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Case Studies

Indoor Environmental Quality "From The Ground Up"

Dawn Tharr, Column Editor

Report by Daniel Almaguer and Thomas Wilcox

A request was received by the National Institute for Occupational Safety and Health (NIOSH) from a local Health Commissioner for a NIOSH health hazard evaluation to assist in locating the source and identifying an odor present in an office building in southern Ohio. Employees reported a petroleumlike odor in the office that they felt was intensifying over time. Several employees also reported health symptoms which they associated with the presence of the odor.

Background

Employees first occupied the office space of concern in August 1991. Six employees spent most of the 40-hour workweek in the office. A field staff of 55 employees reported to the office on a weekly basis; however, most spent only a few hours per week in the office. Six of the 55 field staff were supervisors who spend 1 to 2 days per week in the office.

The office was located in the south building of a two building rental office complex. The structure was built on a graded lot and the eastern half of the office was located below grade level. The offices of concern occupied the southernmost suite of the ground floor.

The building was constructed of brick, with all electric utilities. Each office suite was equipped with a dedicated heating and cooling system. A heat pump was used for heating and cooling the offices of concern.

The air handling unit (AHU) for the heat pump was located in a closet in the middle of the suite and contained a coil, fan, and electric heating element. Return air entered the base of the AHU through floor-level openings in the plenum and adjoining walls of the closet. The outside air intake was located on the south side of the building about 8 to 10 feet above the pavement. Outside air was provided through a 6-inch air duct connected to the AHU and entered the AHU through another face of the plenum.

Water from the cooling coil condensate pan drained to a small sump pump. The sump pump outlet was connected to a sewer pipe located in the closet. This pipe ran from the floor of the suite on the second floor through the floor of the office of concern. A cleanout was located in the sewer drain pit about 3 feet above the floor. Plumber's putty and oakum were used to seal the gap between the sewer drain pipe and concrete floor slab.

In the late fall of 1991, employees began to notice a "petroleum" type odor, which continued to worsen with time. In January 1992, the local Health Commissioner was asked to investigate the problem, and in February, the Health Commissioner requested the assistance of the city Health Department. In March 1992, the building management installed an exhaust fan and vented the exhaust air directly to the outside of the building.

Methods

In March 1992, NIOSH investigators conducted general area air sampling for volatile organic chemicals (VOCs). To evaluate airborne concentrations of VOCs present in the general workroom air, samples were collected at two locations within the office of concern, in an office on the second floor of the building, and in the adjacent office suite. At each sample location two samples were collected; one thermal desorption tube for qualitative screening of VOCs and one charcoal tube for quantitative analysis of VOCs. Thermal desorption tube and charcoal tube samples were analyzed via gas chromatography/mass spectrometry (GC/MS).

Additionally, an HNu® photoionization analyzer was used to locate sources of VOCs within the office and hallway areas of the building.

In April 1992, NIOSH investigators returned to conduct employee interviews. The seven employees present, who spent a significant portion of their work week in the office, were interviewed. Further air sampling was also conducted using the HNu photoionization analyzer.

Results and Discussion

Industrial Hygiene Sample Results

Air Sample Results

Total ion chromatograms of qualitative air samples collected inside the office of concern did not identify any particular petroleum-based product; however, all were very similar and showed a distinctly different pattern from the chromatograms of samples collected in other office suites of the building. For comparison purposes the analytical laboratory collected air samples over the headspace of bulk kerosene and bulk diesel fuel samples. Based on the resulting chromatograms, the field samples appeared to contain some type of petroleum distillate that was similar to the bulk diesel fuel sample; however, the absence of distinct peaks for aromatics (benzene, toluene, and xylenes) in all of the field samples differentiate these samples from the kerosene and diesel fuel headspace samples.

Quantitative sample results indicated the air in the offices of concern contained a complex mixture of hydro-

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carbons ranging from C_4 to C_{12}. These sample results were reported as C_4 to C_6 (concentrations were quantified using *n*-hexane as the standard) and C_7 to C_{12} (concentrations were quantified using *n*-octane as the standard). The results were compared to the NIOSH standard for stoddard solvent (350 mg/m³) because the majority of hydrocarbons detected were in the C_7 to C_{12} range. These results show that total airborne hydrocarbon concentrations within the area of concern on March 26 and March 30, 1992, were less than 10 percent of the NIOSH recommended exposure limit for stoddard solvent, but were more than 20 times higher than total airborne hydrocarbon concentrations in the adjacent ground floor office and in one office suite on the second floor of the building. On March 26, a total airborne hydrocarbon concentration of 7.5 mg/m³ was found in the conference room, and on March 30, a higher total airborne hydrocarbon concentration of 17.5 mg/m³ was found in the conference room. On March 26 the outside temperature was mild, about 70°F, with clear skies. On March 30, the outside temperature was about 65°F and a steady rain had been falling for several hours prior to sampling.

HNu Photoionization Analyzer Results

The HNu measurements showed detectable airborne VOC concentrations within the offices of concern, whereas airborne VOC concentrations outdoors or in other office suites in the building were not detected using this instrument. HNu results also indicated that the vapors appeared to be emanating from below the concrete slab flooring since concentrations (120–160 ppm) detected at the gap between the east wall and the floor in the conference room were from 2 to 160 times greater than anywhere else inside the suite, including inside the sewer drain pipe. The HNu results, in conjunction with the long-term air sampling results, suggest that the VOCs are emanating from the ground beneath the building slab. Identifying the source of the contamination was beyond the scope of the evaluation and soil studies would be necessary to determine this. (Historical information verbally reported to the NIOSH investigators, indicates that a truck stop was formerly located across the road from this office site.)

Ventilation Evaluation

The outside-air supply duct was inserted through a rough-cut hole in the wall of the AHU plenum, and an existing gap between the outside-air supply duct and the wall of the AHU plenum was not properly sealed. Smoke tubes used to visualize airflow patterns showed that air from the closet was pulled into the AHU plenum. The outside air supply to the offices was pulled into the suite using the AHU fan connected by over 30 feet of ducting to a dryer-vent–type cap. The distance of the outside-air supply opening to the AHU fan and the several air duct elbows present could seriously impede the supply of outside air to the suite.

Smoke tubes used to visualize air flow patterns also showed that the suite was under negative pressure when the exhaust fan was operating and even when the exhaust fan had been turned off. Therefore, contaminants from below the concrete flooring could be entering the suite even under normal heating, ventilation, and air conditioning operating conditions, and the amount of contaminants entering the suite would be expected to increase when the exhaust fan was operating.

Medical Interviews

On April 9, the seven employees present who spent a significant portion of their work week in the office were interviewed. Several employees reported that they had occasionally noted the petroleumlike odor when they first moved to the office in August 1991, but most first noticed the odor in the late fall. They reported that the odor had become stronger and more frequent during January and February of 1992 and was usually most noticeable when the office opened at 8:00 AM. Most felt that the intensity of the odor varied from day to day, but was most intense in the conference room. Several of the employees expressed concern about the possible health effects of exposure to the chemical mixture responsible for the odor. When questioned regarding specific symptoms experienced while at work during the preceding month, 5 employees reported frequent headaches, 2 frequent nasal congestion, 4 occasional eye irritation, 2 occasional throat irritation, 3 frequent severe fatigue, 1 frequent and 1 occasional nausea, and 2 reported occasional bouts of dizziness. In general, the symptomatic respondents felt that symptoms were more severe on days when the odor was stronger and that symptoms were more likely to occur after spending several consecutive days in the office. Most felt that the odor had been less noticeable, and their symptoms less severe, during the week of the medical survey.

Conclusions

The air sampling data collected during this investigation suggested that the subsurface of this property may have been contaminated with a complex mixture of hydrocarbons and indicated that the hydrocarbon mixture was volatilizing and most likely entering the building through cracks and gaps in the concrete flooring and foundation. The data showed that instantaneous measurements of VOC concentrations at various locations within the suite ranged up to 160 ppm and time-weighted average (TWA) concentrations of total airborne hydrocarbons ranged from 5.9 to 17.5 mg/m³. The TWA concentrations of total airborne hydrocarbons found in these offices was far less than the relevant standards for industrial exposures; however, the TWA concentrations detected were more than 20 times greater than airborne concentrations detected in two other office suites located in the building. While there was inconclusive evidence that the employee symptoms were due to the total airborne hydrocarbon and VOC concentrations found, it is of interest that research by Molhave *et al.*[9] in Denmark has found that test subjects exposed to solvents in chamber studies at comparable concentrations have experienced symp-

toms similar to those reported by the employees in this evaluation. Therefore, it was recommended that further soil studies be conducted to determine the source of the contamination and that efforts be initiated to lower the concentration of total airborne hydrocarbons and VOCs in the office space.

Subsequent to the NIOSH investigation, the building management retained the services of an environmental consulting firm to conduct a subsurface investigation of the property. The firm concluded that the "soils beneath the site appear to be contaminated with petroleum hydrocarbons." The vertical depth of contamination was identified as approximately 8 to 26 feet below grade at the front of the facility and 4 to 14 feet below grade at the rear of the facility; total petroleum hydrocarbons, benzene, toluene, ethyl benzene, and xylenes were found. The firm also concluded that further investigations of the subsurface should be conducted to identify the exact source of the petroleum.

Recommendations

1. Even though the TWA concentrations of total airborne hydrocarbons measured do not represent a health hazard when compared to the existing industrial exposure criteria, the levels found have been associated with symptoms similar to those reported by the employees at this work site. Therefore, for the comfort and overall well being of employees the source of the chemical contamination should be determined and the contamination should be prevented from entering the office space.
2. Further soil studies and other appropriate investigations should be conducted to locate and characterize the source of underground contamination.
3. After further soil sampling and determination of the contaminant source have been completed, methods similar to those used to mitigate excessive radon gas in buildings may be necessary. The object of this project should be to place the

subslab of the building under negative pressure to remove the vapors before they enter the office spaces to decrease the concentrations of total airborne hydrocarbons to levels found in other areas of the building. Additionally, all cracks in the floor, the foundation, wall/floor gaps, and sewer drain pipe gaps should be sealed to prevent vapors from entering the office area.

4. A booster fan should be added to the outside-air supply system to place office space under positive pressure and to assure an adequate supply of outside air enter the AHU. The American Society of Heating, Refrigerating, and Air-conditioning Engineers recommends that 20 cubic feet per minute per person of fresh outside air be supplied to office spaces. Also, the gap at the point where the outside-air duct enters the AHU should be properly sealed to prevent air from inside the AHU closet from entering the AHU plenum.
5. The exhaust fan that was installed to remove the vapors from the suite should be disconnected, or the fan should be reversed to provide more outside air. The use of the exhaust fan tends to place the office space under negative pressure in relation to the surrounding spaces. This complicates the situation by drawing the vapors out of the ground and into the office space.

Reference

1. Molhave, L.; Bach B.; Pedersen, O.F.: Human Reactions During Controlled Exposures to Low Concentrations of Organic Gases and Vapours Known as Normal Indoor Air Pollutants. Environ. Int. 12:167–175 (1986).

Editorial Note: Daniel Almaguer and Thomas Wilcox, M.D., are with the Hazard Evaluation and Technical Assistance Branch of NIOSH. More detailed information on this study is contained in Health Hazard Evaluation Report No. 92-180-2246, available through NIOSH, Hazard Evaluation and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226; telephone: (800) 35-NIOSH.