were performed, management has received no other complaints regarding worker health.

RECOMMENDATIONS

1. Visible particulates should be removed from work surfaces, equipment, and exhaust diffusers throughout the Pathology Laboratory, preferable by using a vacuum cleaner equipped with high–efficiency particulate air (HEPA) filters for effective results. A good housekeeping program should be implemented to prevent further dust buildup. If dust accumulation throughout the laboratory persists for weeks or months after housekeeping has been improved, then the filtration system should be evaluated for its efficacy.

2. A proactive approach of inspecting for dust accumulation throughout the laboratory and other areas of the hospital will help identify IEQ problems before employee health complaints arise. If feasible, the use of higher efficiency filters should be considered. Ensure air filters are properly positioned in filters racks to obtain an adequate seal to minimize leakage around filters that may allow particulates to enter the occupant space.

3. Supply–air slot diffusers should be modified to lower the air velocity in the occupant zone, especially where diffusers are located near exhaust hoods. This can be accomplished either by balancing the system to achieve air velocities in the occupant zone no more than 50 fpm, or by installing deflectors at each diffuser to reduce air velocity and evenly distribute supply–air. A qualified HVAC person should be consulted for best results.

4. The dehumidifier and humidifier mechanisms of the HVAC system should be evaluated to ensure they are operating properly to maintain humidity levels at about 45% as reportedly intended. If 45% humidity is achieved and temperature levels are maintained at a range of 70°F to 73°F (as measured during the NIOSH initial site visit), the laboratory environment will be within ASHRAE's thermal comfort guidelines. In addition, it is important to maintain humidity levels within ASHRAE guidelines because high humidity (greater than 70%) environments may harbor microorganisms on organic dust particles, thus potentially resulting in occupant exposures.[25]

5. To keep the laboratory under negative pressure as designed, the auxiliary exhaust fan should be operating whenever the laboratory is in use, and workers should be informed about the importance of keeping it on to comply with ANSI's laboratory guidelines. Drafts created by the exhaust fan at the Lab Receiving entrance, which cause thermal discomfort to workers in that area, may be explained by the *unplanned* airflow concept, meaning airflow at that entrance was not anticipated by the designer. There is the possibility that too much exhaust is provided that creates drafts at unplanned airflow locations. If so, laboratory exhaust airflow should be reduced to decrease drafts at the entrance, while maintaining negative pressure in the laboratory. Further investigation is recommended to resolve this issue.

6. Some exhaust stacks on the roof were measured at 5 to 6 feet from the roof line. To protect maintenance and construction employees working near exhaust stacks, a rule of thumb suggests in no case should stacks be less than 7 feet in height.[25]

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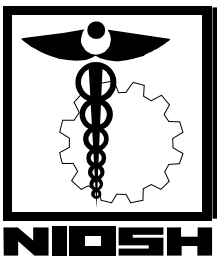

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