Indoor Air Quality

Mold 101: An Overview for SH&E Professionals

Recognizing and handling mold hazards in the workplace

By Michael A. Pinto and David Janke

IN RECENT YEARS, THE BODY of scientific and anecdotal data pointing to interior mold contamination as a potentially serious health threat has grown (e.g., ACGIH; AIHA; EPA; Health Canada; IICRC; OSHA; NYCDH). Despite this, many SH&E professionals do not concern themselves with mold contamination and indoor air quality (IAQ), considering these to be the business of industrial hygienists. However, the overlap between SH&E and IH professionals on issues of mold contamination and remediation is increasing. Entry into confined spaces, formerly the exclusive domain of IHs, has been brought into the realm of SH&E professionals, and mold problems are poised to follow suit.

In light of the growing concern about mold contamination and health issues, SH&E professionals should be prepared to address these issues. This article culls information from several sources to present a basic overview of mold hazards and how to handle them. Readers should be aware, however, that the remediation industry is currently in a state of flux and that few true guidelines are available. The industry's current best practices/standards are detailed here, but they are subject to change as a consensus emerges.

Michael A. Pinto, Ph.D., CSP, *is CEO of Wonder Makers Environmental, a Kalamazoo, MI safety consulting firm that specializes in indoor air quality, asbestos and lead. He has 20 years' safety experience in both the public and private sectors. Pinto is the author of* Fungal Contamination: A Comprehensive Guide to Remediation. *He is a professional member of ASSE's West Michigan Chapter.*

David Janke *is a National Merit scholar and student at Calvin College. He performs microscope analysis of bioaerosol samples and assists in data preparation for Wonder Makers Environmental.*

Some Basics

In common vernacular, the terms mold and fungus are often used interchangeably. However, in the scientific community, molds are one category of nongreen plant-like organisms (along with mildew, mushrooms, yeast, rusts and smuts) that fall under the heading of fungus. Since molds make up the largest component of the fungal classification (with more than 60,000 identified species), the two terms often are interchanged indiscriminately. Regardless of the type of fungal matter, they share the characteristics of being able to grow without sunlight; this means that fungus needs only a viable seed (known as a spore), a nutrient source, moisture and the right temperature to proliferate. This explains why fungal infestation is often found in damp, dark, hidden spaces; light and air circulation dry areas out, making them inhospitable for fungus.

All fungal types can grow through both physical expansion and the spread of spores, a process called "sporation." Dandelions provide a good analogy for this dual method of growth. If conditions are right for such weeds to grow in a lawn, they tend to spread to the point where they will crowd out the grass. If the heads are plucked off the dandelion plants, the weeds will spread locally by expanding the size and number of stems. If conditions are more favorable, dandelions will grow their characteristic yellow flowers that ultimately turn into seedpods. At that point, the wind's physical action can transport the individual seeds great distances where they start new plants (provided they land in an appropriate place).

Most mold species act in a similar manner. Once they get a foothold in a particular location, rapid growth across the surface is possible if the moisture source is sufficient (similar to the dandelion growing in size at the base during the spring). If the moisture source starts to decrease, many mold species enter a sporation phase in which they grow and release large numbers of microscopic spores into the air. One researcher estimated that a single round colony of Penicillium mold 2.5 centimeters in diameter contains 400 million spores, each so small that a microscope is needed to see it (Smith 42). In the dandelion analogy, the spores are the equivalent of light, fluffy dandelion seeds that easily blow off the stems, with the "stems" of mold referred to as hyphae. It is worth noting that certain analysis methods are able to identify hyphae as well as the individual mold spores.

A small amount of visible mold or transient odors may signal greater infestation hidden in various areas, including air ducts (left), air diffusers in the ceiling (below, left), and behind and/or between wall components, such as wallpaper (below, right).

PHOTOS COURTESY EPA

Prevalence of Fungus & Hazard Assessment

Many forms of fungus can be found throughout the natural world. From the earliest of times, not only have people recognized the presence of fungus, they have also learned to distinguish between beneficial and harmful forms. For example, ancient Egyptians understood that yeast was necessary if bread was to rise or beer and wine were to ferment. Many Asian nations have used dried black or green fungus for thousands of years as a seasoning. Certain mushrooms and truffles have long been considered delicacies. Blue cheese receives its characteristic marbling and taste from a mold. In the modern era, a common bread mold was manipulated to create the first class of disease-fighting antibiotics.

Harmful fungi have long been recognized as well. The book of Leviticus contains some of the earliest known instructions for properly dealing with mold growth on interior surfaces. Ancient Roman texts document the dangers of eating moldy grain. The great potato famine of 1845 to 1847 was the result of a fungus called "Late Blight" and led to an estimated 750,000 deaths. In the 1940s, thousands in the former Soviet Union died after ingesting grain contaminated with the mold Stachybotrys atra (the same mold that some doctors link to the death of infants in Cleveland and around cities). Stachybotrys can produce serious injury after ingestion or inhalation through internal poisoning that causes hemosiderosis (bleeding in the lungs) (ACGIH).

Since molds can be beneficial or harmful, one must understand the conditions that would result in a hazard due to a fungal contamination. In other words, if a small amount of black mold appears in the corner of a shower stall, should people run screaming from the building? What about a thick patch that covers part of a two-foot by four-foot ceiling tile and has gray spidery tentacles beginning to creep out of the black mass? Does it make a difference if these situations develop in the crawlspace? The crawlspace of a factory versus that of a school? Is a musty/mildew odor an indication of significant levels of contamination? What if no visible source of the smell can be identified?

While each situation of potential mold exposure must be evaluated individually, several important items should be considered in every case. All visible interior sources of mold—or the characteristic musty/moldy odors—should be investigated carefully. A small amount of visible mold or transient odors may signal greater infestation hidden above ceiling tiles, below carpet, inside HVAC systems or between wall components. It is also a sign of a moisture source. The investigation/hazard assessment should identify possible causes of structural or plumbing leaks, or reasons for elevated humidity levels (e.g., inadequate air conditioning capacity, spraying, mixing or cooking processes, unvented shower rooms).

The location of contamination affects the hazard assessment. Since the most significant problems involve mold in an air stream, any mold contamination of an HVAC system, particularly the supply ductwork, must be addressed promptly. (See sidebar on page 37.) Mold in or near occupied spaces is the next priority. Even mold in less-frequently entered areas, such as basements, crawlspaces, attics or service rooms, should be addressed since doors, floors and walls usually do not create the airtight barriers necessary to contain the microscopic spores.

The amount of mold also plays a role. While any mold should be cleaned up, larger quantities may require the use of PPE and engineering controls. Many organizations suggest that patches of mold smaller than two to three sq. ft. can be cleaned with minimal precautions (NYCDH Section 3.3). Contamination up to 30 sq. ft. requires PPE and controlled activities (OSHA 6-9). Mold infestation greater than 30 sq. ft. normally demands site-specific engineering controls such as dust partitions, air-filtering devices, special cleaners and fungicides (EPA Table 2).

Although controversial, many mold remediation specialists treat certain species differently. Because of their ability to produce mycotoxins, molds such as Stachybotrys and Fusarium are often approached from a more-conservative standpoint —including the use of negative-pressure enclosures for their removal.

Measurement & Identification

Several methods are available to evaluate fungal contamination. Although scientific precision and detailed quantification are important, the first step in evaluating the possible impact of mold contamination is to use three senses—visual sense, olfactory sense and common sense. These help distinguish between nuisance situations (mold in a shower stall) and potential hazards (mold growing inside HVAC ductwork). Several words of caution are necessary at this point. One must remember that the sense of smell can differ greatly from person to person. In addition, exposure to fungal contaminants, even at low levels, can sensitize some individuals who, as a result, will experience progressively greater symptoms even with decreasing exposure. Therefore, some people can experience symptoms even when concentrations of spores in the air are low enough that no telltale musty or moldy smell is present.

This variability in human perception of airborne fungal contaminants is one reason that testing can be crucial. Furthermore, the type of test performed can be as important as the decision to test. Whether taking air samples or surface samples, one can choose between direct analysis samples and cultured samples. Until recently, direct analysis samples were not well regarded, especially for airborne samples. This was due primarily to sampling techniques that resulted in low collection efficiencies and the variability in collection media. With the advent of a commercially available cassette that standardizes the collection medium and increases collection efficiency, use of direct analysis sampling has grown tremendously.

Many IAQ professionals now use these samples as their initial screening tool because the results report both viable spores (those able to reproduce under the right conditions) and nonviable spores. In addition to quantifying spores in the air that can cause allergic reactions but might not grow because they are desiccated or have been altered in some way, direct analysis allows one to identify hyphal fragments; this helps determine whether the spores are from an interior source. Faster turnaround and a simplified collection process are other benefits of this technique.

Cultured samples are used if more-detailed analysis is necessary. In this sampling technique, air is impacted against petri dishes with specific types of sampling media. The dishes are then incubated under controlled temperature and humidity conditions and the resulting growth visually examined. By their design, cultured samples do not identify nonviable spores even though such material can also contribute to allergic reactions, but the technique allows a more-precise determination of fungal types (species and subspecies levels as compared to genus level for direct analysis samples). This technique has a built-in waiting time of three to seven days while samples grow in an incubation chamber.

Standards & Guidelines

Regardless of which sampling technique is used, it is difficult to find definitive standards for comparison of results. OSHA's manual contains some recommendations for indicators of indoor contamination (these are noted in colony forming units per cubic meter of air [cfu/m^3]). The agency tells its inspectors that levels of 1,000 cfu/m^3 or greater indoors is a matter for further investigation (OSHA). American Conference of Governmental Industrial Hygienists (ACGIH) has a relatively new manual on biological contamination, but even that does not have hard numbers for results obtained from either sampling technique. Most expert guidance documents indicate that comparisons should be made between areas out-of-doors and inside the building, and between complaint areas and noncomplaint areas, with levels and types of biological organisms compared to determine whether indoor amplification is present.

The wide range of natural spore levels depends on the season, surrounding vegetation and time of

Mold Contamination Following a Flood

In Feb. 2001, a Michigan company reported that several employees had been experiencing allergy-like symptoms while at work, including one employee whose symptoms were so severe he could not enter the building. The building had experienced water intrusion from excessive rain and it was suspected that indoor mold growth may have been the cause of these symptoms.

Air samples were collected from different areas of the building and analyzed. Analysis indicated that Stachybotrys mold spores were present, along with elevated levels of Aspergillus and Penicillium molds. These types of fungal contaminants have been shown to cause health effects similar to those described by the building's occupants.

Remediation activities were conducted to remove the contamination. This included HEPA vacuuming of all furnishings, removing contaminated carpeting and drywall, and sanitizing wall cavities and floor surfaces. After the remediation work was completed, the wall cavity was encapsulated with a fungicidal encapsulant to prevent mold growth from recontaminating the surface. Employees returned to work with no additional complaints.

Three months later, a large amount of rain caused more water intrusion in the building. This time, however, the encapsulant prevented mold from beginning to grow before the area could be dried. When air samples were taken after the second flooding episode, no elevated levels of mold spores were detected.

day; these factors make the collection of out-of-doors comparison samples critical. However, these sorts of comparisons are not helpful in determining the effectiveness of mold cleanups or even in conducting the risk assessment for building occupants with complaints about the indoor environment.

In an effort to deal more effectively with such cases, several scientists and consultants around the country (led by Dan Baxter of San Diego) have assembled a large body of anecdotal information that relates fungal counts from direct analysis samples to building occupant complaints and symptoms. This data has prompted some experts to adopt 2,000 counts of mold spores per cubic meter of air (c/m^3) as a maximum for a clean building. In addition to the total count, these quasi-industry standards set limits for species known to generate more-significant allergic reactions (e.g., Penicillium and Aspergillus at less than 1,000 c/m^3 each) as well as species that have toxigenic properties (e.g., Stachybotrys or Fusarium are not acceptable in indoor air at any level) (ETA). It is hoped that continued studies of the relationship between airborne mold levels and health effects will eventually move the information from a quasi-industry standard to a full-fledged consensus standard and perhaps ultimately, provide the basis for regulatory guidance.

Teaching Staff Hospitalized Due to Mold Contamination

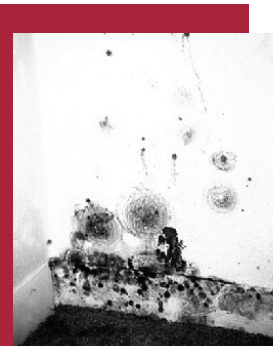
This case, involving a school building in a midwestern state, dramatically illustrates how serious mold problems can be, particularly in a newer building. It also highlights the role that building systems, particularly HVAC systems, can play in magnifying any existing fungal contamination.

On Sept. 28, 1999, seven people were attending a 7:00 am meeting when the HVAC system switched over from heating to air conditioning, sending a pulse of air through the ductwork. Mold was growing in the ductwork, including Stachybotrys, Aspergillus and Penicillium. The pulse of air shook loose some of the mold, causing it to become airborne. The meeting room was at the end of a section of ductwork, so the air carrying the fungal materials stopped right above it. The fungal materials fell into the room through a vent in the ceiling. By 8:30 am, several people in the room began to experience symptoms. By 10:00 am, all seven people who had been in the meeting were experiencing symptoms, including dizziness, high blood pressure, headaches, nausea, tingling and numbness in the mouth and lips, sweating, chills, rapid heartbeat and loss of mental acuity. Several fainted before all seven were taken to the hospital. Four were treated and released, while three stayed overnight for testing and treatment.

Cleaning Up & Controlling Contamination

Although fungus species are natural organisms found throughout the world, their presence in houses, schools and offices can create health hazards that must be addressed. The key to controlling fungal growth is to remove the moisture, nutrients or source of spores. In ancient times, the only option was to try to remove the source of the contamination itself. Homeowners with mold growth on their walls were instructed to scrape it off, then have the area checked by a priest. If successive scraping or cleaning did not keep the mold from returning, the house was to be destroyed and the debris dumped in an "unclean" place (Leviticus 14:43-45). While this may seem extreme, it graphically illustrates that the potential health consequences of indoor mold contamination have long been known.

Source removal is used frequently today where visible mold growth is present on porous materials. Physical removal remains the best choice for plaster, drywall, ceiling tiles, cellulose insulation, cardboard boxes and similar materials. In less-extreme cases, removing the moisture source and cleaning the surface with a sanitizer/biocidal agent can be effective.



Cleanup and/or removal of fungal contamination requires appropriate work practices and PPE. Depending on the type and amount of material involved, the work area may need to be isolated from other building areas.

PHOTOS COURTESY EPA

If such techniques are used, the sanitizing agent must come in full contact with the fungal material for the required amount of time. In addition, the moisture source—be it excess humidity, condensation or moisture intrusion as a result of roof leaks, pipe failures or subgrade seepage—must be controlled. Otherwise, recontamination is possible. This is why ACGIH calls for porous materials that have been wet for longer than 48 hours to be removed regardless of whether the leak came from a clean or dirty water source (ACGIH).

The cleanup and/or removal of fungal contamination requires appropriate work practices and PPE. Anyone who will intentionally disturb fungal con-

IAQ & Mold Resources

An Office Building Occupant's Guide to IAQ
www.epa.gov/iaq/pubs/occupgd.html

Biological Contaminants
www.epa.gov/iaq/pubs/bio_1.html

Building Air Quality Action Plan (for Commercial Buildings)
www.epa.gov/iaq/largebldgs/actionpl.html

Floods/Flooding
www.epa.gov/iaq/pubs/flood.html

Indoor Air Quality (IAQ) Home Page
www.epa.gov/iaq

IAQ in Large Buildings/Commercial Buildings
www.epa.gov/iaq/largebldgs/

IAQ in Schools
www.epa.gov/iaq/schools/

Mold Remediation in Schools and Commercial Buildings
www.epa.gov/iaq/molds/mold_remediation.html

Mold Resources
www.epa.gov/iaq/molds/moldresources.html

EPA IAQ Information Clearinghouse
iaqinfo@aol.com

American Conference of Governmental Industrial Hygienists
www.acgih.org

American Society of Heating, Refrigerating and Air-Conditioning Engineers
www.ashrae.org

Assn. of Specialists in Cleaning and Restoration
www.ascr.org

Even in small projects, basic principles such as isolation, limited dust generation during removal, thorough sanitization and proper disposal are useful.

tamination in any way should wear a respirator or filtering facepiece with a minimum N-95 rating (NYCDH; EPA; AIHA). Those engaged in a cleanup should not confuse a filtering facepiece with a dust mask available at many hardware and discount stores. A standard mask for nuisance dust does not provide appropriate seals or filtration to minimize inhalation of disturbed spores.

Those removing contaminated materials should also wear surgical gloves underneath cotton or leather work gloves, while those performing cleanup and sanitization should wear heavy-duty rubber gloves to protect against possible chemical exposures. Large-scale removal or cleanup projects may require the use of disposable body coverings, hoods and booties to minimize cross-contamination between work areas and clean areas.

Depending on the type and amount of material involved, the work area may need to be isolated from other areas in the building through the use of plastic sheeting to seal doorways, windows, vents and other openings. If the potential for airborne dispersion of contamination is significant, it may be necessary to utilize large filtering fans to create negative pressure inside the work area. Due to these precautions, large mold remediation projects often look like an asbestos or lead abatement jobsite. Incorporating the techniques of separate decontamination stations, sealing of debris, and proper waste loadout from asbestos projects can also be beneficial to large-scale mold remediation activities, although some would argue that such precautions are overkill used to inflate project price. These "set-up minimalists" contend that mold contamination does not have the same dangerous properties as asbestos, lead or hazardous waste.

Nevertheless, continued medical research, an increasingly high level of liability associated with such work, and the practical aspects of utilizing more-extensive set-up to minimize the amount of post-remediation cleaning needed to reach clearance levels are factors that are moving more projects toward extensive set-up. Clearly, not every project needs full-scale asbestos-style precautions. In fact, several commercial products provide tools and supplies designed to help homeowners and maintenance/custodial workers properly address small sections of mold contamination. However, even in such small projects, the basic principles of isolation, limited dust generation during removal, thorough sanitization, encapsulation of residual mold and proper disposal are useful.

Although mold is a naturally occurring phenomenon, the presence of extensive mold growth indoors has been a concern since ancient times. Today, many companies are turning to SH&E professionals for answers to their mold remediation questions. To respond effectively, these professionals must understand the basics of mold hazards. ■

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