Evaluation of Indoor Environmental Quality in a Medical Office Building

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from employees at a medical office building. The employees were concerned about exposure to sewer gas.

What We Did

- We visited the facility in April 2013.
- We measured hydrogen sulfide levels throughout the building.
- We inspected the building's heating, ventilation, and air-conditioning system.
- We measured carbon dioxide, temperature, and humidity levels inside the building.

What We Found

- No hydrogen sulfide was detected in the building.
- The outdoor air intake for the ventilation system was near a manhole where safety and health staff had previously measured a release of hydrogen sulfide.
- We found problems with duct dampers, heat pumps, and the computerized control system.
- More outdoor air is needed in some areas for ventilation and odor control.
- Temperature and humidity were within recommended levels.
- Air flowed from the restrooms into the hallways. As a result, restroom odors could migrate into offices and common areas.
- Some floor drain traps and plumbing fixtures did not work and gave off odors. After our evaluation, maintenance staff installed drain-trap devices to prevent odors from being released.

We evaluated the indoor environmental quality and monitored for hydrogen sulfide, a component of sewer gas, in an office building. We found problems with the ventilation system. We also found odor sources within and near the building such as dry drain traps and manholes. We made recommendations to fix the ventilation problems and eliminate the odor sources.

What the Employer Can Do

- Inspect the building's heating, ventilation, and air-conditioning system and make necessary repairs.
- Test and balance the heating, ventilation, and air-conditioning system.
- Increase the amount of outdoor air coming into the building.
- Remove plumbing fixtures and seal drain pipes that are not used, such as urinals in women's restrooms.
- Replace the remaining cast-iron pipe with polyvinyl chloride piping.
- Create an employee and employer health and safety committee. Hold regular meetings.

What Employees Can Do

- Report odors to managers as soon as they occur.
- Do not open windows in the building.
- Participate in the health and safety committee.

Abbreviations

°F	Degrees Fahrenheit
ACGIH®	American Conference of Governmental Industrial Hygienists
ANSI	American National Standards Institute
CFM	Cubic feet per minute
CFR	Code of Federal Regulations
FPM	Feet per minute
HVAC	Heating, ventilation, and air-conditioning
IEQ	Indoor environmental quality
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PPM	Parts per million
REL	Recommended exposure limit
TWA	Time-weighted average
WEEL	Workplace environmental exposure levels

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Introduction

The Health Hazard Evaluation Program received a confidential request from employees at a medical office building in Kentucky. Employees were concerned about indoor environmental quality (IEQ) and exposure to sewer gas, specifically hydrogen sulfide. We visited the building in April 2013 to conduct an IEQ evaluation. We shared preliminary findings and recommendations with employer and employee representatives in May 2013.

Background

The four-story concrete masonry office building was constructed in the 1960s and originally commissioned as a military barracks. The building had been renovated twice since then, once to house a military police department and a second time, in 2012, to serve as a medical office building. At the time of our evaluation, the three main floors of the building had been converted into offices and exam rooms. Half of the basement level remained a dirt floor crawl space, and the other half was storage and mechanical rooms. The building sat in a valley and was within 30 feet of a 24-inch sanitary sewer trunk line that carried sewage from approximately 60% of the surrounding area toward the wastewater treatment facility. The building was surrounded by manholes that had been previously identified as sources of odors by former occupants as well as the health and safety department. Figure 1 is an aerial photograph of the office building with surrounding sewer lines and manholes identified.

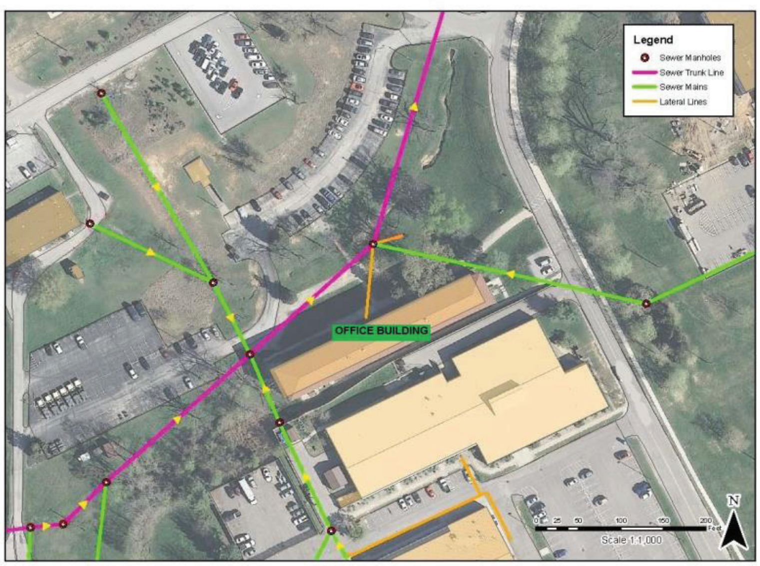

Figure 1. Aerial view of building and location of sanitary sewer lines and manholes. Photo by Veolia Environmental Service.

Ventilation Overview

The office building was equipped with a variable air volume, forced air heating, ventilation, and air-conditioning (HVAC) system. The system used multiple heat pumps mounted above a drop ceiling on each floor. The HVAC system air handling unit was located in a mechanical room in the southeast corner of the basement. Outdoor air entered the ventilation system through louvered vents on the outside wall of the basement mechanical room. A geothermal heat pump preconditioned (heated or cooled) the incoming air before directing it to a main supply duct that supplied air to each floor at the east end of the building above a drop ceiling. This preconditioned air fed the individual heat pump units using the airspace above the drop ceiling as a plenum.

Individual heat pumps conditioned and filtered the air that was supplied to the offices in different zones on each floor. Temperature and airflow control for each zone was achieved by using dampers within the heat-pump zone duct that opened or closed depending on the thermostat setting within each office. In addition, the dampers were controlled by a computerized HVAC monitoring system in a separate building. The building's HVAC system was a single pass design that did not use recirculated air. Instead, air delivered to the offices and hallways was exhausted through rooftop exhaust fans and also passively through building entryways.

Methods

Odor History

We reviewed reports of offensive odor problems, reviewed health and safety monitoring records, and held teleconferences with office staff and personnel from the health and safety and facilities engineering departments.

Hydrogen Sulfide

We monitored for hydrogen sulfide in the hallway on three floors and the basement with BW Gas Alert Extreme monitors. Each monitor was attached to the wall approximately 4 feet above the floor at the midpoint of each hallway. Each monitor recorded a measurement every minute over the course of six consecutive days. We also measured hydrogen sulfide using a Scott Safety™ Scout portable gas monitor during a tour of the building. This monitor can also detect methane and was used to determine if methane was present in a restroom drain trap.

Indoor Environmental Quality, Ventilation, and Comfort Indicators

We measured carbon dioxide concentrations, temperature, and relative humidity at multiple locations on each floor with a TSI Q-Trak™ Plus instrument. These IEQ ventilation and comfort indicators provide information about the operation of the HVAC systems. Spot measurements were taken throughout the building between 12:00 pm and 1:00 pm on April 12, 2013, while employees were working within the building. No windows were open at the time of our evaluation.

Ventilation Assessment

We toured multiple offices on each floor, all mechanical equipment rooms, and the basement to familiarize ourselves with the layout and components of the ventilation system. We also reviewed ventilation plans with the engineering staff. We measured air velocity in feet per minute (fpm) at each restroom exhaust vent with a TSI VelociCalc Plus® thermoanemometer. We then calculated the airflow rate in cubic feet per minute (cfm) for the exhaust vents by multiplying the air velocity by the total area of the vent cover slots. We used ventilation smoke to visualize airflow direction in the offices and restrooms relative to the hallways. We also used ventilation smoke to visualize airflow from ceiling registers, plenum air returns, and outdoor supply air ducts to determine whether these components were functioning properly.

Results and Discussion

Odor History

This building has a history of odor complaints dating back to when it was used as a barracks in the 1960s. Most of the building's current plumbing was the original cast iron waste and vent piping. Cast iron piping can become brittle and crack with age. In addition to normal corrosion of cast iron pipe, the building had experienced seismic activity over the years, which increased the risk of cracking brittle pipes. Once a cast iron pipe is cracked, sewer gas can easily escape and migrate throughout the building via natural air currents or by the HVAC system. Also, plumbing augers (drain snakes) were used in the past to clear blockages within the cast-iron pipes. Plumbing augers can create or increase cracks in brittle pipe. Health and safety representatives reported that maintenance personnel commonly drilled holes into walls and pipes for inspection purposes and attempted to seal the holes with duct, masking, or electrical tape. Over time, the tape fell off the pipe leaving an open hole for sewer gas to escape.

The building was remodeled for use as offices during the summer of 2012. As part of this renovation, the restrooms on each floor were divided into men's and women's facilities. At the time of our evaluation, urinals in the second and third floor women's restrooms had not been removed or sealed, although the water supply had been turned off. On the second and third floors, restroom showers were left in place and window mounted exhaust fans were removed and replaced with a continuous flow vent which exhausts to the roof.

Employees on the second and third floors reported sewer gas odors in offices and hallways after relocating to the building in the fall of 2012. Employees also reported that they noticed sewer odors near toilets, urinals, and floor drains. The health and safety, public works, engineering, and maintenance departments responded to these complaints. The health and safety staff measured hydrogen sulfide concentrations inside and surrounding the building. A hydrogen sulfide concentration of 33 parts per million (ppm) was measured above the manhole on the south west corner of the building. Hydrogen sulfide concentrations inside the building ranged from 0.01 to 0.05 ppm. The concentrations measured inside the building were well below the most conservative occupational exposure limits. However, the odor threshold for hydrogen sulfide in air ranges from 0.0005 to 0.3 ppm [ATSDR 2006]. This means that building occupants can smell hydrogen sulfide well before levels reach occupational exposure limits. Additional information regarding hydrogen sulfide, health effects, and occupational exposure limits can be found in Appendix A.

When inspecting restroom fixtures, maintenance personnel discovered that wax rings had not been installed under some floor mounted toilets. In response, floor mounted restroom fixtures throughout the building were inspected and new wax rings were installed where needed. Additional inspection revealed a rooftop exhaust fan was not operating. In response, all rooftop exhaust fans were inspected and repaired if necessary. To reduce the possibility of sewer gases migrating into the occupied space from the soil beneath the building, a plastic vapor barrier was installed in the lower level crawl space.

Public works staff conducted smoke tests to identify cracks and leaks within the cast iron plumbing. They introduced smoke to each section of the plumbing system and watched for the release of smoke on each floor. No smoke was observed escaping from pipes or sections of wall; however, smoke odor was detected near the center of the second floor hallway. Office employees working in this area had submitted multiple odor complaints. Maintenance staff opened a section of this wall, found a crack in a segment of the cast-iron pipe, and replaced two of the central cast-iron pipe vent risers with polyvinyl chloride pipe. The repairs were limited to the central sewer vent risers between the second and third floors of the building because complaints of odors had not been received from first floor occupants. However, at the time of our evaluation, multiple first floor employees complained of similar sewer gas odors.

A contactor was hired to inspect and maintain the sanitary sewer and storm water system. The contractor performed a closed circuit television inspection of the sanitary sewer trunk line that bordered the west side of the building. The survey covered 81 feet of pipe. Fractures and pipe joint separations were identified. The contractor used a cured-in-place pipe lining method to repair and seal these cracks and separations. To prevent sewer gas from migrating through the vented manhole covers, all manhole covers were replaced with solid lids equipped with rain guards that allow rain water to enter yet prevent sewer gases from escaping (Figure 2).

Figure 2. Manhole with rain guard intact. Photo by Veolia Environmental Service.

Hydrogen Sulfide

We monitored for hydrogen sulfide from April 11–17, 2013. Hydrogen sulfide is only one component of sewer gas. Other gases, such as nitrogen oxides, methane, ammonia, and sulfur dioxide, could also be present among other sewer gas components. We chose to monitor for hydrogen sulfide as a marker for sewer gas because it is easy to measure and has a recognizable odor. Our data logging monitors measured and recorded the hydrogen sulfide concentration every minute for 6 days. Hydrogen sulfide was not detected during the entire sampling period. The limit of detection for these monitors is 1 ppm. Therefore, these results indicate that hydrogen sulfide, if present, was in concentrations below 1 ppm, which is well below occupational exposure limits.

Indoor Environmental Quality, Ventilation, and Comfort Indicators

IEQ issues are common and have been extensively evaluated by the National Institute for Occupational Safety and Health (NIOSH). Symptoms associated with IEQ concerns typically reported by building occupants are diverse and are usually not suggestive of a particular medical diagnosis or readily associated with a causative agent. The building environment is often suspected of causing symptoms, especially where occupants report symptoms lessening or resolving when not at the workplace. Suggested causes can include HVAC system deficiencies, exposures to low concentrations of multiple chemicals, odors, microbiological contamination, psychological factors (stress), and physical factors such as temperature, lighting, and noise. ASHRAE has published ventilation design criteria and guidelines for the thermal comfort of occupants. Measuring ventilation and comfort indicators such as carbon dioxide, temperature, and relative humidity have proven useful in evaluating the performance of HVAC systems.

At the time of our evaluation the outdoor temperature was 54 degrees Fahrenheit (°F) and the relative humidity was 38%. Although windows in the offices could be opened, none were open during this evaluation. The American National Standards Institute (ANSI)/ ASHRAE Standard 55-2010: Thermal Environmental Conditions for Human Occupancy specifies conditions in which at least 80% of the building occupants are comfortable. Temperature ranges from 68°F to 74°F in the winter and from 73°F to 79°F in the summer are recommended. The difference in this temperature range accounts for changes in building occupants' seasonal clothing selection. In addition, ASHRAE recommends humidity levels be kept below 65%. Fifty percent relative humidity is ideal. Excessive humidity can cause discomfort and promote the growth of molds, bacteria, and dust mites. Humidity levels below 30% can cause dry eyes and irritate sinus and mucous membranes. Temperature and relative humidity measurements fluctuated slightly from office to office throughout the building. Table 1 lists ranges for temperature and relative humidity for specific heat pump zones. Most of the levels we measured were within the recommended ASHRAE temperature and relative humidity thermal comfort guidelines [ANSI/ASHRAE 2010].

Carbon dioxide is a component of exhaled breath and is not considered a building air pollutant unless it was generated and released as a contaminant from a production process. In office buildings it is an indicator of whether sufficient quantities of outdoor air are being introduced into an occupied space to dilute human bioeffluents (body odor) [ANSI/ASHRAE 2010]. We measured carbon dioxide concentrations in offices throughout the building, excluding offices that were locked or otherwise inaccessible.

We measured outdoor carbon dioxide concentrations that ranged from 395 to 408 ppm. The ANSI and ASHRAE guidelines for acceptable indoor environmental quality recommend that steady state carbon dioxide concentrations indoors not exceed 700 ppm above outdoor levels [ANSI/ASHRAE 2013]. Our measurements showed indoor carbon dioxide concentrations ranging from 600 to 1,600 ppm. Carbon dioxide concentrations in offices with heat pump zones on the west end of the building were noticeably higher than in other areas of the building. The carbon dioxide concentration generally increased as we moved further away from the supply air duct discharge point on the east end of each floor. This finding indicates that the outdoor air supplied to each floor was not uniformly distributed throughout the building. Table 1 gives ranges for carbon dioxide concentrations for specific heat pump zones.

Table 1. Ranges for carbon dioxide concentration, temperature, relative humidity (April 12, 2013)

Heat pump zones (by office numbers)	Carbon dioxide concentrations (ppm)	Temperature (degrees F)	Relative humidity (%)
100–105 West end	—*	—*	—*
106–114 Center	745–778	70–71	32–33
107–115 Center	599–658	71–72	32–34
118–128 East end	662–900	64†–71	35–47
117–127 East end	606–620	70–72	34–37
200–210 West end	1,154†–1,207†	74–76	32–36
201–211 West end	1,170†–1,508†	74–76	35–37
214–222 Center	921–1,123†	74–85†	32–35
213–221 Center	917–1051	75–77	30–32
226–236 East end	773–876	73–76	31–33
223–233 East end	754–930	74–77	31–33
300–310 West end	1,137†–1,613†	74–76	37–40
301–311 West end	1,034–1,270†	74–76	34–36
314–322 Center	853–798	74–76	33–35
313–327 Center	858–961	72–74	35–36
326–336 East end	679–890	73–75	33–37
329–339 East end	715–855	72–74	33–37

*Indicates that offices were unavailable for monitoring

†Indicates concentration above ASHRAE recommended guidelines

Ventilation Assessment

Using ventilation smoke we found that numerous offices across all floors had no airflow from ceiling registers regardless of whether the thermostat was set for heating or cooling. This finding indicates that the dampers were not operating properly or the HVAC monitoring system was set to override the thermostat. We also found that the supply air duct on the third floor had no airflow even though the damper was set fully open. Following our evaluation, the engineering department reported that maintenance personnel had inspected all heat pump units and system dampers and repaired those that were inoperable.

The building's HVAC system outdoor air intake was on the south west corner of the building on the lower level (Figure 3). Hydrogen sulfide measurements taken at the manhole near the southwest corner of the building indicated that an appreciable concentration (33 ppm) was escaping from the manhole. The manhole was within 40 feet of the outdoor air intake. Because of the proximity of the outdoor air intake to this manhole, sewer gas could enter the outdoor air intake, especially if prevailing winds blew escaped sewer gas toward the intake. In addition, a two-story retaining wall that ran the entire length along the back of the building formed an alley way. Thus, odors released from the manhole could be channeled towards the air intake. These configurations and conditions may explain some of the odors reported by building occupants. Following our evaluation, management reported that this manhole was sealed with an epoxy grout to prevent further sewer gas release.

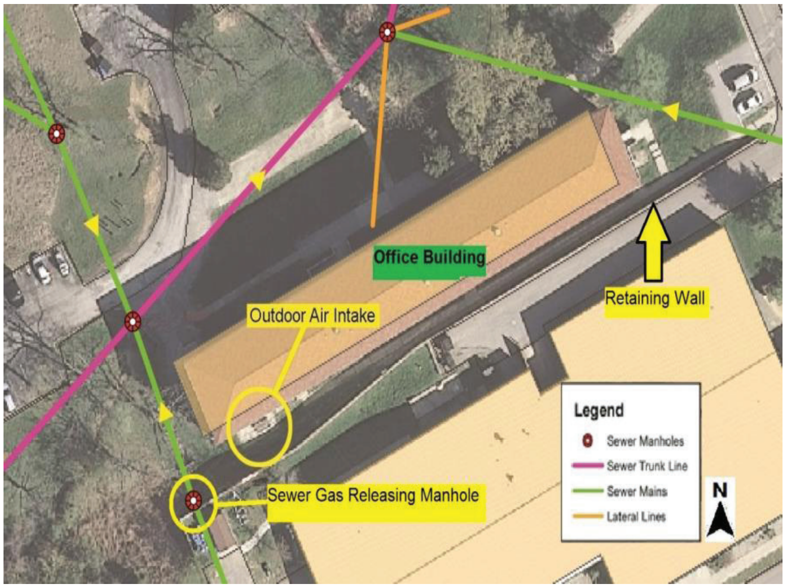

Figure 3. Location of building outdoor air intake and odor generating manhole. Photo by Veolia Environmental Service.

Ventilation smoke testing revealed that restrooms on the second and third floor were under positive pressure relative to the hallway. This pressure differential may allow odors from the restrooms to migrate to the hallways and subsequently into offices and common areas. The custodial closets on each floor where housekeeping chemicals and equipment were stored were properly maintained under negative or neutral pressure. Results for the ventilation smoke testing are shown in Table 2.

When pressure imbalances are created, HVAC system performance and occupant comfort can be adversely affected. Building occupants reported that they adjusted the thermostat in their office or opened a window to improve their comfort. Opening windows allows unconditioned air to enter the work area and may provide a pathway for odors and contaminants to enter the building. In addition, open windows may affect air pressure differentials between offices, hallways, and restrooms and could cause odors and other air contaminants to unintentionally migrate throughout the building. Opening windows also compromises the ability of the computer-controlled HVAC system to regulate temperature and relative humidity.

Table 2. Air pressure differential between janitors' closets, restrooms, and adjacent hallways (April 12, 2013)

Room	Air pressure relationship to adjacent hallway
First floor janitor's closet	negative
First floor women's restroom	negative
First floor men's restroom	negative
Second floor janitor's closet	negative
212 restroom	positive
224 restroom	negative
Third floor janitor's closet	neutral
312 restroom	positive
324 restroom	negative

We measured air velocity in feet per minute at each restroom exhaust vent. ANSI/ASHRAE Standard 62.1-2013: Ventilation for Acceptable Indoor Air Quality has exhaust ventilation guidelines for restrooms in commercial buildings [ANSI/ASHRAE 2013]. A flow rate of at least 20 cubic feet per minute (cfm) is recommended for a continuous flow exhaust vent in a restroom. All measured restroom exhaust flow rates were above the ASHRAE minimum guideline for adequate restroom ventilation. Although the restroom exhaust flow rates were adequate, the supply airflow to several restrooms was high enough to positively pressurize the rooms relative to the hallway.

Additional Findings

We examined restroom plumbing and fixtures throughout the facility. We found dry drain traps in the second and third floor restrooms. A noticeable sewer gas odor was present in these restrooms. Maintenance personnel informed us that despite regular addition of water and mineral oil, water in the drain traps evaporates, resulting in odor infiltration. We measured for methane and hydrogen sulfide at the floor drain with a Scott Safety™ Scout portable gas monitor. None was detected. The instrument's limit of detection was 0% for methane and 1 ppm for hydrogen sulfide.

After our evaluation, maintenance staff installed drain-trap devices in all floor drains throughout the building. The devices are made of an elastomeric material and allow water to flow down the drain; they roll up in the absence of flowing water to prevent the migration of sewer gas back into the rooms. Employees and managers reported a decrease in odors after the drain-trap devices were installed.

Conclusion

Our evaluation found several odor sources and ventilation deficiencies that likely contributed to the odor complaints reported by employees. Carbon dioxide concentrations measured at multiple locations were above ASHRAE guidelines. The HVAC system outdoor air intake was located adjacent to a manhole known to emit odors which may also have contributed to odors in the building. Several restrooms were positively pressurized relative to the adjacent hallway allowing odors to migrate to other areas in the building. Various components of the HVAC system were malfunctioning including heat-pump units, individual office air vents/diffusers, and multiple duct dampers. Upon inspection, we found drain traps in several restrooms to be dry and emitting odors. Following our visit, management reported that drain-trap devices were installed on all floor drains, HVAC components were inspected and repaired, cracks in the sanitary sewer lines were repaired, and manholes were sealed or replaced with solid lids and rain-guard devices. Management reported that odor complaints have decreased since our evaluation.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage management and employees to use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at this building.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix A). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and personal protective equipment may be needed.

Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Remove unused plumbing fixtures from bathrooms. Cap and seal unused pipes.
2. Replace cast-iron plumbing with polyvinyl chloride pipe.
3. Continue remediating sanitary sewer lines surrounding the facility. Additional segments of the line should undergo camera inspection. If structural deficiencies are located, the pipe segments should be sealed using the same method previously used.
4. Adjust the HVAC system to ensure that adequate amounts of outdoor air are introduced into the building according to ASHRAE guidelines. Additional air exchanges can alleviate stuffiness complaints from employees in these areas [ANSI/ASHRAE 2013]. Conduct additional monitoring to ensure that carbon dioxide levels have been reduced to within ASHRAE guidelines under all ventilation conditions

encountered with the variable air volume system.

5. Test and balance the HVAC system to ensure that the system is operating as designed and that offices, closets, and restrooms are properly pressurized.

Administrative Controls

The term administrative control refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Continue regularly scheduled inspections of HVAC systems and promptly correct any problems. Establish a baseline performance standard for airflow and pressure balance between offices and hallways, and compare subsequent inspection results to the baseline standard. If changes or adjustments are made to the HVAC system, recheck performance.
2. Ensure that the computerized HVAC control system is functioning properly.
3. Notify employees if sewer or plumbing repairs will take place during business hours. If odors are expected during such work, schedule the work after normal business hours.

Appendix A: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended occupational exposure limits (OELs) for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limit or ceiling values. Unless otherwise noted, the short-term exposure limit is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- The U.S. Department of Labor Occupational Safety and Health Administration (OSHA) permissible exposure limits (29 CFR 1910 [general industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH recommended exposure limits (RELs) are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Other OELs commonly used and cited in the United States include the TLVs, which are recommended by American Conference of Governmental Industrial Hygienists (ACGIH), a professional organization, and the workplace environmental exposure levels (WEELs), which are recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed

by committee members of these associations from a review of the published, peer-reviewed literature. These OELs are not consensus standards. TLVs are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2014]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2013].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/Gefahrstoffdatenbanken/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 1,500 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause 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))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs. Below we provide the OELs and surface contamination limits for the compounds we measured, as well as a discussion of the potential health effects from exposure to these compounds.

Hydrogen Sulfide

Hydrogen sulfide is a flammable, colorless gas that occurs naturally and as a result of man-made processes. Hydrogen sulfide, one of the principal components of sewer gas, has a characteristic rotten egg odor and can be poisonous at high concentrations [ATSDR 2006]. Exposures to low levels of hydrogen sulfide may cause irritation of the eyes, nose, or throat. Inhalation is the primary route of exposure. Although deaths due to breathing large amounts of hydrogen sulfide have been reported, no health effects have been found in humans exposed to typical environmental concentrations (0.00011–0.00033 ppm) [ATSDR 2006]. OSHA has established an acceptable ceiling concentration of 20 ppm for workplace exposure to hydrogen sulfide, with a maximum level of 50 ppm allowed for 10 minutes maximum duration if no other measurable exposure occurs. NIOSH has set a maximum REL ceiling value of 10 ppm for 10 minutes maximum duration. The American Conference of Governmental Industrial Hygienists (ACGIH) has set a threshold limit value (TLV) of 1 ppm.

NIOSH, OSHA, and the ACGIH have published regulatory standards and occupational exposure limits for industrial work environments. However, standards specific to non-industrial work environments, such as an office building, do not exist. This presents a challenge when interpreting results because contaminants in non-industrial work environments generally fall well below occupational exposure limits. Occupational exposure limits do not provide guidance for indoor environmental quality evaluations because they allow exposures that are higher than non-industrial workers expect to tolerate and no occupational exposure limits exist for many known indoor air contaminants.

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Availability of Report

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