CASE STUDY

[In each issue, **IAQU** *presents a case study on an investigation of indoor air problems in a particular building or on proactive efforts to design buildings with good IAQ. The editorial staff relies on information provided by the environmental consultants involved in the investigation.* **IAQU** *presents a variety of approaches to design, 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 design strategy, 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.]*

School Woes Continue, Despite $400,000 and Two Investigations

Building owners and managers — as well as IAQ consultants — become frustrated when investigations and remediation fail to find the "smoking gun" in an IAQ problem. The problem grows worse when the case involves a school, and both students and parents, as well as teachers, become agitated and suspicious over the seeming lack of progress.

Just such a scenario has developed in Peabody, Massachusetts, where IAQ problems at a 1,500-student high school have lingered over the past year — or have increased, according to some anecdotal reports. The concerns actually began several years ago, but grew dramatically worse last January when numerous students and teachers began reporting typical IAQ-related symptoms.

A subsequent full-scale investigation found nothing that consultants could link to the sudden outbreak, but did turn up numerous building deficiencies that had a potential negative impact on IAQ. Later, school officials contracted with another IAQ firm to review the work done by the first consultant.

Subsequently, the school administration has implemented about two-thirds of the consultants' recommendations, but the IAQ symptoms continue, and public anxiety is reaching a fever pitch. In late November, parents at a public hearing demanded that officials close the school and find somewhere else to house the students. The teachers' union, noting that more than 60 teachers have reported building-related symptoms, echoed the call.

School officials, understandably reluctant to take such a drastic step, have asked for another investigation, this time from the Massachusetts Department of Public Health. That investigation was scheduled to begin in early December.

Building Description

The school, a three-story building, occupies a 110,000-square-foot (ft^2) footprint. Built in the early 1970s, the school relies on electric heat. The complex also contains a 33,000-ft^2 field house, while the main school building houses science laboratories with exhaust hoods and a cosmetology room, as well as a kitchen and cafeteria, a bank area, and administrative offices. Some areas, such as the offices and administration section, have carpeting, while most other areas have tile floors.

The original design called for air conditioning, which was never installed. Consequently, many rooms have windows that can't open. Some areas receive ventilation air from a central system, and some are air conditioned, while others rely on one of 140 unit ventilators.

History of Symptoms

Complaints about poor indoor air had lingered for years. The teacher's union filed a complaint in 1989 over IAQ, and a subsequent investigation by the state concluded that the situation stemmed from design flaws, an inadequate ventilation system, and generally poor working conditions. Ironically, these conclusions summarized what the later report also found.

The situation continued until January 1996, when strong odors, described as an "acetone-like" smell, forced the administrators to shut the school for two days. Some students reported that the fumes had made them sick, and the school began an off-site tutoring program for those who couldn't return to the building.

The problems continued during the month, causing scores of students to report to the health clinic and to leave school because of fumes. Table 1 shows the number of students who were

Table 1 — Students Dismissed Due to IAQ Problems

Date	To Clinic	Dismissed
January 24	72	35
January 30	110	66
January 31	58	30
February 1	52	28
February 2	40	17
February 5	32	15
February 6	30	10
February 7	22	7
February 8	51	21
February 9	56	25
February 12	44	21
February 13	38	18
February 14	45	18
February 15	37	8

Source: Peabody School Dept.

recorded as leaving due to fumes during late January and early February.

Both parents and students claim that the situation has grown worse over the past year, but records showing that are hard to come by. The available reports don't include the information. Also, some students say they have stopped reporting their symptoms because they feel they're wasting their time.

When the current outbreak first surfaced in January, teachers stayed on even though some students moved off-site. However, as the year progressed, teachers began to feel the effects. A few have left their jobs and either filed suit against the city, requested transfer to other schools, or initiated worker's compensation claims.

Among the symptoms reported by students and faculty, in order of their prevalence, are eye irritation, headaches, dizziness, throat irritation, fatigue, skin irritation, respiratory problems, nausea, nasal congestion, cough, and stress. At the most recent meeting, some participants blamed the school conditions for more exotic illnesses, even going so far as to attribute an isolated case of ovarian cancer to the school.

Among school staff, 9 out of 13 reported building-related symptoms, while 2 of the 13 refused to be interviewed.

Investigation

Shortly after the fume-related incident in January, school officials called in Environmental Health and Engineering (EH&E — Newton, Massachusetts) to conduct a full-scale investigation. The firm conducted a thorough examination of the school facilities and its mechanical systems.

Investigators also monitored for volatile organic compounds (VOCs), biocontaminants, ozone, combustion gases, carbon dioxide (CO_2), carbon monoxide (CO), dust, temperature, and relative humidity. They repeated these periodically over the next four months, trying to determine ongoing conditions and whether interim remediation efforts were working.

For example, when the investigators conducted their initial tests, they concluded that the mechanical system required extensive work, including testing and balancing, and that facility managers need to bring in more outside air (O/A).

CO_2 measurements on February 14 indicated that 56%, or 44 out of 79, of the spaces studied had concentrations that exceeded 900 parts per million (ppm). As work on the ventilation system progressed, another survey on March 6 showed 36%, or 40 out of 111, above 900 ppm. A further study on May 6 revealed 13%, 14 out of 105.

Results

The investigation turned up numerous deficiencies in the building design and systems that could have a possible adverse impact on IAQ. It also found several safety violations, mostly in the laboratories, where numerous hazardous chemicals posed a potential risk to the people working with them.

Among the design and system problems were:

- O/A ventilation rates below state requirements or industry standards;
- Exhaust ducts that were designed but never installed;
- O/A intakes too close to dumpsters, loading docks, and a service road;
- Odor-causing activities in rooms that hadn't been designed for them;
- Radon levels above the federal action level;
- Dirty and malfunctioning unit ventilators;
- Recirculating air from exhaust hoods;
- Boarded up O/A intake vents; and
- Malfunctioning equipment.

As a results, EH&E made numerous recommendations to school authorities. These appear in Table 2.

Table 2 — Findings and Recommendations for Peabody High School

Finding	Recommendation
Indoor Air Measurements	
CO_2 measurements indicate improvement since HVAC system improvements and increased O/A intake.	Conduct periodic CO_2 monitoring to verify proper operation.
Carpeting, installed in 1971, is worn, dirty, and frayed in spots.	Replace carpeting, especially in high-traffic areas, where it is most worn.
Acid neutralization tanks in science laboratories have holes in elbow joints, possibly used for clean-out access.	Cap each joint to return it to original design. Provide tanks with gaskets to minimize seepage. Clean tanks regularly.
School contained excess amounts of dirt and dust.	Design maintenance program to include daily cleaning during the school year, as well as more thorough cleaning during vacation times.
Radon levels in some areas exceeded the EPA action level of 4 picocuries per liter.	Redesign ventilation strategy to deliver O/A to these spaces. Implement long-term radon monitoring.
Building Ventilation	
O/A intakes on east side of the school may entrain odors from the dumpster, vehicles operating on the service road, and delivery trucks at the loading platform.	Restrict traffic on the service road, advise truck drivers to turn off engines at the loading dock, and use filters to keep odors from the building. If this is ineffective, relocate O/A intakes.
Many areas don't meet state standards (10 cubic feet per minute per person) for O/A. This is related to deteriorated mechanical control systems.	Tune up mechanical controls to ensure that ventilation works according to original design.
Ventilation system needs adjustment. Several exhaust fans and dampers either didn't operate or performed poorly.	Remedy problems with poorly operating fans. Replace those that are irreparable.
Several exhaust ducts included in the school's design were never installed. Also, in some areas, the supply and exhaust systems are inadequate for current uses.	Rectify known problem areas. This ranges from simply installing ducts to a more complex redesign of supply and exhaust systems to handle areas that need more ventilation.
Unit ventilators in classrooms require recalibration.	Service and recalibrate unit ventilators so that the minimum O/A introduced to the building is increased to 30%.
An energy management system has been installed in the building to control HVAC units. The efficacy of the system has yet to be determined.	Carefully review all proposed energy conservation measures to ensure that they don't compromise IAQ.
Routine maintenance on unit ventilators has been neglected or performed infrequently. Unit interiors are dirty and several suffer from inoperable O/A dampers. Missing or damaged grilles allow foreign objects to enter the units. This either causes disruptive noise during operation or jams the unit.	Expand unit maintenance to include more than just changing the filters every 90 days. Clean and inspect interiors periodically. Maintenance staff should promptly repair malfunctioning units.
The school has no way to control relative humidity (RH) within the building. During winter, the RH can drop to below 40%.	The building will require an engineering analysis to determine whether systems can provide increased humidity and whether the school design can tolerate introducing moisture. Under the current configuration, additional moisture could lead to further IAQ problems.
Science Laboratories	
The science laboratories have an unusually high inventory of chemicals. Many of these are unidentified and some are potentially dangerous.	Staff should complete a complete inventory of the volume and age of all chemicals. Those not needed should be discarded. This should be repeated on a regular basis. Several containers of ethyl ether, a potentially explosive chemical, have already been discarded by authorized personnel.
In one laboratory, one liter of phosphoric acid was stored on the same shelf as 2.5 liters of ammonium hydroxide.	Acids and bases constitute a potentially explosive combination. These should be stored separately.

Table 2 — Findings and Recommendations for Peabody High School, continued

Finding	Recommendation
Although protective gear was available, some goggles were missing pieces, some aprons were worn through or stored on the floor, and some face shields were broken or dirty.	Ensure that all personal protective equipment is well-maintained. Discard broken or punctured equipment.
Eyewashes and showers appeared to be dirty and no one could say when they had last been tested.	Inspect, test, and clean all such equipment on a regular basis.
Eight of 15 fume hoods were below the recommended rates of 80-120 feet per minute. Sash height indicators were missing. Several hoods were used to store equipment.	Maintain all fume hoods for recommended air flow rates. Evaluate and balance the exhaust system. Mark hoods to indicate appropriate sash heights. Clearly mark all hoods intended for equipment storage.
Safety infractions in the laboratories included a soda can in a hood and cardboard boxes next to a hood containing a Bunsen burner.	Prohibit food and beverages in areas where chemicals are used, and don't store combustible materials near ignition sources.
Laboratory fume hood design was state of the art when installed, but is now outdated. The sequence of operations doesn't properly pressurize the area, failing to capture some chemical fumes, which may migrate to spaces outside the laboratory.	Reevaluate the sequence of operations and modify the ventilation system controls to ensure that they provide appropriate containment for the materials.
The fume hood exhaust stacks, with a "mushroom" design, discharge effluent downward onto the roof, making reentrainment likely.	Fume hoods should discharge vertically at a height determined by modeling or, at a minimum, 1.3 times the tallest point in the building.
Laboratories have more than 380 chemicals, some of which are too hazardous for a high school laboratory.	Dispose of the current chemical stock and adopt a curriculum that uses less hazardous chemicals. This may lessen the capital cost of redesigning the exhaust system.
Specific Areas	
Art room: Spray paint booths exhaust outside at the second-floor level. The exhaust from two pottery kilns also exits the building near several O/A intakes.	Reevaluate filter options to deal with fume containment and reentrainment problems. Exhaust the kiln up the side of the building and discharge the fumes vertically above the roof.
Cosmetology classroom: In an area originally designed as a drafting classroom, this room contains chemicals that can produce relatively strong odors, which the ventilation system design can't accommodate.	Temporarily suspend cosmetology activities (manicuring) that produce the most odors. Install an effective fume capture and filtration system. Keep the area under slight negative pressure relative to the outside.
Metal shop: Air from a hood over the welding and metal melting furnace recirculates through the ventilation unit.	The shop heating and ventilation unit should not permit recirculation of air collected from the exhaust hood.
Kitchen: The kitchen heating and ventilation system recirculates from the stove exhaust hoods. This is a code violation, and probably was at the time the school was constructed.	Remove the recirculation duct.
Kitchen: The kitchen exhaust hood operates with a wall timer switch, which has always appeared in the "off" position.	The control for the kitchen hoods should work in conjunction with the ventilation unit to maintain negative pressure relative to the surrounding areas.
Planetarium: The planetarium often experiences odors from the team room. Both ventilation units share the same O/A intake, perhaps allowing planetarium supply air to mix with team room return air.	Modify the O/A intake to prevent reentrainment of air from the team room into the planetarium.
Bank: The bank area, originally designed to be a coat room and now occupied by workers and visitors, contains two exhaust fans, but no supply fans.	Add either a supply or relief duct to air in ventilation.
Field house: The field house ventilation unit didn't work for 12 years after installation, until someone determined that the wires to the thermostat had never been connected. O/A intakes had been covered with plywood.	Remove plywood from O/A intakes and check sequence of operations for field house units to supply the building with adequate air.
Plumbing: Gas and smoke tracer tests located several dry traps in the sanitary sewage lines in the women's locker room and the kitchen.	Replenish water in traps monthly to ensure a barrier between sewer gases and the indoor air.

Source: Environmental Health & Engineering, Inc.

Second Investigation

Even before EH&E had completed its final report, five months after the odor incident in January, teachers and school committee members were becoming impatient. Some claimed that conditions were getting worse instead of better, and others began calling for a "second opinion."

During the summer, the school department hired the H. L. Turner Group, Inc. (Concord, New Hampshire) to review the EH&E work and do a walk-through investigation of the building. For the most part, the Turner report agreed with the EH&E findings and corroborated the recommendations.

Turner, however, added several items, recommending that the administration develop long- and short-range plans for modifying the HVAC system to achieve adequate ventilation, while maintaining energy conservation. Using electricity as the sole heat source adversely affects the system's ability to provide adequate air economically.

Turner also noted that the age of the current equipment most likely makes it difficult to operate it properly, suggesting that it might be more economical to provide new systems that would be easier and cheaper to operate and maintain. If that's not done, Turner recommended meticulous repairs, maintenance, and operation.

The Turner report stressed the need to ensure proper pressure relationships between spaces to reduce the probability of irritating chemicals migrating from one area to another. It also urged extensive commissioning after completion of all work to ensure that the system is capturing all contaminants and exhausting them without reentraining them back into the O/A.

The building roof has been leaking for years. The Turner report recommended removing and replacing materials — ceiling tiles and gypsum board — that had suffered water damage. The suggestion was based on the assurance that the roof problems had been resolved. However, recent reports indicate that roof replacement is still pending.

Mitigation Efforts

Some of the mitigation that EH&E recommended took place while the investigators were still studying the building, and both the EH&E and Turner reports document the effects those efforts had. Subsequent reports in *The Salem Evening News*, the local newspaper, indicate that some of those changes may have been short-lived.

According to school authorities, they have implemented about two-thirds of the recommendations and are studying the others. While school officials did increase O/A intake during the spring, as EH&E suggested and with which Turner agreed, the administration decided over the summer to revert to lower levels. At the same time, they decided to replace the carpet, installing $150,000 worth of new carpeting, according to local press reports.

Now, the school system's new superintendent has ordered the school to begin bringing in more O/A. However, nothing has been done to relocate O/A intakes that reentrain either exhaust or fumes from dumpsters and loading docks, meaning the increased ventilation will probably bring in more pollutants.

Officials have yet to replace the leaking roof, but have budgeted about $400,000 for the project. While the superintendent says the school will increase the O/A brought into the building, he balked at switching to another heat source, as Turner recommended, citing the overwhelming cost.

The school department has also budgeted $120,000 to replace the faulty exhaust hoods in the science laboratories, but as of late November, the work had not begun.

The heightened concern, which spurred the meeting in late November, came from a recent increase in occupant complaints. Symptom reports jumped dramatically in the two weeks after the school turned on its heating system. According to press reports, some 60 teachers, about 40%, have reported illness, with as many as 20 out sick on a given day. This has led to using numerous substitutes or, in worst cases, leaving entire classes with no instructor.

At the recent public hearing, the administration rebuffed calls for closing the building, but said that school officials were about to meet with investigators from the Massachusetts Department of Public Health to begin yet another building study and review of the previous investigation.

For More Information

Environmental Health and Engineering, 255 Washington Street, Newton, MA 02158, USA; (617) 964-8550, Fax: (617) 964-8555.

The H. L. Turner Group, 6 Loudon Road, Concord, NH 03301, USA; (603) 228-1122, Fax: (603) 228-1126.