Controlling Summer Mold Growth in Schools

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Air conditioning over the summer vacation presents significant challenges to school HVAC operators in humid climates, where mold growth is a common occurrence in unoccupied areas. Although health effects of mold exposure are generally limited to sensitive individuals, musty odors and visible growth are unacceptable to occupants and disruptive to school programs.[1,2,3,4] Summer mold growth is sometimes attributed to shutting off school HVAC systems for energy conservation. However, in half of the schools experiencing summer mold growth investigated by the authors, the HVAC was running, but overventilating or over-cooling unoccupied areas.

Water damage is the most common cause of indoor mold growth, but extended periods of high relative humidity or over-cooling can cause similar problems in otherwise dry buildings. The underlying cause of this type of mold growth is relative humidity at the surface (water activity) sustained at a level supporting microbial growth. This occurs where relative humidity at surfaces passes the mold threshold, for example, where surface temperature is below the dew point.[5,6,7] Duration is an important factor in mold growth.

For example, several weeks of relative humidity exceeding 80% is generally needed to initiate mold growth in the absence of other moisture sources.[7] An important difference between mold growth associated with damage from liquid water and excessive relative humidity is that water contact often causes structural damage necessitating drywall replacement, while relative humidity-related mold growth affects surfaces only and can generally be remediated by treatment with a disinfectant.[4]

Although older school HVAC systems were not designed for humidity control, mold growth does not generally occur unless there are significant equipment, controls or scheduling deficiencies, significant infiltration of humid air, evaporation of excess moisture or there are surface temperatures below dew point of the room air.

Methodology

This review is based on the authors' experience as mechanical engineering/industrial

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hygiene consultants to school districts in the Washington D.C./ Baltimore area, where outdoor dew-point averages approximately 60°F (16°C) during the summer, with some days exceeding 70°F (21°C). These schools are generally not in session from mid-June to mid-August, with many areas remaining vacant. Summer HVAC operation varies widely, with some schools shutting off most systems for the summer to conserve energy, while others run on a normal or reduced schedule.

PHOTO 1 Mold growth caused by elevated relative humidity.

PHOTO 2 School fan coil unit.

The authors have investigated a variety of schools subject to summer mold growth. (See sidebar, "Surveyed School Descriptions" for generalized description of typical school.)

Site surveys generally included:

Review of HVAC plans, maintenance tickets, automation trend logs and schedules of HVAC operations and building activities.

Environmental inspection to note locations of visible growth and moisture damage (i.e., bowed ceiling tiles), building envelope openings, site orientation, etc.

Site measurements including relative pressurization, air distribution, surface temperatures, air temperatures and relative humidity.

HVAC evaluation to check control sequences, thermostat calibration, chilled water temperature, damper operation, exhaust fan operation and pipe sweating.

Identification of root causes and contributing factors to mold growth.

Recommendations to improve humidity control.

Findings

The authors found that problem schools fell into one of three categories: (1) HVAC generally off; (2) overventilation; or (3) over-cooling. In the majority of schools investigated, mold growth was localized and re-occurred year after year in the same areas. Where over-cooling was the underlying problem, schools experienced a widespread, one-time mold growth episode.

HVAC Off for the Summer

Mold growth only occurs in some schools when HVAC systems are deactivated for the summer.

In each of those school investigated by the authors, mold growth was limited to areas where other contributing factors were present:

Unit ventilators valves remaining open. HVAC sequences of operations typically have open control valves when systems are off during cold weather. In two-pipe systems, these valves often remain open in the cooling season with HVAC fans off and the chiller running, allowing chilled water to flow through the coils. When humid outdoor air infiltrates around outdoor air dampers/louvers, condensation forms inside and on the cover of the unit ventilator, surrounding floors, and the underside side of nearby furniture.

Negative pressure. In some schools where supply fans had been de-activated, exhausts remained on, drawing in humid air through the building envelope. Mold growth tends to be localized in areas with greatest infiltration (i.e., openings through the envelope, proximity to exhaust fans).

Reduced solar loads. Relative humidity is generally higher in rooms with a northern exposure or tree shade.

Rooms with high paper loads. Porous materials in libraries retain moisture and are susceptible to mold growth. Closed storage closets with no air circulation can also be problematic.

Outdoor air dampers remaining open with fans off. Open dampers allow unconditioned, outdoor air infiltration to pass though the unit and into the building.

Areas with excessive moisture evaporation. This may be produced from poorly drained sites, high water table, ongoing leaks, chilled water pipe sweating, standing water in condensate trays or summer cleaning activities.

Surveyed School Descriptions

Building Envelope The typical school surveyed was constructed between 1970 and 2000. Walls are of masonry construction with cinder block on the interior and red brick on the exterior. The roofs are built up flat roofing with at least 2 in. (51 mm) insulation and covered with light-colored gravel. Exhaust fans and rooftop units are mounted on these roofs. Building wall envelopes are typically not well-sealed.

Central Plant The typical school surveyed had the following mechanical system characteristics. A central plant provides chilled water in the summer (generally designed to supply 45°F [7°C]) and heating hot water in the winter. The distribution system is two-pipe with constant volume pumping. A single piping circuit to three-way valves in unit ventilators, fan coil units and air handlers delivers cooling in summer and heating in winter. In most schools, there is also a heating only loop that serves heating hot water to areas that are not cooled in the summer (e.g., gymnasiums).

Energy Management All schools surveyed had a DDC overlay system to enable/disable units based on school schedules. Once enabled, pneumatic controls regulate the actual control of the units. DDC enables/disables unit ventilators and fan coil units by zones, rooftop units, air handling units and selected exhaust fans. Other exhaust fans run continuously. A typical classroom zone might include a building wing with 15 unit ventilators commanded from one digital output point. A typical elementary school is divided into approximately 12 zones for DDC control, while a middle school may have 30 zones of DDC control.

Classroom Unit Ventilators The typical classroom has a unit ventilator to provide heating, cooling and ventilation. At a minimum, these units include a fan, a two-pipe chilled/hot coil and an outside/return air damper. Air dampers provide minimum ventilation and are capable of delivering 100% outside air in economizer mode. The unit ventilator control systems are pneumatic.

Rooftop Units Areas such as administrative offices, multipurpose rooms and media centers generally have rooftop units with DX refrigerant cooling. The heating coil is active in winter, but is closed in summer. These units have a minimum outside air damper for ventilation. The roof top units are a combination of pneumatic and electric control with the DDC overlay to enable/disable units.

Air-Handling Units The air-handling units bear many similarities to the unit ventilators but larger. Most commonly, they are two-pipe; the same coil is used for cooling in summer and heating in winter. The outside air damper is capable of 100% outside air for economizer mode. The controls are pneumatic. Refer to the unit ventilator section above.

Several options are available for preventing further mold growth:

Operate HVAC on a reduced schedule (i.e., activate for a short-cycle each day).

Prevent chilled water from flowing into coils by programming system to close chilled water valve if unit fan is off.

Install DDC system with two-way valves to close valves when off or scheduling chiller plant and associated units "on" at same time.

Close outdoor air dampers and shut off exhaust fans when the building is unoccupied.

Open doors to storage closets to provide air circulation.

Control sources of excess dampness (e.g., site drainage, leaks, sweating pipes).

Operate portable dehumidifiers where needed to replace dehumidification by the HVAC system when no cooling is required.

The selection of corrective measures is site-specific. Although lowering relative humidity is the key to control of mold growth, it is not necessary to achieve comfort levels prescribed by ASHRAE Standard 55 in unoccupied areas.

Overventilation of Unoccupied Areas

Where air conditioning is provided when cooling requirement is low, coil valves modulate for reduced flow and room air is cooled but not dehumidified. This condition may occur in school areas not used during the summer, but also in zones with limited occupancy (i.e., occasional summer school classes) or where custodians call for air conditioning to dry wax, or shampoo rugs. Custodial staff may also ask for air conditioning in unoccupied work areas for comfort.

Other factors contributing to localized mold growth with HVAC running:

HVAC is oversized.

Chilled water temperature is set too high, reducing the system's capacity to dehumidify.

Chilled water temperature is set too low, over-cooling and promoting condensation.

Outdoor air dampers open too wide (e.g., at 100% when should be at minimum).

PHOTO 3 Portable dehumidifier installed in classroom.

PHOTO 4 Rusting diffuser from over-cooling.

Start/stop failure (e.g., HVAC fans run 24/7 without chillers operating to provide dehumidification at night).

Exhaust volume exceeds supply air, drawing in unconditioned air through the building envelope.

Reduced solar load in shaded areas and rooms with a northern exposure.

Doors and windows remain open during periods of high relative humidity.

Lower-cost options for addressing overventilation:

Reevaluate school activities and limit normal HVAC operation to periods when areas are actually occupied. If air conditioning is needed to dry wax, shampoo carpet or paint, consider using portable dehumidifiers and fans as an alternative.

Operate HVAC on a reduced schedule (e.g., cycle on for a few hours during the afternoon when there is some load on the building).

Run HVAC fans at lower speeds.

Minimize outdoor air damper settings (i.e., correct minimum damper position if occupied and close dampers when unoccupied, adjusting exhaust to maintain positive pressurization to outdoors).

Ensure controls start and stop systems when intended.

Reduce negative pressure (i.e., deactivate unnecessary exhaust fans).

Keep doors and windows closed as much as possible.

Other response measures to reduce relative humidity:

Rebalance air and water systems.

Seal penetrations through the building envelope to minimize outdoor air infiltration.

Add demand-control ventilation (i.e., install motion sensors/controls to disable outdoor air intake when area unoccupied; install DDC controls sequence for summer low occupancy, adjusting exhaust to maintain positive pressurization to outdoor).

Operate portable dehumidifiers in lieu of using the HVAC system for dehumidification when no cooling is required.

Where feasible, consideration may also be given to replacing the HVAC system with a design selected for more effective dehumidification.

Over-Cooling

Lowering room temperature without removing moisture increases relative humidity, producing condensation where dew-point of room air approaches surface temperature. This condition can occur where room thermostat setpoints are reduced (e.g., for improved occupant comfort or as an inappropriate response to dampness). In other cases, over-cooling is caused by equipment or controls failures. The most severe cases of summer mold growth encountered by the authors involved controls failures with extreme over-cooling. In those situations, condensation pooled on classroom floors (one student actually slipped and broke his arm), and widespread mold growth on contents and furniture.

Options for addressing over-cooling:

Restore chilled water to the design setpoint.

Calibrate thermostats and set to moderate temperature.

Repair HVAC equipment, as needed.

Restore HVAC controls to design settings.

Energy Implications

Improved indoor environmental quality is commonly assumed to require additional energy use. While re-instating a normal HVAC schedule when areas are unoccupied for the summer increases energy use, this can be minimized by limiting HVAC operation in vacant areas to that needed to prevent mold growth, for example, a brief time in the late afternoon.[8] Improved humidity control can also be achieved by a variety of other measures which may produce a net energy savings.

The following actions may reduce energy use:

Eliminate overventilation by limiting HVAC operation to periods when areas are actually occupied.

Reduce supply air fan speed.

Restore minimum outdoor air damper setting during hot/humid weather to minimum.

Increase chilled water temperature setpoint to design.

Disable exhaust fans that are not needed.

Raise room thermostat setpoints.

Rebalance HVAC systems.

Seal exterior penetrations.

Model Action Plan to Prevent Summer Mold Growth

Based on these findings, the authors suggest that school districts subject to summer mold growth do the following:

Identify schools at risk for summer mold growth by reviewing historical documentation, interviewing maintenance personnel and inspecting for signs of excess moisture (e.g., musty odor, bowed ceiling tiles).

Prioritize schools subject to summer mold growth for enhanced maintenance and increased attention to energy management controls.

Identify factors most likely to cause mold growth and resolve these, where feasible, or operate portable dehumidifiers, where necessary.

Frequently inspect unoccupied classroom during the summer and immediately implement control measures at the first sign of excessive dampness. Musty odor, elevated relative humidity and condensation are readily recognized by custodial personnel without detailed measurements.

If mold grows on surfaces, take immediate steps to reduce relative humidity and remediate.[4] While porous materials such as drywall and paper are most susceptible to mold growth, hard surfaces coated with dust and dirt can also be affected. Surfaces can be wiped with a sanitizing solution registered as fungicidal. Consideration should be given to treating all structural and furniture surfaces in rooms where humidity-related suspect growth is observed. Porous materials and contents may need to be discarded if highly damaged.

Conclusions

Deactivating HVAC systems for energy savings is not the primary cause of summer mold growth in schools. The authors have found deficient system operation as the root cause in approximately half of the cases they have investigated and contributing factors in the others.

Mold growth associated with excessive humidity generally can be prevented by low-cost corrective measures and increased attention to preventative maintenance and energy management systems. Costs of improved dehumidification to avoid mold growth should be balanced against expenses incurred for the remediation of mold growth. Contrary to popular belief, improved humidity control can actually lower energy use where overventilation or over-cooling is the underlying cause.

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