Identifying and avoiding indoor air quality problems

Methodology for assessing building indoor air quality and ways to avoid IAQ problems

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During the past decade, there has been an increasing awareness of health concerns related to exposure to low levels of pollutants in the indoor office environment. A large number of buildings have been studied, revealing a variety of similar complaints and symptoms. These complaints often center around issues of thermal discomfort and irritation (irritation of the eyes, nose, throat, and lungs are common themes). Unfortunately for the building manager, the causes of these complaints and health concerns are unique to each building.

Often occupational type pollutant surveys are conducted by in-house staff or consultants, which lead to little insight because results are often reported as below OSHA standards or below minimum detectable levels. This often leaves the occupants with an even greater sense of frustration and eventual hostility.

Techniques have been developed to identify the causes of these complaints so that solutions can be developed. Often equipment is employed that is 10 to 100 times more sensitive than occupational type surveys would dictate.

The purpose of these low level measurements is to evaluate what is actually happening to the air within the building, not just whether it meets certain OSHA requirements.

Once a good understanding of ventilation rates, temperature and humidity extremes, pollutant levels, air flow patterns, pollutant sources, and control equipment has been developed, corrective actions can be developed and implemented if warranted.

This article outlines a methodology that has proved useful for building evaluations where there is no identifiable suspected source of air contaminants causing complaints or situations where there is an identifiable suspected source but unknown pathways of transmission. This article will draw upon illustrative case studies to show how the parameters discussed have contributed to various cases of degraded indoor air quality.

The performance of effective indoor air quality (IAQ) evaluations depends on the ability to understand the interactions of the variables affecting IAQ. These variables include the effective ventilation rates within the building and the introduction of air contaminants from within or outside the building or from the mechanical or unoccupied spaces of the building. The techniques presented in this article for performing building assessments focus initially on determinations of the effective ventilation rates and then consider the potential sources of air contaminants.

Building ventilation rates

The concept of effective ventilation rate (EVR) refers to the actual removal rate of air contaminants from the occupied spaces in the building. One procedure for determining the effectiveness of the ventilation system involves the measurement of carbon dioxide, CO_2, concentrations throughout the building. In addition to measuring CO_2 levels in the occupied spaces, one should obtain measurements of the concentration of CO_2 in the supply air to assess the proportion of outdoor air coming from the mechanical HVAC system vs. the building enclosure infiltration. When this procedure is used, measurements of the outdoor (background) concentrations of CO_2 must be obtained.

The procedure used to assess an effective ventilation rate is based on monitoring carbon dioxide concentrations in the building. Modeling of this building can then be performed, relying on the assumptions that the source strength is proportional to the occupancy rate, the outdoor concentration is fairly constant, and the only removal mechanism is the exhaust of contaminated air. If there are enough people present, the concentration of CO_2 present in a building, therefore, can provide a measure of how well the ventilation system is diluting and removing air contaminants generated within a building.[1] In this analysis, it is the people occupying the space that are the source of the CO_2 being measured.

When evaluating situations where the pollutants of concern are

[1] *Superscripts refer to numbered references at end of article.*

Ways to avoid problems

Based on the problems that have been identified to date in buildings, a laundry list of preventive measures should include, but not be limited to, the following:

Provide proper ventilation air: Deliver to the occupants a minimum of 15 cfm per person of outside air in accordance with ASHRAE recommended practice to dilute body odors and carbon dioxide.

Maintain HVAC systems: Keep these in top operating condition: clean drip pans; clean coils; service high quality filters, operating controls, and calibrated sensors; and clean ductwork.
Provide 73 F comfort temperature whenever feasible.

Exhaust building contaminants:
- Cigarette smoke from smoking lounges.
- Wet process photocopies (all sizes).
- Dry process photocopies (especially high use large machines).
- All processes that emit odors.

Keep out unwanted pollutants:
- Pressurize loading docks.
- Design lab exhaust to keep exhaust from reintrainment in the building's wake.
- Pressurize entrances from basement parking lots.
- Keep air intakes away from all pollutant sources.

Don't let excess amounts of harmful microscopic organisms grow in a building:
- Keep carpets clean and dry, following directions for cleaning compounds carefully.
- Use monolithic flooring in high traffic wet areas.
- Dry out flooded areas within 12 hr maximum and/or discard flooded carpeting.
- Avoid wet wicker baskets under plants.
- Keep relative humidities below 55 percent RH everywhere unless specially designed for higher amounts.
- Avoid stagnant water anywhere.
- Repair steam leaks and water leaks immediately.

fication equipment or mechanical systems.

Specific types of equipment implicated in past evaluations as sources of microbial aerosols include water spray systems, humidifiers that use recirculated water, cold mist vaporizers, and fan-coil units.[3] Sampling for the concentrations of viable organisms in occupied spaces typically involves drawing the room air across an agar medium. Analysis of this culture plate involves incubation and subsequent counting of the number of colonies formed. Other biological indicators may include the presence of insects. This procedure involves microscopic examination for insect hairs or parts.

- *Organic chemicals*—The complexity and diversity of the organic chemicals introduced into many indoor environments can make assessments of these compounds difficult and air cleaning for their removal impractical. Hence, one must rely on the effectiveness of the ventilation system for the removal of the off-gas from building materials and office equipment alike. Survey methods are available for identifying potential sources. Sophisticated, expensive analyses such as gas chromatography followed by mass spectrometry (GC/MS) or dual mass spectrometry (MS/MS) can be performed to determine the components of the organic soup in modern office buildings.

- *Fibers*—The presence of fibers, including glass fiber and asbestos, may be related to the presence of acoustical or insulation materials often located within the ceiling plenum of a building or in mechanical rooms. If there is frequent construction activity and access to these areas, there may be increased risk of exposing the whole building to air contaminants from these areas.

Outside building sources

This section discusses sources of air contaminants that are outside the occupied spaces of the building and are drawn into the building either through the mechanical system or through infiltration.

During the heating season, buildings usually behave like chimneys. This thermal stack effect is created by the escape of buoyant heated air at the upper levels of the building, which creates negative pressures capable of causing infiltration at the lower levels of the building. Therefore, because of this induced upward flow and the normal supply of outside air to the building, the following items can be identified as potential sources of air contaminants:

- *Radon*—The *potential* for radon can be crudely assessed by a few questions as to the radon content of the soil, sources of water, and building materials. Definitive assessments can only be provided by measurements with detectors such as track-etch cups, charcoal detectors, or more expensive real-time monitors. The release of this naturally occuring radioactive gas into a building may be related to the infiltration of soil gas, the use of certain stone and masonry products, or ground water supplies.

- *Loading docks*—Loading docks are potential sources of air contaminants for some buildings. The combination of idling diesel vehicles and penetrations at the loading docks, under the influence of typical negative pressures, can draw pollutants into the building's interior.

- *Parking lots*—Parking lots and roadways are potential sources of air contaminants for some buildings because of the accumulation of carbon monoxide and carbon dioxide from idling vehicles. This is especially true for multi-level parking facilities in congested areas. These may be considered large area sources for pollutants such as carbon monoxide.

port; even though the outside damper may be wide open, *no* outside air is introduced.

Localized exhaust parameters

The evaluation of localized exhausts, such as fume hoods or process emissions, cuts across the distinctions between the above subtopics and, therefore, requires a systems approach to deal with several interrelated factors.

- *Capture efficiency*—The capture efficiency of the localized exhaust system refers to the ability to prevent the air contaminant being controlled from being released into the room itself. This can be assessed to some extent by the use of air current tubes.
- *Negative pressurization*—The over pressurization of a room containing a source requiring a localized exhaust system creates the potential for contaminant leakage to other areas. As above, the pressurization can be determined using air current tubes. For a localized exhaust system to function properly, there must be some provisions for a makeup system.
- *Discharge parameters*—The air contaminants from a localized exhaust system can re-enter the building at another location if the stack is not tall enough to discharge out of the aerodynamic wake of the building. The requirements for source receptor distances, stack height, and discharge velocity can be evaluated using algorithms of dilution achieved.[4] All too often, short stacks are selected for esthetic considerations. This is an invitation for the air contaminants discharged to be drawn back into the building.

Summary

The presence and location of various potential sources, both inside and outside of the building, can often be determined by observation by a trained individual. However, to determine how the ventilation system or systems of a building are performing, it is necessary to use more sophisticated approaches. The evaluation of a ventilation system requires the measurement of at least one component of the gas stream. Options for this evaluation include either compounds that are normally present in the occupied spaces or a compound that is specifically introduced into the occupied spaces for the purpose of this evaluation, such as sulfur hexafluoride.

If the evaluation of ventilation rates and the determination of air movement pathways are not sufficient to deduce the source of air contaminants, further specific sensitive measurements of sources and contaminant concentrations can be employed.

The techniques and procedures described have been used by the authors to investigate several buildings with histories of occupant complaints. These buildings had "passed" OSHA type surveys with flying colors, and yet when looked at very closely as "office buildings," they had situations occurring that were causing irritation and discomfort to the occupants. Solutions have been developed from these investigations that have eliminated or minimized both the problems and complaints. Ω

References

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2) ASTM Standard E 741-80, *Standard Tracer Dilution Method for Infiltration Measurement*, 1980.

3) Morey, P. R., and Rundus, R. E., "HVAC System Operational Parameters Affect Airborne Fungal Levels in Occupied Spaces," Proceedings of 3rd International Conference on Indoor Air Quality and Climate, Volume 3, *Sensory and Hyperreactivity Reactions to Sick Buildings*, Stockholm, Sweden, August 1984.

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