This also increases the pressure on system designers to include filter assemblies that are easy to maintain. When filters are located where they are difficult to maintain, it becomes more likely that building staff will put filter maintenance low on their list of priorities.

For more information, contact: Philomena M. Bluyssen, TNO-Building and Construction Research, Department of Indoor Environment, Building Physics and Systems, Delft, The Netherlands.

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. In the following case study, **IAQU** obtained the information from consultant reports filed as public records. Much of the case study was taken directly from those reports.]*

Moisture Intrusion Causes Fungal Contamination in Courthouse

A southern US court complex, subjected to severe microbial contamination, faces renovations that will total nearly half of the cost to build the structure about four years ago.

Officials at the Martin County Courthouse Complex in Stuart, Florida, USA, ordered employees to evacuate the building after IAQ consultants hired to investigate complaints of employee illness discovered fungal growth ranging as high as one billion colony forming units per square inch (cfu/in^2) and bacteria levels as high as 40 billion cfu/in^2.

Engineers called in to examine the building made a number of recommendations for remediation in late April. At press time, county officials were considering which option to adopt.

Building and HVAC Description

The court complex includes three connected buildings, the Martin County Courthouse (MCC), the Constitutional Office Building (COB), and the Public Defender Building. The MCC and COB were built in 1988, and the Public Defender Building dates back to 1975.

The COB has four floors, about 15,000 square feet (ft^2) each. The second and third floors house county offices and the first floor contains public business areas, such as the tax collector's department and the motor vehicles department.

The MCC, with three floors, each 15,000 ft^2, has courtrooms and judges' chambers on the second and third floors, while the first floor contains public access areas, such as family services and a jury assembly room. The building is designed for a maximum occupancy of 900, but the actual figure varies with court schedules.

The Public Defender Building is a one-story structure, with approximately 3,000 ft^2, and houses primarily offices.

The three buildings had suffered moisture problems since construction, according to county officials, both from water leakage and high humidity. Water leaks caused considerable damage in some areas, and maintenance personnel continued to seal leaks as they occurred.

The original HVAC system at times provided humid outdoor air directly to occupied spaces, and at times the relative humidity (RH) in some offices exceeded 80%. The HVAC system was renovated in the autumn of 1992.

The complex's current HVAC system consists of either central station air handling units (AHUs) or fan-coil units (FCUs), which are suspended from the structure above the lay-in ceiling. This means the units can only be accessed by ladder through the ceiling system.

Each unit has a chilled-water cooling coil, which is located inside the unit casing and has a condensate drain pan with a gravity feed drain system. A secondary pan, located under the system, has a float switch to shut off the unit if it detects moisture.

The units' filters consist of two-inch-thick, 20%-30% efficient pleated-media fiberglass either in the duct work or in a unit-supplied filter support tray. To remove or replace filters, workers must use a ladder to get above the ceiling system.

Design calls for the units to circulate a constant volume of air to and from the space, and each unit is ducted to supply air and return air outlets in the ceiling. Duct work consists of both galvanized steel and fibrous-glass duct board.

The makeup air system consists of three units for the courthouse, two on the roof and one on the first floor, and one unit on the fourth floor of the office building. The Public Defenders Building has no source of fresh makeup air, and units in the building recirculate air from the ceiling plenum into the conditioned space.

The makeup air units' design calls for them to supply dehumidified air to the AHUs or FCUs. The makeup units also have three-stage filtration, including activated carbon to filter the outdoor air.

Investigative Focus

Due to continuing complaints from building occupants and visible signs of microbial contamination, county officials called in an environmental consulting firm in November 1992 to examine the building and perform an IAQ evaluation.

This firm visually inspected the premises and the HVAC system and conducted direct readings of temperature and humidity, as well as respirable particulate concentrations. Investigators also interviewed building occupants.

The firm also collected air samples, as well as source or bulk samples — such as pieces of vinyl wall covering and dirt on ceiling tiles — and submitted them for laboratory analysis.

Investigators collected a total of 16 sets of airborne fungi samples at indoor and outdoor sites using a two-stage Andersen sampler. The upper stage collects particles 7 micrometers (µm) and larger, while the lower stage collects particles 0.65-7 µm. The larger particles are inhalable, but not respirable, while the smaller particles can deposit in the lower airways of the lungs.

The investigators also took numerous samples of vinyl wall coverings from various walls, both with and without visible water damage, ceiling tiles from different locations, and padding from a sweater that had been left in the building.

After the IAQ consultants had reported their findings and made initial recommendations to the county officials, the officials called in an engineering firm to examine the building's systems and determine the best way to carry out the IAQ recommendations.

This firm reviewed the HVAC systems as modified in 1992 and evaluated them for their ability to:

- Positively pressurize the building to prevent outdoor air infiltration;
- Dehumidify the air, thus controlling high humidity in the spaces;
- Effectively distribute outdoor air to the occupants;
- Uniformly control temperature;
- Provide easy access for routine maintenance; and
- Provide proper filtration.

The engineering firm also performed a detailed examination of the building envelope to determine areas of probable moisture intrusion and problem patterns, and to make recommendations for remediation.

IAQ Assessment

The IAQ consultants reported that their visual inspection indicated visible fungal growth on ceiling tiles and under vinyl wall coverings on some perimeter walls. The investigators noticed a moldy smell from some carpeting.

Almost all ceiling tiles in the MCC and COB were sagged or warped, indicating elevated RH levels. Many of these tiles were water stained and the upper surfaces were covered with a black fungus.

The water damage on some of the ceiling tiles appeared to be associated with the chilled water pipes and FCUs above the ceiling tiles. A facility manager reported that the chilled water pipes were wrapped with ½ inch of insulation, instead of the specified 1½ inches.

Some perimeter walls covered with vinyl wallpaper were slightly stained or discolored, with small purple, blue, pink, or orange areas. Peeling or removing small pieces of vinyl wallpaper revealed gray and tan fungi at the gypsum board-vinyl interface.

Some carpeted areas had obvious water damage, and investigators noticed a strong odor associated with volatile organic compounds (VOCs), which was traced to battery-operated and plug-

in air fresheners that were emitting terpenes into the air.

Direct readings showed that indoor temperatures ranged from 71.3° to 77°F and RH ranged from 45.2% to 68.2%. At the time of the readings, outdoor temperature was 81.8°F and RH was 75.2%.

Outdoor sampling for respirable particulates found a high of 264,920/ft^3 for particles from 0.5 to 5.0 µm and 2,160/ ft^3 for particles above 5.0 µm.

Indoor readings varied, but sampling for particles above 0.5 µm ranged from 32,580/ft^3 to 152,640/ft^3 in quiescent sampling, and up to 897,514/ft^3 when surfaces were agitated. Sampling for larger particles indicated a range of 260/ft^3 to 3,360/ft^3 in quiescent sampling and as high as 107,512/ft^3 during agitation.

Microbiological Sampling

Testing for airborne fungi found outdoor concentrations in the area of 617 cfu/in^3, mostly of *zygosporium*. Indoor sampling showed concentrations of both *aspergillus versicolor* and *penicillium* as high as 350,000 cfu/in^3.

In the laboratory testing of source samples for viable fungi, the main findings were *aspergillus versicolor* in concentrations that ranged from 100,000 to 1,000,000,000 cfu/in^2, and *stachybotrys* in concentrations up to 400,000,000 cfu/in^2. There was also some evidence of *cladosporium*. Table 3 shows some of the higher concentrations found.

Most of the microbial types present in the building have been implicated in health problems. The types and concentrations found are not typically present in healthy indoor environments

Table 3 — Viable Fungi Present in Source Samples from Martin County Court Complex (Selected Findings)

		Laboratory 1		Laboratory 2	
Sample No.	Description	cfu/in^2	Taxa	cfu/in^2	Taxa
100	Fiberboard from outdoor air duct upstream of dampers	4,300	*Cladopsorium* (59%) Nonsporulating (27%) *Penicillium* (14%)	7 billion	Pseudomonas-like bacteria
101	Fiberboard from outdoor air duct downstream of dampers	ND		3 billion	Pseudomonas-like bacteria
103	Vinyl wall covering from tax collection department east wall	12,000,000	*Aspergillius versicolor* (93%) Penicillium (3%)	335,000,000 200,000,000 1.2 billion	*Aspergillus versicolor* Morphotypes of *Penicillium* *Pseudomonas fluorescens*
105	Vinyl wall covering from tax collector department south wall	40,000,000	*Aspergillius versicolor*	935,000,000	*Aspergillus versicolor*
106	Vinyl wall covering near ceiling in family services	24,000,000	*Aspergillius versicolor*	—	—
110	Ceiling tile in law library	3,500,000	Possible *Stachybotrys*	40,000,000	*Stachybotrys*
111	Vinyl wall covering in jury box	38,000	Immature fungi	350,000,000	*Chaetomium*
117	Vinyl wall covering in tag section of tax collection office	20,000,000	*Aspergillius versicolor*	1 billion	*Aspergillus versicolor*

Source: Clayton Environmental Consultants

and, in the words of the investigator, "should not be tolerated."

IAQ Recommendations

The consultants presented county officials with a number of recommendations for remedial action.

- Undertake an engineering study to determine why the moisture was entering the building and to devise ways to prevent water and moisture incursion into the occupied spaces.
- Use finishes that are permeable to moisture on the interior surface of perimeter walls. This would allow moisture that entered the building to mix with interior air and be removed by the ventilation system.
- Control relative humidity in the occupied spaces to 60%, as specified by ASHRAE Standard 55-1992. (See related story on page 14.)
- Initiate a routine maintenance program in the complex using HEPA-filtered vacuum cleaners for all porous and nonporous surfaces in the occupied spaces.
- Prohibit the use of deodorizers, odor maskers, and air fresheners that emit VOCs.

The consultants also recommended removing all microbiologically contaminated wall coverings, gypsum board, and ceiling tiles. This should be done under strict isolation controls to protect workers or others from the mycotoxins that could be produced by the fungi.

This contamination control would involve isolating areas under remediation, providing workers with contamination gear and respirators, and establishing a safe method of disposal for the material that was removed.

The IAQ consultants also advised officials to increase the accessibility of the FCUs so that preventive maintenance could easily be performed on filters, fans, drain pans, and coils. If the accessibility cannot be improved, they added, the units should be removed and placed in another location.

HVAC Investigation

The review of the mechanical systems by the engineering firm determined that the mechanical condition of the air handling equipment is acceptable, and that if it is not contaminated, it can be reused.

The chiller condenser coils show some fin corrosion and should be replaced with new aluminum coils and coated for corrosion protection.

The engineers agreed with the IAQ firm that the AHUs and FCUs have limited access for normal maintenance. Only a few of the units allowed convenient access by maintenance staff, but in all cases access is through the ceiling tiles and changing filters, adjusting belt tension, or ensuring proper operation would interrupt work in the area.

The systems adequately pressurize the courthouse when both makeup air units and above-ceiling units are operating. However, the systems are less effective when the above-ceiling units are off.

The HVAC system has the capacity to dehumidify the air, but that requires that the system be running. Often, the system satisfies space temperature requirements before the humidity requirement is met.

One way around this would be to reheat the air with electric heat coils in the units, but that is prohibited by the Florida Energy Code.

The existing three-stage filters in the outside air units have the ability to filter particles as small as 0.45µ. However, some of the filters are less effective because of air bypassing them. In one instance, frame corrosion is allowing the filter to move out of the frame.

Building Envelope

The engineers found cracks throughout the exterior envelope of both buildings in the masonry system. Some of these occur at transitions between materials, such as where the pre-cast concrete lintels border the brick veneer.

The upper areas of the masonry system lack weep holes, although some seem to have been drilled subsequently. Numerous cracks appear in the pre-cast concrete sill and coping system, and, again, attempted repairs are evident.

The hardcoat system in both buildings reveals several failures, allowing rainwater to intrude into the building. Most of the vertical joint work shows cohesive failure.

There are numerous cracks within and near the hardcoat panels and, even where someone had tried to patch them, the repair caulking has cohesively failed.

Many of the windows, which are predominantly located in the north and south walls, show water stains, which most likely came from gaps between the sills and the vertical mullions. The inspection of the exterior window system showed that many frames are not true and plumb, leaving unsealed gaps. Also, the sills show signs of sealant failure.

The roof shows signs of water intrusion, occurring mainly near mechanical systems and where the ductwork penetrates the roof. Also, water intrudes directly into the air intake exhaust systems on the roof.

In the hardcoat wall system, the exterior insulation has significant diffusion retarding characteristics and is a good vapor retarder. In the masonry wall system, the felt paper on the exterior sheathing does not provide as good a barrier to moisture, although it keeps rainwater out.

Many interior walls have vinyl wall covering, which has a low ability to transfer moisture. Consequently, it acts as a moisture barrier, trapping moisture that enters the wall system.

HVAC Recommendations

The engineering firm offered the county two options for HVAC renovations. The first is central air handling systems that would be single-duct, medium-velocity, variable-air-volume (VAV) systems.

These could be sized as two rooftop units per building or one AHU per floor. The advantages to the rooftop units would be the fact that they would not consume interior floor space and would isolate sound and vibration from the occupied zones. This option would also centralize filtration and maintenance activities.

Recommendations include replacing all ductwork with round, spiral seamed duct with factory-fabricated fittings and exterior vapor retarder.

With this system each interior temperature control zone would need a VAV terminal control unit with hot water reheat coil, resulting in a need to distribute hot water to each zone unit, along with the chilled water that is presently piped in.

Engineers determined that each major AHU should be able to dehumidify the ventilation air properly, even when running at 100% outside air.

The existing makeup air systems, no longer needed, could serve the Public Defender building.

Under this option, all controls would be replaced with a direct digital control (DDC) system, and this would allow monitoring of space temperature, humidity, and air flow, with appropriate changes in operating conditions to maintain the proper environment.

The second option recommends the installation of floor-mounted FCUs with standalone control capabilities that could be monitored through a central system. Under this option, the makeup air systems would be reused. This would require an upgrade to the Public Defender building to add outside air to the ventilation system.

Structural Recommendations

The engineering consultants gave a number of recommendations for improving the impermeability of the building envelope, and increasing the masonry wall system, hardcoat wall system, windows, and roof. For the first two, they list two options.

For the masonry wall, engineers recommend either maintaining the existing system by resealing joints and replacing damaged components, or covering the existing system with new exterior insulation and finishing it with a non-cementitious coating.

For the hardcoat wall system, the first option is to repair the existing wall by grinding out or cutting away joint work and replacing it with new sealant. The second option is to install a new wall system.

For windows, the engineers recommend drilling weep holes in the sills, sealing all openings in the framing, and closing gaps between the wall and the frames. They also recommend roof work, including replacing the parapet coping system.

Cost of Renovations

Whichever option the county officials choose, the total will be close to half the US $10.6 million the county spent to build the buildings in 1988. The *Palm Beach Post* reported in early April that the county had already spent over $1.75 million — before renovation work had begun. This broke down as follows:

Attorneys	$123,000
Engineering work	100,500
Courthouse Evacuation	497,000
HVAC Renovation	214,000
HVAC Cleanup	59,000

Environmental Experts	149,000
Blood Tests	22,000
Project Manager	56,000
Extra Maintenance	100,000
Temporary Judicial Center	435,000
Total	$1,755,500

Engineering consultants estimated the cost of recommended remediation work as follows:

Removing contaminated material	$1,056,344
Seal/repair exterior	354,490
Complete envelope rework	678,555
HVAC Option 1	1,103,912
HVAC Option 2	976,036
Public Defender HVAC	160,000
Chiller Replacement	179,567
Monitoring System	111,785
Build-out of 4th Floor	531,945

For More Information

For more information from Martin County, contact David Peach, Project Coordinator, County Administration Center, 2401 SE Monterey Road, Stuart, FL 34996, USA; (407) 288-5457.

The IAQ investigation was carried out by Philip Morey, Clayton Environmental Consultants, 160 Fieldcrest Avenue, Raritan Center, Edison, NJ 08837, USA; (908) 225-6040, Fax: (908) 225-4577.

The engineering work was headed up by David Odom, CH2M Hill, 225 E. Robinson Street, Orlando, FL 32801, USA; (407) 423-0030, Fax: (407) 839-5901.

NEWS AND ANALYSIS

Don't Expect Big Changes in ASHRAE Standard 62 Revision

Work is proceeding on the update to ASHRAE Standard 62-1989, *Ventilation for Acceptable Indoor Air Quality*, but the effort probably won't result in anything startling or revolutionary. Most likely, the biggest changes will be a discussion of residential ventilation, a section on operation and maintenance, and greater emphasis on a procedure to account for nonoccupant sources of pollution.

W. Gene Tucker, chair of the revision committee, told ***IAQU*** that his group hopes to have a first draft of the standard ready for the ASHRAE annual meeting this June in Denver, Colorado, USA, and hopes to have a version ready for public comment by sometime in 1995.

While the current standard represents a major increase in minimum ventilation rates from its predecessor, the revision currently in progress will most likely emphasize sections of 62-1989 that are largely ignored.

Tucker said the new version will probably include a section on residential ventilation, something mentioned only in passing in the current standard, which focuses more on commercial and institutional space. He added that the committee gave some thought to removing it altogether and issuing a separate standard for residential applications, but decided to leave it in.

Operations and maintenance will be stressed because, as Tucker points out, IAQ is not just a matter of design. How a building is operated and maintained often has a greater impact on IAQ. "You have to follow a building throughout its life," Tucker told ***IAQU***.

IAQ Procedure

Perhaps the biggest change will be the greater emphasis on what, in the 62-1989 version, is called the "Indoor Air Quality Procedure." This is a formula-driven system to account for nonoccupant sources of pollution and compensate for them by changing ventilation rates.

While this procedure theoretically exists in the current standard, it is difficult to use and lacks sufficient data for most designers to use it properly. Consequently, most designers or building operators simply ignore it and rely on the "Ventilation Rate Procedure," which specifies minimum amounts of ventilation for different types of spaces, depending upon use or expected occupancy.

New European guidelines rely heavily on calculations of pollutant source strength and the level