#6756

CASE STUDY

*[In each issue **IAQU** presents a case study on an investigation of indoor air problems in a particular building. The editorial staff relies on information provided by the environmental consultants involved in the investigation. **IAQU** presents a variety of approaches to investigation and mitigation implemented by consultants with a broad range of experience, philosophies, and expertise. Inclusion of a particular case study in the newsletter does not imply **IAQU**'s endorsement of the investigative procedures, analysis, or mitigation techniques employed in the case. **IAQU** invites readers to submit comments, suggestions, and questions concerning any case. At the discretion of the editors, correspondence may be presented in a future issue.]*

Poor Garage Exhaust Leads to Elevated CO Levels in Offices

This case involves a building, located in an industrial park near an asphalt/cement plant, and housing a garage facility in its basement for the firm's service vans. Employees in the offices above the garage complained of respiratory problems and headaches, as well as offensive odors. They also complained of excessive dust particles on the second floor.

Investigators found inadequate ventilation and filtering, as well as a lack of proper exhaust from the garage facility.

Building Description

The building, in a metropolitan area of the northeastern US, consists of the basement garage, a first-floor warehouse, and second story offices, with each floor containing 20,000 square feet of space. Windows in the facility are nonoperative, and the asphalt plant is located across the street.

About 125 employees work at the facility. Most of the staff leave in the morning with the service vans, and about 25 work in the offices on the second floor.

History of Complaints

The firm had occupied the building for about 18 months prior to the investigation. Employee complaints had begun as soon as the firm moved into the building. Major complaints included nose and throat irritation and headaches, as well as a strong tar-like odor under certain climatic conditions.

The odors were strongest when the prevailing winds were blowing from the direction of the asphalt plant. The odor complaints had been highest during the previous winter, but odors were not a problem on rainy days when the asphalt plant was not operating.

Employees said they felt relief from the respiratory symptoms and headaches within 30 minutes of leaving the building, and noticed no problem when at home or in other locations.

Investigative Focus

The building's facility manager called in the IAQ investigators, who developed a plan for a building investigation to include:

- Measurement of basic IAQ parameters: temperature, relative humidity, carbon dioxide (CO_2), and carbon monoxide (CO);
- A visual inspection of the HVAC system as well as a visual survey of possible pollutant sources;
- Air sampling for volatile organic compounds (VOC), especially coal tar pitch volatiles and selected polynuclear aromatic hydrocarbons; and
- A detailed review of the HVAC operations and maintenance.

The investigators conducted the study on two successive Fridays during the course of a normal workday. Included on the team were a mechanical engineer, an industrial hygienist, and an engineering technician.

HVAC System Description

Six air handling units (AC-1 through AC-6) are located on the roof. AC-4 serves the repair area on the east side of the first floor. AC-6 primarily serves the second floor office area, although it also serves a few offices in the southwest corner of the first floor. The rest serve the second-floor office area.

Each unit is self-contained and can provide heating and cooling to selected areas. An internal gas-fired system with an electric direct expansion (DX) system provides the heat.

One fan in each unit supplies and returns the air to and from the conditioned space, and the air reaches the supply outlets through sheet-metal ductwork. A return air duct terminates in

the ceiling directly below the unit, and the space above the hung ceiling acts as a return air plenum.

At the time of the investigation, only three of the air handling units (AHU) could provide outside air (O/A) to the building. The other three units had the O/A inlets sealed with a factory-installed panel. The units with O/A capability had automatic dampers to control the amount of air entering, and double-depth aluminum mesh screen filters.

Remote thermostats in the controlled zones regulate the units. Supply fans operate continuously, and the units' internal heating or cooling system operates to satisfy the thermostat set point.

Three timer-controlled exhaust fans on the roof serve the basement-level garage, drawing the exhaust air from outlets located near the garage floor slab along the east and west walls. Makeup air enters from two louver sections on the east perimeter wall.

Local gas-fired units heat the garage and first-floor warehouse. Design drawings designate supply air for the first floor coming from air louvers with motorized dampers on the east and west perimeter walls. However, investigators were unable to determine how and when the dampers operate. During the two days of the investigation, the dampers remained closed.

HVAC Investigation and Results

Investigators found that the existing HVAC systems had many deviations from the mechanical design drawings, particularly for the quantities, capacities, and types of AHU. During both surveys, the automatic O/A dampers were closed on all the rooftop AC units, and no outside air was reaching the occupied spaces.

Local building codes require outside air to be delivered to all office spaces without operable windows during the time the space is occupied. ASHRAE standard 62-1989 recommends 20 cubic feet per minute (cfm) per person.

The timers for the two exhaust fans that serve the west side of the garage were set to operate daily from 7 a.m. to 8 p.m. The third fan, however, did not operate automatically. Investigators noted that during their first visit the fan was not operating, and during the second visit it was.

Air flow readings indicated that the total amount of air being exhausted from the garage, while all three fans were operational, was 6,200 cfm. Based on the garage area of 19,750 ft^2, the exhaust ventilation rate was 0.31 cfm/ft^2. Local building codes require 1.0 cfm/ft^2 and the more stringent ASHRAE 62-1989 recommends 1.5 cfm/ft^2. The design blueprints call for 24 exhaust outlets at 1,000 cfm each, but only 11 outlets were actually installed. Investigators recommended that, at a minimum, the garage exhaust should be upgraded to meet the local building code.

Investigators also noted that the thermostat that served the training and work order room on the second floor was located outside the controlled zone. This had the potential to create adverse thermal conditions.

Air flow measurements showed readings that were generally below the design value. Since no outside air was entering the HVAC systems, there was no way to calculate the amount of outside air reaching individual occupants. However, some areas appeared to be receiving very little air.

IAQ Assessment

Various air quality components were monitored during the two-day investigation. CO_2 was sampled using a portable real-time continuous reading instrument with a nondispersive infrared detector. The monitor senses CO_2 concentration over a range of zero to 3,000 ppm with an accuracy of 5%.

A portable psychrometer with a set of wet and dry bulb thermometers measured temperature and relative humidity. An internal fan in the instrument maintained the air flow at 15 feet per second.

Carbon monoxide was sampled with a pocket-sized logging device, which provided continuous monitoring, as well as time-weighted average (TWA) and maximum peak value. The logger senses CO concentration over a range of 0-999 ppm, with an accuracy of ±3%.

Carbon Dioxide

CO_2 levels in the occupied area were generally within acceptable limits, with the highest reading of 700 parts per million recorded only one time. Average readings were in the 500-625 ppm range. ASHRAE standards recommend that levels be below 1,000 ppm.

Investigators attributed the low levels to the low occupant density on the second floor. Without a large amount of CO_2 being exhaled by building

occupants, CO_2 levels remained low, despite the lack of outside air entering the building.

Carbon Monoxide

Carbon monoxide levels on the first visit to the building — measured between 9:50 a.m. and 4:35 p.m. — measured from nondetectable to 1 ppm on the second floor. In the basement garage, a level of 8 ppm was recorded at 11:40 a.m.

However, the investigators learned that the service vans usually left the garage between 8:30 and 9:30 a.m.. They decided to conduct CO measurements earlier on the second visit.

One the second visit, readings at 8:58 a.m. showed CO registering at 57 ppm in the garage and, a few minutes later, at 7 ppm in the second-floor reception area. Later readings in the garage showed levels peaking at 67 ppm, although they dropped back down to 9 ppm by noon. Levels in the reception area rose as high as 12 ppm. Outside concentration was 2 ppm.

Air current testing on the second day showed a positive pressure for the basement of the building.

The permissible exposure level (PEL) for CO set by the US Occupational Safety and Health Administration (OSHA) is 35 ppm, based on a TWA over an eight-hour period, with a ceiling level of 200 ppm over any one minute period. However, CO at levels as low as 9-10 ppm can cause headaches.

Volatile Organic Compounds

Because one of the complaints was a tar-like odor and because of the proximity of the asphalt plant, investigators sampled for VOC. While there are no established limits for VOC in a non-industrial environment, scientific literature indicates that levels around 5 milligrams per cubic meter (mg/m^3) can cause adverse reactions.

In this building, test results showed varying levels, but all were below 1 mg/m^3. However, on the day of the first visit, it was raining, and the asphalt plant was not operating. During the second visit, the plant was operating, but the wind was blowing in the opposite direction.

Occupants reported that the tar-like odor was an "on and off" phenomenon and occurred when the wind was blowing from the direction of the plant. Investigators noted that the tests indicated there were no processes internal to the building that were generating VOC.

Recommendations

Investigators recommended O/A intakes with damper and filter sections be added to AC-1, AC-2, and AC-4, which can accommodate this modification. They also recommended that the remaining AC units be adjusted to provide adequate O/A whenever they operate.

The aluminum filters on the AC units couldn't prevent fine particles in the outside environment from entering the occupied space. Also, the filters fit poorly in the AHU, causing blow-by at the filters. The investigators felt that 80% efficient filters, properly seated, could reduce these particles.

Also, the tar-like odors caused complaints from many people. The investigators recommended installing charcoal filters after the 80% efficient filters to absorb VOC, as well as ozone from the outdoor air. However, the investigators also cautioned that the resistance caused by this added filtration would require an increase in fan motor horsepower, something that might be impossible with current equipment.

Investigators also felt that supplying all AC units with sufficient filtered outside air might require a separate central O/A supply unit. They recommended an engineering study to determine the feasibility of this. However, they also recommended that, if this course were followed, it include static pressure sensors on the second floor to control the amount of air entering the system. They recommended a static pressure high enough to create a positive pressure on the second floor to limit infiltration through the building envelope and interior penetrations.

Because most of the vehicles enter the garage during relatively short intervals in the morning and afternoon, the investigators recommended installing a CO-actuated exhaust system in the garage. The current exhaust system could probably handle this task with some modifications. This type of system would reduce the time the exhaust fans would be operating and would reduce the amount of outside air being brought into the garage. An added benefit would be that this would reduce the infiltration of particulates and odors from the asphalt plant.

The investigators theorized that the energy saved by not heating more outside air during the winter would probably yield a short payback period for the new system.

Also, they recommended installing motorized dampers on the two makeup air intake louvers on the east wall, as well as filter housings and filters on the interior side of the air inlets. The team also recommended adding filters to the dampers on the east and west walls on the warehouse level to control the particulates entering there. They recommended keeping loading dock doors closed as much as possible.

The building's main entrance door is very slow in closing and, at various times, remains in the open position. The door is on the side of the prevailing wind and faces the asphalt plant. Investigators recommended improving the automatic door closer on the outside door, as well as adding an interior entrance vestibule with a second door.

Investigators noted a small utility penetration on the north exterior wall. As this was at positive pressure to the garage and was not adequately sealed, it allowed noticeable odors to enter the garage. The team recommended sealing it with a pliable, fire-stopping material.

Conclusions

Lack of adequate outside air and a buildup of CO from the basement garage could account for some of the symptoms reported by the building occupants. Inadequate ventilation is identified in a large number of IAQ cases and opens the way for other problems, such as contaminant buildup.

The CO infiltration from the basement garage was greatest in the morning, but could have accounted for the headaches experienced, especially because carboxyhemoglobin — which forms when CO binds to hemoglobin in the blood — is relatively stable and can last in the body for up to four hours.

While it can be assumed that the asphalt plant contributes to the tar-like odors within the building, investigators were unable to determine this in their two visits. This points up a problem with episodic occurrences such as this. It's not always possible to detect the source during the time the investigator is on the scene.

As far as remedying the situation, it's unlikely that the asphalt plant will move. So, unless the odors were strong enough to force the client to move to another location, it has to be assumed that more moderate measures, such as the charcoal filters recommended by the investigators, would have to suffice.

For More Information

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INFORMATION EXCHANGE

Indoor Air '93: Triennial Conference Set for Helsinki

The premier event for the indoor air quality (IAQ) community — Indoor Air '93 — will be held in Helsinki, Finland, July 4-8, and those planning on attending have until April 1 to register at reduced rates.

The triennial event — last held in Toronto, Ontario, Canada, in 1990 — will feature plenary sessions, oral presentations of scientific papers, poster sessions, and workshops. Organizers expect several thousand persons from more than 40 countries to attend.

Plenary sessions include such topics as:

- Irritation and odor: symptoms of indoor air pollution;
- Allergy and environmental hypersensitivity related to indoor air environment;
- Microbial contamination of buildings;
- Healthy buildings and their effect on productivity;
- Indoor air quality as a public health issue;
- Curing sick buildings; and
- Indoor air quality: exploring policy options to reduce human exposure.

Scientific and technical sessions will be broken down into four main categories: health, comfort, and performance; characterization, measurement, and modeling of the indoor environment; building technology and remedial measures; and risks, policies, and regulations.

So far, organizers have planned 16 workshops, including such topics as *Indoor Air Quality and Energy Efficiency; New Criteria for Ventilation;*