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Evaluating a Persistent Nuisance Odor in an Office Building

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Introduction

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. We met with employer and employee representatives, observed the office layout and workplace conditions, and spoke with employees. We measured temperature, relative humidity (RH), carbon dioxide (CO_2), and carbon monoxide (CO) in the office. For comparison, we also took general area air samples for hydrogen sulfide (H_2S), formaldehyde, and volatile organic compounds (VOCs) in the office and in two nearby businesses in the same building. We collected two bulk samples of carpet from the office and analyzed them for VOC emissions. We also sent each office employee a survey asking if he or she smelled an odor while at work and if he or she had health concerns associated with this odor.

Observations

The office is located in a two-story multi-tenant commercial building constructed in 2007. The approximately 3000-ft^2 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 surveys. No chemicals other than liquid detergent (used to clean the Tygon tubing and cyclone samplers) and small cylinders (less than 100 L) 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.

Assessment

During a walkthrough survey of the office we looked for evidence of water damage, water incursion, visible mold, and other potential indoor environmental quality (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 Inc., Shoreview, Minn.). The air sampler inlets for H_2S, formaldehyde, and VOCs were positioned 5 ft above the floor in the office conference room, at a workstation, 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 heating, ventilating, and air-conditioning (HVAC) systems and were not carpeted.

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 2,4-dinitrophenylhydrazine (DNPH) tubes (Part No. 226–120; SKC Inc., Eighty Four, Pa.) at a nominal flow rate of 200 mL/min. The samples were analyzed using high performance liquid chromatography/mass spectrometry (HPLC/MS) detection according to NIOSH Method 2016.[(1)] The minimum detectable concentration (MDC) was 0.0005 ppm, and the minimum quantifiable concentration (MQC) was 0.0011 ppm.

Area air samples for VOCs were collected using thermal desorption (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 gas chromatography and mass spectrometry (GC/MS) detection.[(1)] Charcoal tube samples were collected side by side with the TD tubes at a nominal flow rate of 200 mL/min. Our general practice is to 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.

We collected one paint sample and two bulk carpet 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. 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 chemicals that may be present. Headspace samples were collected at a nominal flow rate of 100 mL/min and analyzed per NIOSH Method 2549.[(1)] 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 min in the TD unit, and analyzed by GC/MS.

The HVAC system in the office was an all-electric, residential style (demand mode) system installed in 2007 when the building was completed. We used ventilation smoke tubes to evaluate air patterns in the office and restrooms. We examined the HVAC system, including the type of air filters used and the outdoor air intakes installed in the HVAC system by the building's owner in 2010, in response to the odor complaints. The only other source of outdoor air for the office was from air that leaked around doors and windows.

Because we had the opportunity to speak with only three office employees during our site visit, we mailed a survey to each office employee. Confidentially, we 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

IEQ Comfort Indicators

Temperature in the office had a range of 71–75°F, and RH was in the range of 21–28%, compared to an outdoor temperature that had a range of 18–27°F and RH of approximately 20%. The CO_2 concentrations in the office had a range of 750–1160 ppm; outdoor concentrations had a range of 420–440 ppm. We did not observe any water damage in the office.

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 0.020 ppm, while the concentration outside the office was estimated at 0.00019 ppm (below the MDC). The indoor formaldehyde concentrations in the two nearby businesses had a range of 0.020–0.030 ppm. 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 (charcoal tubes were not analyzed). 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 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 1 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.

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 was well maintained, and the 1-inch-thick pleated air filters (MERV 8) were in good condition and correctly installed.

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.

Discussion

Temperature and RH values in the office were within the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommended thermal comfort guidelines for the winter season.[2] We usually compare indoor and outdoor CO_2 concentrations to determine if indoor occupied spaces are adequately ventilated.[3] 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.

Formaldehyde concentrations in the office building and two nearby businesses were below a recommended exposure guideline of 0.10 ppm for office spaces, which has been adopted by several organizations.[4,5] 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.[6] This recommendation is based in part on IEQ specifications developed for new office buildings by the State of Washington.[7] A more conservative recommended indoor air level for formaldehyde (0.003 ppm) was suggested by Salonen et al.[8] 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 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.[9] Previous NIOSH investigations of odor complaints where carpet was installed over a concrete slab found similar VOCs.[10,11] 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.[12] The Carpet and Rug Institute (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 from incompletely cured carpet adhesive or hydrolysis of plasticizers from the carpet backing.[13]

Apte and Daisey[14] 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.[14] Hodgson and Levin[15] reviewed indoor VOC concentrations measured in office buildings in North America since 1990. 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.[15,16] Alcohols are one of the groups studied by Hodgson and Levin[16,17] because these compounds have low odor thresholds. Interestingly, 1-octanol was an alcohol of interest because of its low odor threshold (0.7 ppb) and nasal pungency threshold (310 ppb); however, no occupational exposure limit (OEL) was deduced because 1-octanol has low toxicity.[17] Odors in buildings caused by VOCs may not be of toxicological concern.[17] Symptom prevalence is often decreased with increasing the per person ventilation rate.[18]

Conclusion

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. The office was not properly ventilated, and this could have contributed to the intensity and persistence of the odor.

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 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

To reduce the odor, we recommended improving the ventilation in the office by following the recommendations listed under the Engineering Controls section. If the odor persists even after ventilation improvements, then changing the carpeting following recommendations listed under the Elimination and Substitution section could be considered. Recommendations listed under Administration Controls are to ensure prevention and management of health complaints during the intervention process.

Engineering Controls

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.[3]
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[3] and Mendell et al.[19] A qualified ventilation engineer should be consulted.

Elimination and Substitution

1. Remove the carpet and adhesive using a method that will not void the warranty for replacement carpet or other floor covering. In particular, note that the CRI Technical Bulletin states that use of liquid adhesive removers may adversely affect the new adhesive or new floor covering, thus voiding applicable warranties.[13]
2. Hire a qualified independent company to test the concrete slab for alkalinity and moisture vapor emissions. CRI Standard 104 states, “As a minimum, testing agencies or individuals must demonstrate verifiable experience in vapor emission testing or be certified by recognized organizations, such as the Institute of Inspection, Cleaning and Restoration Certification or the equivalent.”[13] Testing must conform to American Society for Testing and Materials (ASTM) Standards

F1869–04 and F710–08.[20,21] Written test results must be provided to the flooring contractor.[13]

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, 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 steps 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 that could cause irritation to some sensitive individuals.

Administrative Controls

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 reoccupied 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.

Acknowledgments

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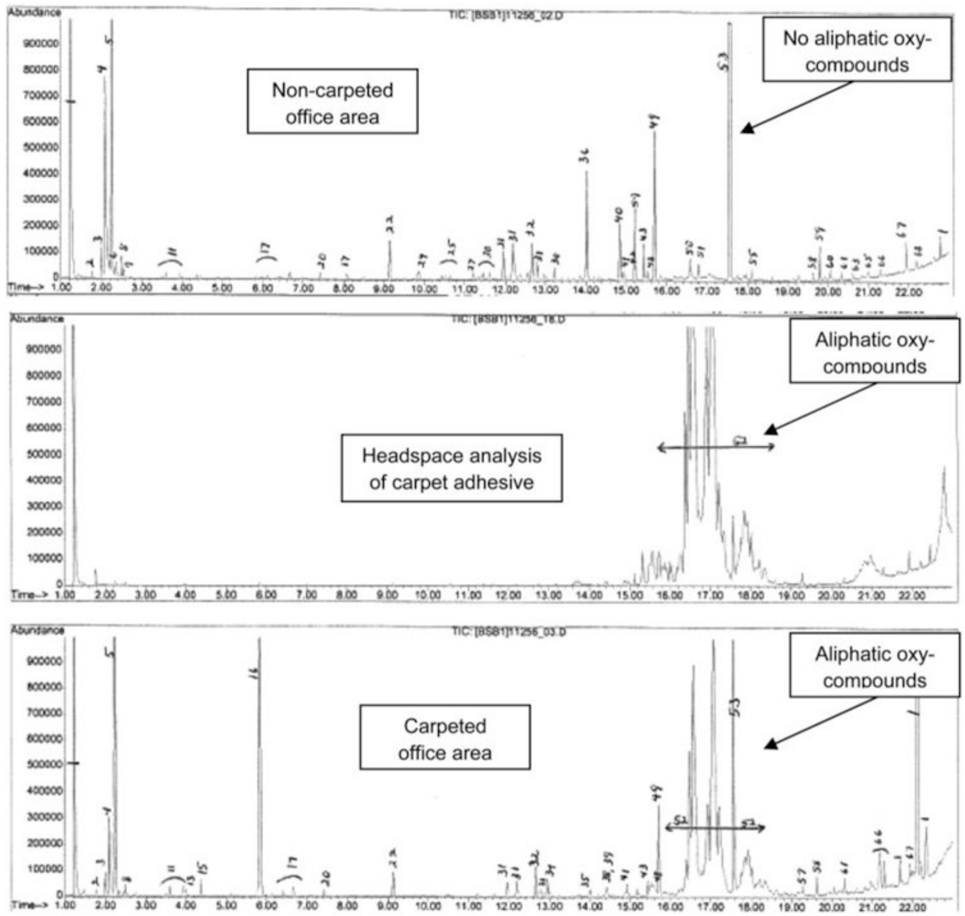

Figure 1.

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