Building Maintenance Affects Indoor Air Quality

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Reports of mold problems in schools seem all too common today. This article shows that occupant complaints oftentimes are brought on by a combination of physical, chemical and psychosocial factors.

The subject facility is a large, suburban high school located in a major metropolitan area of the upper Midwest. The original design of this building was based on an open floor concept, but the classroom spaces were extensively remodeled in the early 1990s.

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After completing an indoor environmental quality (IEQ) audit of all district facilities, we were asked to conduct a more focused assessment of this high school. A number of staff had insisted that an outside expert conduct an evalution of the reported health effects, the status of HVAC hygiene, and the impact of suspected microbial contamination.

Facility and HVAC Description

This 285,000 ft^2 (26 475 m^2), three-story high school was built in 1972. With corridors around the entire perimeter of the building, less than one-half of the classrooms have windows that face directly outdoors. Substantial remodeling in 1992–93 divided the space into discrete classrooms. Improvements also were made to the HVAC systems to accommodate the revised floor plan.

More than 20 central air-handling units (AHUs) serve this building, with most located in dedicated mechanical rooms. Space heating and cooling are accomplished with a traditional two-pipe system that feeds the primary coil in each AHU. A steam-powered absorber supplies the required chilled water. All ventilating systems are of the constant volume type, and zone-level coils control the final supply air temperature.

Space temperature controls for the entire facility were based on the original pneumatic system, which had experienced many component failures including periodic loss of the compressed air dryer.

Occupant Concerns

Symptoms reported by faculty and staff included headaches, eye and throat irritation, sinus infections, nasal congestion, chronic cough, excessive fatigue, dizziness, and thermal discomfort. There also were frequent reports of distinct odors, including diesel exhaust and cigarette smoke.

Specific concerns were voiced regarding an apparent lack of exhaust ventilation in a photography darkroom and a deficient system for venting the ceramics kiln. These concerns were exacerbated by knowledge that the art and science classrooms shared a common air-handling system with general instructional spaces.

Investigative Activities

We first met one-on-one with all faculty who wished to share their observations regarding the indoor environment. This demonstrated that the district was taking this effort seriously, gauged the level of fear and outrage, and accelerated the identification of temporal and spatial relationships in health complaints. We used a simple interview format to initiate conversations, and gave a detailed health questionnaire to each person to complete anonymously.

The health questionnaires identified a spatial relationship in the reported health complaints. This allowed us to focus our further efforts on areas served by only five of the 20 AHUs.

We reviewed the original construction documents and subsequent modifications to the HVAC systems. Thorough visual inspections of the air conveyance systems and limited microbiological sampling were performed, guided by our observations from a detailed walkthrough survey of the building.

Sampling and testing conducted in this case included data logging temperature, relative humidity, carbon dioxide and carbon monoxide levels; wipe samples of dust from supply air diffusers; direct measurements of supply air volume as delivered to occupied spaces, with comparisons to design values; performance testing several AHUs, including a static pressure profile and electrical consumption characteristics; fungal and bacterial analyses of debris from AHU condensate pans; and, viable fungal bioaerosols from a representative number of classrooms.

Photo 1: Truck exhaust and odors entered the building at the school's loading dock.

Summary and Findings

The written report included many findings of significance:

• The outdoor air intake louver for six primary AHUs was located immediately adjacent to the loading dock, resulting in the intake of truck exhaust and odors from trash receptacles (*Photo 1*). We also noted that school personnel would occasionally use tobacco in the area shielded from view by the trash container.

• The dampers at the primary outdoor air (OA) intake louver no longer functioned properly. When operating in economizer (i.e., free cooling) mode, the dampers did not open fully, causing the AHUs to draw significant quantities of air from the mechanical rooms.

• During the cooling season, the OA dampers moved to a closed position, resulting in minimal flow of fresh air to building occupants. Although this measure was intended to mitigate humidity problems and to reduce operating costs, it appeared to constitute a violation of state building codes.

• The bird screen behind the OA intake louver had failed, resulting in an accumulation of organic debris and numerous sparrow carcasses within the OA plenum serving the six primary AHUs (*Photo 2*).

• No access panels into the AHUs existed. As a result, routine cleaning of the coils, condensate pans and unit interiors had not been performed.

• Filtration at most AHUs consisted of automatic roll filters, which generally provide an atmospheric dust spot efficiency (ADSE) of less than 10% when tested in accordance with ANSI/ASHRAE Standard 52.1-1992, *Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter*.

• Condensate pans in many of the AHUs were not sufficiently sloped, and were drained on only one side, even in units that were 7 ft or 8 ft (2.2 m or 2.4 m) wide. The combination of inadequate filtration, lack of routine HVAC hygiene efforts, and standing water in the condensate pans created an ideal environment for the amplification of bacteria and hydrophilic fungi.

• No dedicated mechanical exhaust existed in the photography darkroom, and a return duct drew air from the darkroom, effectively mixing contaminated air with the common supply to adjacent classrooms.

• The exhaust duct from a ceramics kiln was not properly routed to the outdoors. Rather, it was ducted to the vicinity of a large capture hood. Upon further examination, we found that a manual one-hour timer controlled the exhaust fan serving this hood, whereas the kiln might be fired for several hours.

• The type of vacuum cleaner used by custodial staff was equipped with a low-efficiency filter bag. As a result, a substantial portion of the smaller particles were being dispersed and distributed back into the occupied space.

• Visually, the school was not clean. We learned that the custodial and maintenance staff had been operating short-handed (more than two full-time positions) for some time. As a result, the schedule for routine cleaning had been stretched out.

Recommendations

Our recommendations included the following activities:

• Professionally clean the cooling coils, the interior of all AHUs, and the supply and return ductwork, and plan to clean the condensate pans *at least* once a year. If cleaning is not sufficiently effective, replace heating/cooling coils that have become plugged with debris.

- Once the AHUs and ductwork are cleaned, restore the design volume of supply air to each zone.
- Revise the outdoor air intake currently located near the loading dock to draw outdoor air from above the roofline to reduce the frequency of entraining fumes and exhaust.
- Provide a sufficient number of custodial staff to keep the building clean. Implement a program of enhanced cleaning to improve the overall level of cleanliness in the building, including use of HEPA-filtered vacuums and damp wiping techniques to clean surfaces.
- Replace the existing temperature controls, either with a completely new pneumatic system or a direct digital control (DDC) system.
- Replace the existing roll filters with a new filtration system having a minimum dust spot efficiency of 30% or a MERV 8 rating as defined by the newer ANSI/ASHRAE Standard 52.2-1999, *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*.
- Install mechanical exhaust in the photography darkroom with a minimum design volume of 0.5 cfm/ft^2 (2.5 L/s per m^2) of floor area, and vent the exhaust from the new ceramics kiln directly to the outdoors.

Conclusions

Of course, there is more to this story than we can present here. Our experience shows that a combination of factors more often than not underlies occupant comfort and health complaints.

Photo 2: A bird screen failed behind the outdoor air intake louver, allowing organic debris into the air plenum.

Based on our findings and recommendations, this district has made tremendous strides in protecting and improving the indoor environment of this facility. Nearly all of the recommended actions have been implemented, and school personnel report that conditions are much improved, both in terms of their comfort and health.

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