Evaluating a Persistent Nuisance Odor in an Office Building – Maryland

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The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].

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Abbreviations

ASTM	American Society for Testing and Materials
CRI	Carpet and Rug Institute
CO	Carbon monoxide
CO_2	Carbon dioxide
DNPH	2,4-Dinitrophenylhydrazine
GC/MS	Gas chromatography, mass spectrometry
H_2S	Hydrogen sulfide
HHE	Health hazard evaluation
HPLC/MS	High performance liquid chromatography, mass spectrometry
HVAC	Heating, ventilating, and air-conditioning
IEQ	Indoor environmental quality
MERV	Minimum efficiency reporting value
mg	Milligrams
mL/min	Milliliters per minute
MDC	Minimum detectable concentration
MQC	Minimum quantifiable concentration
NAICS	North American Industry Classification System
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
ppm	Parts per million
RH	Relative humidity
TD	Thermal desorption
VOCs	Volatile organic compounds

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a technical assistance request for a health hazard evaluation from a federal government property manager. The request concerned nausea; headache; and eye, nose, throat, and respiratory irritation, among employees at an office leased by the property manager. Employees believed that a persistent chemical odor in the office might be responsible for these symptoms.

What NIOSH Did

- We visited the office on December 15–16, 2010.
- We measured temperature, relative humidity (RH), carbon dioxide, and carbon monoxide (CO).
- We took air samples for hydrogen sulfide (H_2S), formaldehyde, and volatile organic compounds (VOCs) in the office. We also took air samples for the same substances in two nearby businesses for comparison.
- We took one paint sample and two carpet bulk samples from the office and analyzed them for VOCs.
- We looked for water damage.
- We checked the heating, ventilating, and air-conditioning (HVAC) system in the office.
- We talked with employees about the odor in the office.
- After our visit, we mailed a survey to all office employees asking if they noticed any odors at work or had any health concerns.

What NIOSH Found

- The HVAC system did not bring in much outdoor air to the occupied office areas.
- The HVAC fan ran only when heating or cooling was needed. This can cause stagnant air in the office.
- Odors from the bathrooms and locker rooms could enter the office.
- Temperature and RH levels were within suggested guidelines.
- No H_2S was detected, and CO concentrations were low in the office.
- Although formaldehyde concentrations were low, some employees still could have irritation symptoms.
- Six out of eight employees described an odor in the office as similar to glue, adhesive, plastic, chemical, or a cleaner.
- One employee reported occasional headaches caused by the odor and two reported burning eyes.

- VOCs in air samples collected in the carpeted areas of the office matched VOCs from the two bulk carpet samples. These VOCs were not found in air samples collected from non-carpeted areas in the office or the two nearby businesses that were not carpeted.
- The odor is likely caused by VOCs from the carpet adhesive and backing.

What Managers Can Do

- Talk with the building owner about removing the carpet and adhesive to eliminate the source of odor.
- Prepare the concrete slab floor appropriately before any new flooring is installed.
- Set the HVAC fan to run continuously.
- Test the efficiency of the HVAC system outdoor air intake.
- Exhaust the bathrooms and locker rooms to keep odors from entering the office.
- Limit the use of air fresheners, room deodorizers, and cleaners.
- Record any work-related complaints or problems from employees and quickly investigate these issues and record any actions taken.

What Employees Can Do

- Tell management if you have concerns about the odor of cleaning products used in office or odors from renovation projects.
- Avoid using air fresheners and room deodorizers. The odor from these can irritate some people.

Summary

NIOSH was asked to evaluate a persistent odor in an office. We found that air samples from the carpeted areas of the office had the same VOCs that were found in bulk samples of carpet and carpet adhesive. Eye irritation and headaches reported by some of the employees are consistent with exposure to the VOCs found in the air. To eliminate the odor, we recommend removing the carpet and adhesive from the office.

NIOSH investigators evaluated a federal government office on December 15–16, 2010, after receiving a technical assistance request from the property manager. The office employees believed a chemical odor present since the building opened in 2007 was responsible for their symptoms, which included nausea; headache; and eye, nose, throat, and respiratory irritation. We measured temperature, RH, CO_2, and CO in the office. We took air samples for H_2S, formaldehyde, and VOCs in the office and in two nearby businesses for comparison. We took carpet and paint samples from the office and analyzed them for VOCs. We also looked for water damage in the office and checked the HVAC system. We surveyed employees about odors in the office, asking them to describe the odors and health concerns they associated with the odor.

The CO_2 concentrations inside the office had a range of 750–1160 ppm, while the CO_2 concentrations outdoors had a range of 420–440 ppm. Usually, CO_2 concentrations are used to determine the adequacy of an HVAC system, but not for sparsely occupied areas such as this office. However, with only two employees working, the fact that indoor CO_2 concentrations were nearly triple the outdoor concentration indicated the HVAC system was likely not introducing much outdoor air into the occupied office areas. Temperature in the office had a range of 71–75 °F and RH had a range of 21–28%, compared to outdoor temperature, which had a range of 18–27 °F and RH at 20%. These levels are within the recommended thermal comfort guidelines for the winter season. The CO concentrations were low (0–0.1 ppm) and were likely caused by the entrance door to the office being located adjacent to a parking lot. No water damage in the office was identified.

No H_2S was detected (detection limit was 1 ppm) and formaldehyde was less than 0.02 ppm in the office and ranged up to 0.03 ppm in the adjacent businesses. The formaldehyde concentrations are below some exposure guidelines for office spaces (0.05–0.10 ppm) but above other recommended indoor air levels for offices (0.003 ppm). In area air samples collected from carpeted areas of the office, we identified VOCs (specifically alcohols) that were similar to VOCs from a headspace analysis of carpet taken from the office. These VOCs were not found in air samples taken in non-carpeted areas of the office or from two nearby businesses that were not carpeted. This suggests that either the carpet or incompletely cured carpet adhesive may be the source of the odor. Incomplete curing of the carpet adhesive can happen when the concrete slab onto which the carpet was installed had excessive alkalinity and water vapor.

We also surveyed employees about odors in the office, asking them to describe the odors and any health concerns they associated with the odor. All eight office employees returned surveys. Six reported having smelled an odor at the office, and four still smelled the odor. The odor was described as a glue, adhesive, plastic, chemical, or cleaner smell. Two employees mentioned burning of their eyes and one mentioned occasional headaches during work, which are irritation symptoms typically associated with indoor VOC and formaldehyde exposures.

The residential-style electric HVAC system serving the office was well maintained and had been modified in 2010 to introduce outdoor air. Under some conditions the bathrooms and locker rooms were under positive pressure in relationship to the office, meaning that odors from the bathrooms and locker rooms could enter into the occupied office spaces.

We recommended removing the carpet and adhesive to eliminate the source of the odor. We recommended running the HVAC system continuously to minimize stagnant air, evaluating the HVAC system to determine if enough outdoor air is being introduced into the occupied spaces, and to determine if bathrooms are under negative pressure. We recommended that employees minimize other sources of odor, like air fresheners. We also recommended that employees be informed in advance about any remediation efforts, such as carpet and adhesive removal and the installation of new flooring.

Keywords: NAICS 926150 (Regulation, Licensing, and Inspection of Miscellaneous Commercial Sectors), odor, irritation, office, VOCs, indoor environmental quality, IEQ, ventilation, carpet, carpet adhesive

Introduction

On December 15–16, 2010, we conducted an HHE at a federal government office. The HHE was conducted in response to a technical assistance request from the property manager for the office and concerned reports of eye, nose, throat, and respiratory irritation, as well as nausea and headache, among employees at the office leased by the property manager. Employees believed that a persistent chemical odor in the office might be responsible for their symptoms.

During the visit we met with employer and employee representatives to discuss the HHE request. We observed the office layout and workplace conditions, and we spoke with employees who were in the office that day. We measured temperature, RH, CO_2, and CO in the office. We also took area air samples for H_2S, formaldehyde, and VOCs in the office and in two nearby businesses for comparison. We collected two bulk samples of carpet from the office and analyzed them for VOC emissions. An interim letter, dated January 19, 2011, was sent to the property manager and an employee representative. We also sent each office employee a survey asking if they smelled an odor while at work and if they had health concerns associated with this odor.

Assessment

The office is in a multitenant two-story commercial building that was constructed in 2007. The approximately 3,000-square-foot office is on the first floor and contains cubicles separated by fabric-covered dividers, one private office, a conference room, an employee break room (equipped with a refrigerator, microwave, sink, wall cabinets, and small table), and two restrooms. Each restroom has an adjoining locker and shower area. One room in the office is used by employees to store and calibrate air monitoring equipment (battery-powered air sampling pumps, respirable dust cyclone samplers, and combustible gas meters) used by employees during mine surveys. No chemicals other than liquid detergent (used to clean the Tygon® tubing and cyclone samplers) and small (less than 100 liter) cylinders of calibration gas were used.

Although eight employees work out of the office, at the time of this evaluation only two employees were present the entire day (an office assistant and office supervisor). Most employees arrived early to calibrate their sampling equipment and then spent the remainder of their workday conducting field evaluations outside the office.

During a walkthrough survey of the office we looked for evidence of water damage, water incursion, visible mold, and other potential

Assessment (continued)

Figure 1. The air sampler inlets were positioned 5 feet above the floor to measure hydrogen sulfide, formaldehyde, and VOCs.

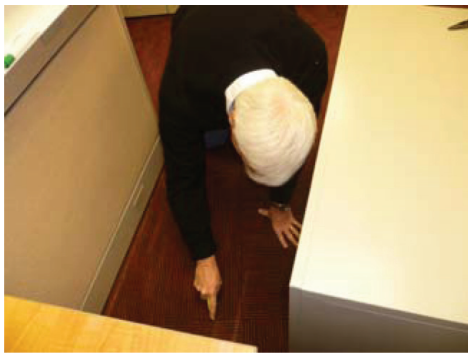

Figure 2. NIOSH investigator collecting a bulk carpet sample.

IEQ problems. Spot measurements were taken for CO_2, temperature, RH, and CO using a Q-TRAK™ Plus Indoor Air Quality Monitor, Model 8554 (TSI Incorporated, Shoreview, Minnesota). We collected air samples for H_2S, formaldehyde, and VOCs in the office conference room, at a work station, and in a non-carpeted information technology room. For comparison, we also sampled for H_2S, formaldehyde, and VOCs in two nearby businesses where there had been no odor complaints. Both businesses had separate HVAC systems and were not carpeted. Figure 1 depicts the equipment used in these areas to sample for H_2S, formaldehyde, and VOCs.

Area air samples for H_2S were collected using a direct-reading GasAlert Extreme meter (BW Technologies America, Arlington, Texas). This meter continuously measures H_2S in the range of 0–100 ppm. Formaldehyde area air samples were collected using DNPH tubes (Part No. 226-120, SKC Inc., Eighty Four, Pennsylvania) at a nominal flow rate of 200 mL/min. The samples were analyzed using HPLC/MS detection according to NIOSH Method 2016 with an MDC of 0.005 ppm and MQC of 0.0011 ppm [NIOSH 2011].

Area air samples for VOCs were collected using TD tubes and charcoal tubes. The TD tubes, each containing three beds of sorbent material (90 mg Carbopack Y, 115 mg Carbopack B, and 150 mg Carboxen 1003), were collected at a nominal flow rate of 50 mL/min and then qualitatively analyzed by NIOSH Method 2549 using GC/MS detection [NIOSH 2011]. Side-by-side charcoal tube samples were collected at a nominal flow rate of 200 mL/min. We quantitatively analyze the charcoal tube samples only if the qualitative TD tube results suggest specific air contaminants are present in concentrations sufficient for quantitative analysis. Because this was not the case in this evaluation, the charcoal tubes were not analyzed.

We collected one paint sample and two carpet bulk samples from the office to determine if the carpet or paint may have been the source of the persistent odor. One carpet sample taken from beneath a filing cabinet had adhesive residue that was still tacky to the touch (Figure 2). The other carpet sample, taken from a more exposed area in the office conference room, had no tacky adhesive residue. The paint sample was taken from the conference room wall. Each bulk sample was placed in a separate sealable plastic bag for transport. The bulk samples were analyzed in the NIOSH laboratory by inserting a TD tube into the plastic bag to sample the air at room temperature (a technique commonly described as a headspace analysis). An air sample was also collected from a clean, unused plastic bag to correct for any background

Assessment (continued)

chemicals that may be present. Headspace samples were collected at a nominal flow rate of 100 mL/min and analyzed per NIOSH Method 2549 [NIOSH 2011]. In addition, a small portion of the tacky carpet adhesive from the bulk carpet sample was placed in a quartz TD tube, secured at both ends with glass wool, heated to 50 °C for 10 minutes in the TD unit, and analyzed by GC/MS.

We used ventilation smoke tubes to evaluate air patterns in the office and restrooms. We examined the residential style (demand mode) HVAC system, including the type of air filters used and the outdoor air intakes installed by the building's owner in 2010.

Because we only had the opportunity to speak with three office employees during our site visit, we mailed an IEQ survey form to each office employee. This form confidentially asked the employees about their work history, how frequently they were in the office, whether they had ever smelled an odor while at work, and if they have had any work-related health concerns or discomfort.

Results and Discussion

IEQ Comfort Indicators

The CO_2 concentrations in the office had a range of 750–1160 ppm; outdoor concentrations had a range of 420–440 ppm. We compare indoor and outdoor CO_2 concentrations to determine if indoor occupied spaces are adequately ventilated [ANSI/ASHRAE 2010a]. Because the office was sparsely occupied during our evaluation, comparing CO_2 concentrations is not a good indicator of the adequacy of the ventilation system. However, considering that with only two employees working, indoor CO_2 concentrations were nearly triple the outdoor concentration, the HVAC system was not introducing much outdoor air into the occupied office areas.

Temperature in the office had a range of 71–75 °F and RH had a range of 21–28%, compared to an outdoor temperature, which had a range of 18–27 °F and RH of approximately 20%. These temperature and RH values are within the American Society of Heating, Refrigerating, and Air Conditioning Engineers recommended thermal comfort guidelines for the winter season [ANSI/ASHRAE 2010b].

Hydrogen Sulfide, Formaldehyde, and Carbon Monoxide

No H_2S was detected; the limit of detection was 1 ppm. Formaldehyde concentrations inside the office remained consistent over the 2 days of this evaluation at 0.02 ppm, while the concentration outside the office was estimated at 0.00019 ppm (between the MDC and MQC). The indoor formaldehyde concentrations in the two nearby businesses had a range of 0.02–0.03 ppm. These formaldehyde concentrations were below a recommended exposure guideline of 0.10 ppm for office spaces, which has been adopted by several organizations [EPA 1991; NIOSH 1991]. Although this guideline is intended to provide reasonable protection against irritation (e.g., irritation of the eyes, nose, or throat) in the normal population, hypersensitivity reactions may occur at lower levels of exposure. A NIOSH researcher has recommended that a 0.05 ppm concentration of formaldehyde be used as a pre-occupancy guideline for NIOSH facilities [Wallingford 2009]. This recommendation is based in part on IEQ specifications developed for new office buildings by the State of Washington [State of Washington 1989]. A more conservative recommended indoor air level for formaldehyde (0.003 ppm) was suggested by Salonen et al. [2009]. Because formaldehyde concentrations inside the office were above 0.003 ppm, it is possible that some of the irritation symptoms in the office could be associated with indoor formaldehyde emissions. The CO concentrations were very low (0–0.1 ppm) and were likely due to vehicular traffic in the parking lot immediately adjacent to the office.

Volatile Organic Compounds

A pattern of VOCs identified as aliphatic oxy-compounds (possibly alcohols) were detected in area air TD samples collected from the carpeted areas of the office where the odor was reported by employees. These compounds eluted between n-octanol and n-decanol. The same VOC pattern was identified in headspace analyses of bulk carpet samples but not from the headspace of the bulk paint sample taken from the office. Further, the same VOC pattern identified in carpeted areas was not identified in the air samples taken in non-carpeted areas of the office or from two nearby businesses that were not carpeted. The bulk carpet sample obtained from beneath a filing cabinet in the office had a more distinct odor compared to the other carpet sample that was collected in a conference room, presumably because it had less opportunity to off-gas as compared to the more exposed carpeting. Some of the sticky adhesive from the back of the less exposed carpet

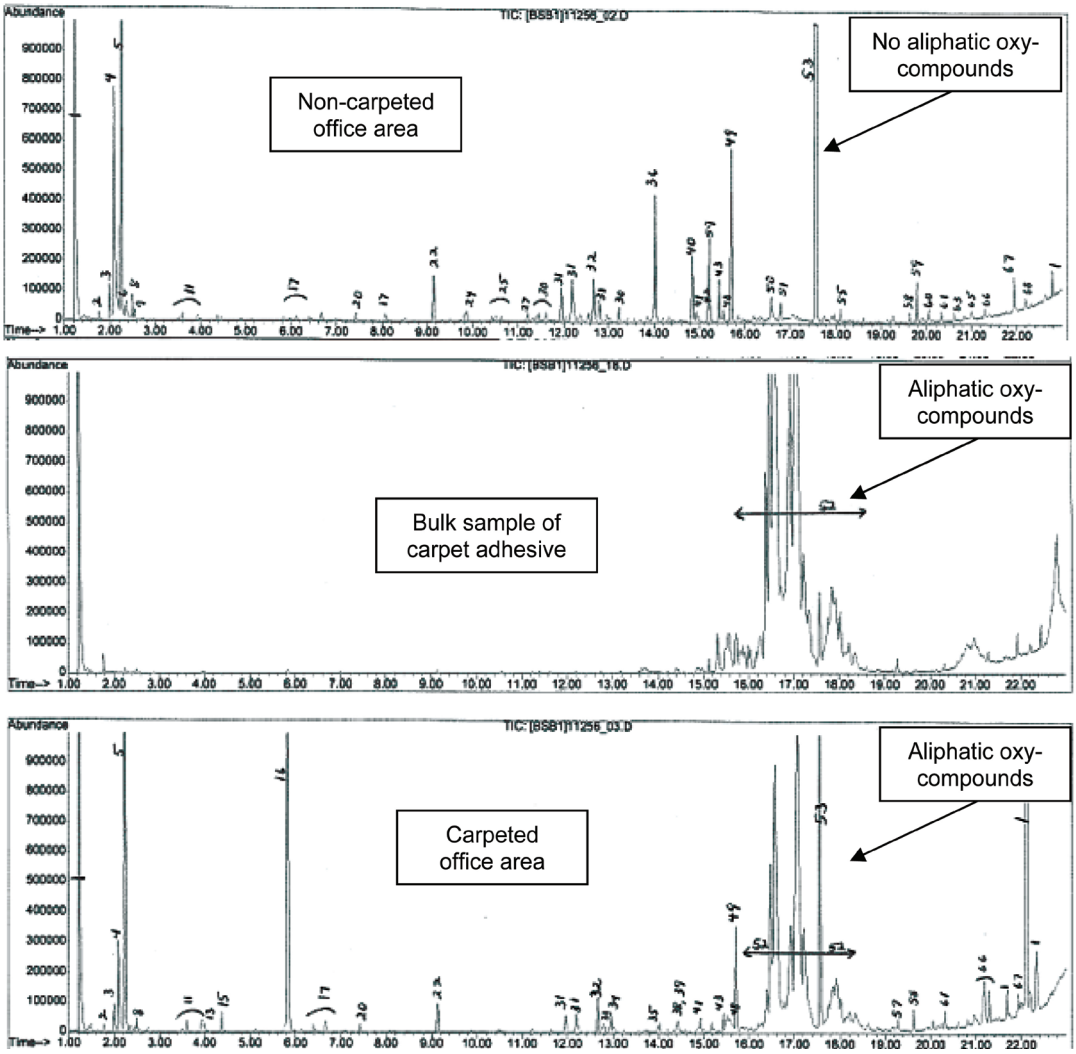

Figure 3. GC/MS chromatographs comparing air samples from carpeted and non-carpeted areas to the results from a headspace analysis of carpet adhesive.

sample was removed for headspace analysis. These same aliphatic oxy-compounds were the only ones detected in this sample, suggesting that the odor may be from the carpet adhesive and not the carpet backing. Figure 3 shows the GC/MS chromatographs from the analysis of air taken from carpeted and non-carpeted areas as well as the headspace analysis of carpet adhesive.

The presence of aliphatic oxy-compounds in air samples collected in the carpeted areas of the office along with the headspace analyses from the bulk samples of carpet and adhesive suggest that the incompletely cured carpet adhesive is the likely source of the odor in the office. However, we cannot conclusively exclude the carpet backing as an odor

contributor. Excessive alkalinity and water vapor from the concrete slab onto which the carpet was directly installed are known to cause hydrolysis of carpet backing and adhesive [Offermann et al. 2000]. Previous NIOSH investigations of odor complaints where carpet was installed over a concrete slab found similar VOCs [Wallingford 2002; Sylvain 2009]. Other researchers have suggested the odor may originate from the hydrolysis or other degradation of carpet square backing components, including incomplete curing of carpet adhesive due to the impermeable backing of carpet squares or hydrolysis of carpet adhesive by the moisture in the concrete slab beneath the carpet [McLaughlin and Aigner 1990]. The CRI has published guidelines specifying suitable environmental conditions, floor preparation, and testing of concrete subfloors prior to adhesive installations, and these guidelines may be used to address odor problems caused by incompletely cured carpet adhesive or hydrolysis of plasticizers from the carpet backing [CRI 2011].

VOCs are a large class of organic chemicals (i.e., containing carbon) that have a sufficiently high vapor pressure to allow some of the compounds to exist in the gaseous state at room temperature. It is widely recognized that airborne concentrations of many VOCs in office buildings are higher than concentrations in outdoor air because of numerous indoor sources of VOCs, and because the relatively low rates of outdoor air ventilation typically used in offices prevent the rapid dispersal of airborne contaminants [Daisey et al. 1994; Tucker 2000]. The many consumer products used in offices (such as cleaners, air fresheners, and insect repellents) contain and emit numerous VOCs as well as materials and products used in new construction, remodeling, and redecorating [Hodgson and Levin 2003].

IEQ studies have measured widely ranging VOC concentrations in indoor air, as well as differences in the mixtures of compounds present. However, concentrations are usually much lower than any occupational exposure standards, except in rare cases with unusual sources. A measurement of total VOCs has been used in some studies attempting to predict certain types of health effects, but results have been inconsistent [Molhave 1991; Levin 1998]. Currently no guideline or standard exists for VOCs in nonindustrial workplaces such as the office. The European community has revised the concept of total VOC measurement to include the identification and quantification of 67 specific chemicals [Levin 1998]. This is outlined in a report by the Nordic Committee on Building Regulations, which recommends 26 chemical guidelines and presents toxicologically based methodology for preparing more [Neilson et al. 1996]. Although important to IEQ research, these guidelines are still two-to-three orders of magnitude

higher than typical indoor VOC concentrations [Brown et al. 1994; Levin 1998].

Although office buildings were extensively studied in the 1980s and 1990s, few U.S. studies have been published since 2000 [Jia et al. 2010]. In the 1990s, VOC studies in offices were conducted in 12 buildings in northern California [Daisey et al. 1994]; 70 telecommunications offices, data centers and administrative offices across the United States [Shields et al. 1996]; and 100 representative office buildings nationwide [Apte and Daisey 1999; Girman et al. 1999; Brightman and Moss 2000]. Apte and Daisey [1999] reported that carpets are a common indoor source of VOCs. Upper respiratory and mucous membrane irritation (including the eyes, nose, and throat) and headache are the most frequently reported symptoms in office buildings with VOC exposures [Apte and Daisey 1999]. Hodgson and Levin [2003] reviewed indoor VOC concentrations measured in large office buildings in North America since 1990. Even though VOC concentrations in small offices generally have not been characterized, the review included large office buildings. A new methodology that classifies the relative importance of VOCs commonly present in indoor air with respect to their odor and sensory irritation potency and noncancer chronic toxicity was developed [Hodgson and Levin 2003]. Alcohols are one of the groups studied by Hodgson and Levin [2011] because these compounds have low odor thresholds. Interestingly, 1-octanol was an alcohol of interest because of its low odor threshold (0.7 parts per billion) and nasal pungency threshold (310 parts per billion); however, no OEL was deduced because 1-octanol has low toxicity [Hodgson and Levin 2011]. Odors in buildings caused by VOCs may not be of toxicological concern [Hogdson and Levin 2011]. Symptom prevalence is often decreased with increasing the per person ventilation rate [Seppänen et al. 1999].

Employee Surveys

All eight office employees completed surveys. Their tenure averaged 2.4 years (range of 0.8–3.5 years), and they averaged 4 days a week in the office (range of 2–5 days), working an average of 4.2 hours per day (range of 1.5–9 hours per day). Six employees reported having smelled an odor at the office, and four of them could still smell the odor. Employees described the odor as "like a glue or plastic," "cleaner or adhesive," "carpet glue smell," "chemical smell," and "plastic." Two employees associated burning of their eyes with the odor, while another employee reported occasional headaches. One employee reported symptoms that began in May 2008 and improved after the employee left the office. This person added that the smell was not as strong, and

the health concerns were not an issue any more. No employees reported having any other health concerns related to their work at the office.

Ventilation

The HVAC system in the office was an all electric, residential style (demand mode) system installed in 2007 when the building was completed. The HVAC system was well maintained, and the 1-inch thick pleated air filters (MERV 8) were in good condition and correctly installed. In 2010, the building owner connected the HVAC system to a duct that goes to an outside wall to introduce more outdoor air into the office and in turn alleviate the persistent odor. Other than from this modification, no outdoor air is introduced into the recirculating HVAC system beyond air that may leak in around the doors and windows. We did not observe any water damage in the office.

Using ventilation smoke tubes, we determined that the bathrooms and locker rooms did not remain under negative pressure in relationship to the office if (1) the exhaust ventilation fans in the bathroom/locker areas were not operating (note: the bathroom/locker room exhaust fan and lights were jointly controlled by a wall switch), or (2) the HVAC system fan for the office was operating (regardless of whether the bathroom exhaust fans were operating). This means that in either of these two situations, nuisance odors from the bathrooms and locker rooms could migrate into the office.

CONCLUSIONS

The persistent chemical odor in the office is likely associated with airborne VOCs, specifically aliphatic oxy-compounds (possibly alcohols), released from the carpet adhesive and/or the carpet backing. We reached this conclusion considering that these VOCs were found in air samples collected from carpeted areas of the office (the area with the persistent odor) and from headspace analyses obtained from two bulk carpet samples from the office. These same VOCs were not detected in air samples collected from two nearby businesses that were not carpeted and did not have any odor complaints.

Although these VOC exposures were not quantified, we estimate that they were below recommended occupational exposure levels because of the low response obtained from the TD technique used to identify them. VOCs even at low concentrations can be a nuisance odor to some individuals. Low levels of formaldehyde were also found in the office and in the two adjacent businesses and may be contributing to office employees' irritation symptoms. Eye, nose, throat, and respiratory

Conclusions (continued)

irritation, as well as nausea and headache are consistent with irritation due to VOC and formaldehyde exposure. However, these symptoms are also common to the general population and cannot be directly linked to specific work exposures.

Recommendations

Based on our findings, we recommend the actions listed below to create a more healthful workplace. We encourage the office to use a labor-management health and safety committee or working group to discuss the recommendations in this report 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 the office. Our recommendations are based on the hierarchy of controls approach. 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 may be needed.

Elimination and Substitution

Elimination or substitution of a toxic/hazardous process material is a highly effective means for reducing hazards. Incorporating this strategy into the design or development phase of a project, commonly referred to as "prevention through design," is most effective because it reduces the need for additional controls in the future. To eliminate the source of the odor, we recommend the following:

1. Remove the carpet and adhesive using a method that will not void the warranty for the replacement carpet or other floor covering. In particular, note that the CRI Carpet Installation Standard does not recommend the use of liquid adhesive removers on a concrete slab that will receive a new floor covering installed with adhesive [CRI 2011].
2. Hire a qualified independent company to test the concrete slab for alkalinity and moisture vapor emissions. The CRI Standard recommends that, as a minimum, testing companies should demonstrate verifiable experience in concrete moisture testing or be certified by a recognized organization [CRI 2011]. Testing must conform to ASTM Standards F-1869-04 and F-710-08 [ASTM 2004, 2008]. Written test results must be provided to the flooring contractor [CRI 2011].

3. Check the bare concrete slab for any noticeable odor. Individuals who reported health problems in the office should be offered the opportunity to check for odors prior to installing new flooring. If an odor is present, determine if concrete needs to be sealed.
4. If new carpeting is installed, wait until the cleaned concrete is dry, odor-free, and prepared according to the CRI Standard [CRI 2011]. We recommend following the carpet manufacturer's instructions. Manufacturers of low-emitting carpet squares are available at http://www.greenguard.org.
5. Many IEQ complaints occur in buildings undergoing renovation. The following NIOSH website describes the steps necessary to ensure acceptable IEQ during building renovation: http://www.cdc.gov/niosh/topics/indoorenv/ConstructionIEQ.html.
6. Minimize the use of air fresheners or room deodorizers, which could cause irritation to some sensitive individuals.

Engineering Controls

Engineering controls reduce exposures to employees by removing the hazard from the process or placing a barrier between the hazard and the employee. Engineering controls are very effective at protecting employees without placing primary responsibility of implementation on the employee.

1. Set the HVAC fan to run continuously.
2. Evaluate the ventilation in the bathrooms and locker rooms to make sure that these areas are maintained under negative pressure when the office is occupied. Refer to bathroom ventilation recommendations from ANSI/ASHRAE [2010a].
3. Evaluate the HVAC system to determine if the outdoor air intakes installed in 2010 are effective. Refer to recommendations regarding outdoor air intakes by ANSI/ASHRAE [2010a] and Mendell et al. [2006]. A qualified ventilation engineer should be consulted.

Administrative Controls

Administrative controls are management-dictated work practices and policies to reduce or prevent exposures to workplace hazards. The effectiveness of administrative changes in work practices for controlling workplace hazards is dependent on management commitment and employee acceptance. Regular monitoring and reinforcement is necessary to ensure that control policies and procedures are not circumvented in the name of convenience or production.

Recommendations (continued)

1. If carpet is replaced, inform office employees about the carpet removal and reinstallation project. Information on carpet removal, the concrete slab, the characteristics of the replacement carpet or flooring systems, and what to expect when the office is re-occupied should be provided to employees in a clear and timely manner.
2. Follow-up with employees to ensure that the remedial action has been effective.
3. Track and promptly investigate work-related complaints or problems reported by employees.

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