MOLD: CAUSE, EFFECT AND RESPONSE

FWCI

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Prepared for the
Foundation of the Wall and Ceiling Industry

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Preface

Foundation of the Wall and Ceiling Industry

In the late 1970s, there was a clear recognition among industry leaders for the need to unite and expand the educational and research activities available to contractors, manufacturers, distributors and the public, in general. At the time, there were many issues facing the industry—from a national energy crisis to injuries in the workplace, to unsafe buildings occupied by the public. In response to these issues, the Foundation of the Wall and Ceiling Industry was formed in 1977 with the following mission statement as an IRS designated non-profit 501(c)3 corporation to pursue educational and research activities benefiting the industry and the public at-large:

The Foundation's mission is to be an active, unbiased source of information and education to support the wall and ceiling industry.

To fulfill this mission, the Foundation owns and maintains the largest independent library serving the wall and ceiling industry, provides educational scholarships for those pursuing careers in engineering, construction and design, provides research support to industry inquiries and publishes research papers.

This paper offers a review of a variety of scientific, technical and medical resources to answer questions and to educate readers about the complex and often controversial issues surrounding mold growth in buildings. This paper is intended for the construction industry, including manufacturers, contractors and building owners and managers. It is not intended to provide design guidance or to serve as a training manual for mold assessment and remediation. The goal is to provide readers with an understanding of the state of the science so they can be better equipped to prevent mold problems, handle mold complaints when they do occur, and practice good risk management.

To obtain additional copies of this research paper or to learn more about the Foundation of the Wall and Ceiling Industry, please contact

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Introduction

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Are Toxic Molds Miving You Headaches, Asthma–or Worse?

These recent news headlines reflect an increasing interest and concern about how mold affects indoor environments and building occupants. While mold is nothing new, its prolific growth in some buildings and fears of adverse health effects are a more recent development. Are these concerns justified? Who is at most risk for having health problems as a result of mold? What molds are considered "toxic" molds? Are all molds toxic? Where and when does mold grow in buildings, and why does it seem there is more mold growing in buildings today as compared with 20 or 30 years ago? What can be done to clean up mold, prevent it from coming back and reduce liability in case of mold infestation?

Who, What, Where, When, Why of Mold

The first step in answering the questions posed in the Introduction is to realize that mold growth in buildings and its relation to health effects is not as simple as is presented in news reports and litigation. It also requires looking at why mold is becoming a more prevalent problem in buildings, where mold grows and why, and what is it about mold that has prompted so many concerns.

Mold Growth and Health Effects: It's Not That Simple

By and large, news reports and litigation tend to treat problems associated with mold as a three-step process:

1. Water and/or moisture get(s) into or occur(s) in a building.

2. Mold grows.

3. People get sick.

This is an over-simplified approach. The actual process is more complicated and has variables that are not yet well understood:

1. Water and/or moisture get(s) into or occur(s) in a building.

2. Building component(s) and substrate(s) can be affected to more or lesser degrees.

3. Mold may or may not grow. Whether mold grows and which species may grow depends on several factors, such as whether the moisture dries, lingers or if there is repeated water damage; the amount of water content or activity in or on the surface of the substrate(s) for long enough to support mold growth; and the nutrition source available in or on the surface of the substrate. Some mold species such as *Stachybotrys chartarum*, for example, will grow on carpet backings and materials containing cellulose, including gypsum wallboard, whereas *Wallemia sp.* grows primarily on textiles, and *Phoma sp.*, another common mold found indoors, grows on painted walls.

4. Exposure to mold and health effects. The state of the science in this area is incomplete, and exposure standards for molds and mycotoxins as yet do not exist. As a result, the topic of health effects associated with mold is controversial. A byproduct of this controversy is news reports and litigation that often make assumptions about mold exposure and health effects that are not supported in the medical and scientific literature.

The medical and scientific literature does support the following positions:

- If mold grows, there is no direct evidence as yet that building occupants will automatically be exposed at sufficient levels to cause health effects.

- Just because mold is visible or there is invisible mold growth does not mean that allergens, irritants, volatile organic compounds (VOCs) or other potentially toxigenic components, such as mycotoxins that can produce adverse health symptoms, are being produced.

- Not all people are susceptible to developing adverse health reactions or to the same degree.
- It is quite possible that purported health effects are not attributable to mold exposure, or may be attributable only in extreme cases.

Overview of Mold in Construction

Buildings are dynamic environments, affected by geographic location; climate; heating, ventilating and air-conditioning (HVAC) system design and operation; types of building materials used in construction and finishing; moisture intrusion; pest colonization; and human activities. In order to grow, mold needs a nutrient source, appropriate temperature and moisture.

The following discussion takes a closer look at these elements and their relationship to supporting mold growth, including an in-depth consideration of the role of moisture. Throughout this discussion and this paper, the terms “mold” and “fungi” are used interchangeably.

Nutrient Sources. There are numerous sources in today’s buildings to satisfy the nutritional needs of fungi, including materials containing cellulose, such as gypsum wallboard, wood paneling, plywood, oriented strand board (OSB), pre-cast panels and ceiling tiles; fabrics and carpets; upholstered furniture; fiberglass-lined air ducts; and other porous materials where fungi break down the material itself or use organic debris that has collected. Some traditional construction and finishing materials contain natural chemicals that retard biodeterioration; for example, the heartwood of some tree species contains terpenes and other substances that inhibit fungi growth. Man-made products such as ceiing tiles, fabrics, carpets, draperies, upholstered furniture, fiberglass insulation, gypsum wallboard covered in paper with cellulose and pressed wood products with added binders and resins are susceptible to mold growth as they lack natural antimicrobials and provide a nutrient source.[1]

Temperature. Buildings are typically maintained at a temperature of 65 degrees F to 75 degrees F (18 degrees C to 24 degrees C), which is hospitable to many molds, some of which can survive at temperatures below 50 degrees F (10 degrees C) or above 122 degrees F (50 degrees C). At relatively low temperatures (50 degrees F to 60 degrees F), spores take longer to germinate, and growth is slower.

Moisture. For mold to grow in buildings requires sufficient moisture for a long enough period of time. There are primarily three factors that influence the amount of moisture available for mold growth:

1. Building tightness, which does not allow moisture to escape to the outside.
2. Liquid water infiltration from outside as a result of a leaky building envelope or structural failure.
3. Moisture condensation on mold susceptible substrates, which originates from water vapor inside or outside the building.

The following is a more detailed discussion of these factors and why they contribute to high moisture levels in buildings.

Building Tightness. By and large, buildings are built much tighter than their counterparts in the first half of the 20th century. A typical building today is almost twice as tight as those built a few decades ago. This increase in tightness can be attributed to an introduction of new materials and production techniques, thermal insulation and elimination of active chimneys in residential construction, and the advent of mechanical HVAC systems.[3] In response to the energy crises in the 1970s, tightening up buildings to save energy became the mantra of all commercial, institutional and residential building construction.

Efforts to save energy have been successful. While the number of commercial buildings and the amount of commercial floor space has increased since 1979, total energy consumption has remained flat.[4] One significant unanticipated byproduct of these efforts, however, is increased moisture levels, in terms of relative humidity in interior spaces and moisture content and water activity in building materials.

As buildings became tighter, the amount of air exchanged between the interior conditioned space and outdoors diminished, resulting in significantly less dilution of moisture and indoor pollutants, such as formaldehyde, volatile organic compounds and carbon dioxide. This trend occurred concurrently with the introduction of metal windows, glass wall systems that do not permit natural ventilation, and new synthetic materials and products for building furnishings, finishings, flooring and cleaning.[3] With today's construction techniques and available building systems, highly energy efficient buildings can be designed, built and operated that also provide superior indoor air quality.

Water Infiltration. Any opening in the building envelope may permit liquid water to penetrate the building and accumulate on mold-susceptible materials. These sources include the following:

- Leaky windows and door openings.
- Roof leaks.
- Missing, inadequate or poorly designed flashing.
- Lack of gutters.
- Foundation leaks.
- Plumbing leaks.
- A myriad of other causes.

Surprisingly, large quantities of water can pass through very small cracks/openings if they are located at critical junctures in the drainage path of the envelope. Since such junctures typically occur at the base of window openings and where roofs intersect walls, generally tiny cracks develop exactly where they can do the most harm. This is why seemingly minor details with missing or poorly designed flashing can have such a profound impact. Regardless of the cause, entry of liquid water into any building must be prevented *(see Section 4, Eliminate Sources of Moisture).*

In addition, water and moisture present in building materials or at the construction site can provide ideal conditions for mold growth once the materials are installed, such as OSB and other press-wood products, ceiling tiles and gypsum wallboard that are allowed to get wet from rain and/or other sources.[5] Water also may enter a structure through porous materials such as wood and concrete, or as a result of leakage and structural faults. Inadequate drainage around the foundation also allows considerable moisture to enter a basement.[1]

Water Condensation: A Matter of Dew Points, Humidity. Mechanical HVAC systems became popular in the mid-1960s and really gained momentum in the 1970s. As the building envelope becomes tighter, the depressurization and pressurization of conditioned spaces is increased, which can lead to infiltration of moisture. At the same time, warm moisture-laden air can exfiltrate into wall and roof cavities. In addition, thicker insulation in the exterior wall cavities creates lower drying potentials for materials making up the wall structure.[3]

The urea formaldehyde foam insulation used in Canadian homes until the early 1980s provides a useful example of how new construction materials can contribute to creating suitable conditions for mold growth. Extensive growth of *Penicillium* s*p*., *Trichoderma harzianum* and *Paecilomyces variotii* were frequently found in external walls of affected homes.[6] In addition to condensation and leakage problems, moisture responsible for the mold growth may have originated from water released in the wall cavity during the curing of the foam insulation.[1]

In cold climates, moisture can collect in and on internal surfaces of exterior walls. When the internal surface of these walls becomes too cold, the surface relative humidity may exceed 65 percent, or condensation may occur when the temperature at the inner surface of the external wall is at or below the dew point temperature of the room air. Both instances provide a ripe environment for mold growth. Hidden mold growth also can occur at the first condensing surface, which may be the OSB or plywood on the internal surfaces of the external sheeting. Internal humidity sources in pressurized buildings, envelope vapor barriers placed on the cold side of insulation or placed on both the warm or cold side of insulation, and basements insulated on the inside all can contribute to envelope moisture problems.[1]

In warm climates, air conditioning plays a key role. The accumulation of moisture on or in the building envelope is strongly influenced by indoor temperature and outdoor humidity conditions. Mold growth typically occurs on internal surfaces of external walls because the surfaces are cooled by air conditioning to below or near the dew point of the humid air infiltrating into the envelope. At the same time, if low permeable wall coverings are used, moisture is not able to escape out of the wall cavity and into the indoor environment. As a result, the backside of the wall covering and the wallboard to which the covering is attached become an ideal place for mold growth. Moisture can enter a building as a result of leakage, such as windows or around roof flashing, movement of humid air into the interior through loose construction of the building envelope, and diffusion of water vapor from the outside toward the cooler interior.[1]

Water requirements for mold vary over a broad range and in the scientific and technical literature they are usually referred to in terms of the water activity (a_W) at which the fungus can grow. Harriett A. Burge, Ph.D., a recognized expert in mycology, defines water activity as "the equilibrium relative humidity in the immediate vicinity of the substrate material and is expressed as a decimal. For reference animal cells require a_W near 0.99 or 1.00, which is essentially saturation."[2] In other words, water activity is a measure of a building material's ability to contain water to support mold growth at its surface and not the ambient relative humidity in the room. Rooms can have hot and cold spaces and thus different relative humidity levels. The ambient relative humidity expresses an average of these various levels. This is not necessarily representative of the relative humidity at a building material's surface.[42]

Some fungi can grow and reproduce at a_W as low as 0.69, although optimal growth probably occurs at somewhat higher levels. Many fungi have an optimal a_W of 0.80 to 0.90, which means that if the humidity at a surface reaches 80 percent, providing the substrate contains the appropriate nutrients and no inhibitors, some fungi will be able to grow and possibly reproduce. Humidity levels at the surface of the substrate must be maintained long enough for fungi to become established, usually about 48 hours. The more water that is available, the more fungi there are that can colonize a surface.[2, 42]

Mold, Mildew, Fungi–What's The Difference?

Fungi are naturally occurring organisms that make up approximately 25 percent of the earth's biomass and play an essential role in the processing of decaying organic matter into substances that are necessary for sustaining plant and animal life.[7] *Mold* and *mildew* are generic terms that are used to describe essentially the same fungi, with mold used to describe fungi growing on surfaces and mildew to describe fungi growing on fabrics.

Unlike bacteria and algae, fungi cells are *eukaryotes*; that is, they have a nuclear envelope.[8] The majority of species, including those most abundant in the environment are *saprobes*, which obtain nutrients from nonliving organic matter. Structurally, fungi exist as single cells such as yeast, or far more commonly, as threadlike *hyphae*. The collective mass of interwoven hyphal filaments is referred to as *mycelium*. While individual hyphae are microscopic, the mycelium is often visible to the naked eye.[9]

Fungal spores germinate to produce hyphae, which grow and branch within or on the substrate, typically producing a colony that eventually forms a new generation of spores.[9] Fungi also can spread if a fragment of broken hyphae is transplanted to an area with adequate moisture and nutrient source.[10] Spores contain one to many cells and differ greatly in size, shape, color and method of formation; however, they are always microscopic, ranging from fewer than 2 micrometers to more than 100 micrometers. Under adverse environment conditions, some fungi are able to form *chlamydospores*, which are thick-walled dormant spores that develop from transformed vegetative hyphae.[9] Fungi spores also can survive for many years in dry or hot environments, requiring only moisture and available organic matter in order to germinate.[10]

Fungi are resilient and adaptable and can colonize dead and decaying matter, such as textiles, leather, wood and paper, and even damp inorganic matter, such as glass, painted surfaces, metal and bare concrete, if organic nutrients, such as dust and soil particles, are present. Some fungi can germinate in as little as 4 to 12 hours, and, if left undisturbed, fungi can grow and spread in 24 to 72 hours.[7, 10]

Different Types of Indoor Molds

Approximately 69,000 species of fungi have been described in the scientific literature and estimates for the total number exceed 1.5 million.[9] Fungi are divided into groups based on spore shape and method of formation. Only members of three of these groups commonly grow on building materials. *Zygomycetes*

Table
Common Indoor Molds

Fungal Species	Indoor Substrate
Alternaria alternata	Window sills, walls, carpets, textiles
Aspergillus versicolor	Wood, wallpaper glue
Asperfillus fumigatus	House dust, potting soil
Chaetomium sp	Paper, materials containing cellulose, plant compost
Cladosporium herbarum	Window sills, wood, textiles, fiberglass duct liners
Cladosporium sphaerospermum	Paint, textiles, plants, food, soil
Epicoccum sp.	Plants, soil, textiles, paper products
Fusarium sp.	Soil, humidifiers
Geotrichum sp	Paper, soil, water
Paecilomyces sp.	Soil, dust, less frequently in air
Papulospora sp.	Soil, textiles, paper
Penicillium chrysogenum	Wallpaper, behind paint
Penicillium expansum	Wallpaper
Scopulariopsis sp.	Wallpapers covered with Paris green, house dust
Stachybotrys chartarum (aka Stachybotris atra, Stachybotrys alternans)	Carpet, materials containing cellulose
Trichoderma sp.	Other fungi, materials containing cellulose, unglazed ceramics
Ulocladium sp.	Dead plants, materials containing cellulose, textiles
Wallemia sp.	Textiles

are relatively common in building and house dust and require relatively simple carbon sources and very wet conditions. *Basidiomycetes* include all mushrooms and shelf fungi, including those that degrade wood products, and a few yeasts found in buildings. By far, the largest of the groups that can colonize building materials are *Ascomycetes*. What is typically known as mold and mildew fall within this group.[2]

The University of Minnesota Department of Environmental Health and Safety's web site features a fungal glossary on its indoor fungal resources page, included species-specific information derived from an extensive review of available scientific literature. The following discussion of *Cladosporium sp, Phoma sp., Rhodotorula sp*. and *Stachybotris* is from that glossary.[12]

Cladosporium sp. is the most commonly identified outdoor fungus. The outdoor numbers are lower in the winter and often higher in summer. It also often is found indoors but in lower levels than outdoors.

Indoor *Cladosporium sp.* may be different from the species identified outdoors. A wide number of organisms have been placed in the *Pencillium* genera. Identification to species is difficult. It is often found in aerosol samples, soil, food, cellulose, grains, paint and compost piles. It also is commonly found in carpet, wallpaper and in interior fiberglass duct insulation.

Phoma sp. is common mold found indoors. It is similar to the early stages of growth of *Chaetomium sp.*, and produces pink and purple spots on painted walls. It also will grow on butter, cement and rubber. *Rhodotorula sp*. is a reddish yeast typically found in moist environments such as carpeting, cooling coils and drain pans. In some countries, *Rhodotorula sp*. is the most common yeast genus in indoor air.

Stachybotris atra, *Stachybotrys alternans* and *Stachybotrys chartarum* are considered to be the same organism. Stachybotrys is a slow-growing fungus and does not compete well with other rapidly growing fungi. This dark colored fungus grows on building materials with high cellulose content and low nitrogen content and areas with a relative humidity above 55 percent. *Stachybotrys* is rarely found in outdoor air samples, and is usually difficult to find in indoor air samples unless it is physically disturbed or if there is a drop in the relative humidity. The spores are in a gelatinous mass and will die readily after release, but the dead spores can still be allergenic and toxigenic.

The table on page 14 lists some of the common molds and locations found in indoor environments.[7, 12]

Are Molds Really Toxic?

There is no simple yes or no answer to this question. Although much as been made in news reports and in recent litigation about the health effects from exposure to mold, especially with regard to *Stachybotrys chartarum*, this topic is somewhat controversial as there is little scientific or medical evidence that demonstrates that some molds are indeed "toxic." But at the same time there is consensus that some fungi species can produce *mycotoxins*, which are considered to be toxic to humans and animals. Opinions differ, however, whether exposure to these mycotoxins produces disease. Harriet A. Burge, Ph.D., a recognized expert in mycology said that such reports "are anecdotal and lacking sufficient data to document a clear connection between exposure and disease."[2]

Specifically, data are lacking to support threshold limit or dose-response relationship for exposure. The Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH) or the American Conference of Governmental Industrial Hygienists (ACGIH) have not established permissible exposure limits (PELs), recommended exposure limits (RELs) or threshold limit values (TLVs) for bioaerosols associated with mold.

The medical and scientific communities also agree that fungi species can be allergenic and irritants and, in some cases, cause infections. Systemic infections caused by mold, however, are not common, although opportunistic fungal pathogens, such as *Aspergillus sp*., are common in indoor air. Those at most risk for these infections include people who have severely compromised immune systems, such as those undergoing chemotherapy, people with HIV/AIDS or those who have had organ or bone marrow transplants.[7, 13]

In addition, whether or not symptoms develop depends on the nature of the species involved, the metabolic products being produced by the species, the amount and duration of exposure and the specific susceptibility of those exposed. It also depends on whether the spores, hyphae fragments and metabolites such as VOCs are released into the air and inhaled, physically contacted (dermal exposure) or ingested.[14]

Volatile Organic Compounds. In the process of degrading substrates as nutrients, fungi produce many metabolic products, primarily carbon dioxide and water. Under some circumstances, most fungi can also produce *ethanol* and *ergosterol*, which are useful compounds for determining if there is active mold growth, and a variety of volatile and non-volatile organic compounds. Volatile organic compounds (also called microbial volatile organic compounds [MVOCs]) are responsible for the musty odors characteristic of mold growth.[15] Exposure to high levels of VOCs, from any source—not just mold—can irritate mucous membranes and cause headaches, attention deficiencies, inability to concentrate and dizziness.[7]

Allergens. Allergic reactions are the most common response to molds. People who are *atopic*; that is, who are genetically capable of producing an allergic response, may develop symptoms when their respiratory system or skin is exposed to mold or mold byproducts to which they have become sensitized. Sensitization can occur in atopic individuals with sufficient exposure. Symptoms can range from mild to transitory responses such as watery eyes, runny nose, throat irritation, coughing and sneezing to severe, chronic illnesses such as sinusitis and asthma. An important note is that indoor fungal allergens probably affect fewer people than do allergens from cats, mites and cockroaches. A significant proportion of people with asthma (10 percent to 32 percent) are sensitive to mold.[7]

Mycotoxins. A wide variety of molds can produce mycotoxins, and some of these compounds are toxic to humans and animals.[8] While some mycotoxins are associated with hyphae, the primary mode of human exposure to mycotoxins is inhalation of spores and mold-contaminated materials. Molds that are important potential producers of mycotoxins indoors include certain species of *Fusariu* and *Penicillium*, *Aspergillus versicolor* and *Stachybotrys chartarum*. There is a great deal of information about the effects of ingesting certain mycotoxins in humans and animals, but investigators have only just begun to study health implications of inhaling these substances.[7]

Among the health effects attributed to mycotoxins are mucous membrane irritations, including eye, nose and throat, from exposures at high levels.[7, 16] When mycotoxins or particles carrying mycotoxins are inhaled, they may reach the lung alveoli and induce an inflammatory reaction, creating toxic pneumonitis. Severe toxic pneumonitis can cause fever, flu-like symptoms and fatigue. Inhaling large concentrations of dust with mold spores may cause hypersensitivity pneumonitis. This condition is generally an occupational hazard in agriculture, but has been reported in individuals in residences.[7, 13] Other symptoms attributed to mold mycotoxins include headache, dizziness, dermatitis, diarrhea and impaired or altered immune function.[17]

Researchers do not yet fully understand the specific conditions needed for mycotoxin production, but studies are under way. The U.S. Environmental Protection Agency (EPA), for example, is presently conducting research on *Stachybotrys chartarum* to determine “the environmental conditions required for sporulation, emission, aerosolization, dissemination and transport of [*Stachybotrys*] into the air.”[18] A complicating factor to determining these conditions is a single species of mold may produce several different mycotoxins, while different mold species may produce the same mycotoxin.[19, 20] Mycotoxin production for a given species is highly dependent on growth conditions, such as nutrient availability, temperature and humidity. Ronald E. Gots, M.D., Ph.D., states, “Just because a toxigenic mold is found in an indoor environment, it does not necessarily mean that the mold is producing mycotoxins.”[21]

Mold and Sick Building Syndrome. Although not attributed exclusively to mold, sick building syndrome is ascribed to inadequate ventilation, chemical contaminants from indoor and outdoor sources, and biological contaminants such as molds, bacteria, pollens and viruses. A 1998 survey on indoor air quality, ventilation and health symptoms in schools by Lawrence Berkeley National Laboratory revealed that microbiological pollutants, along with VOCs, carbon monoxide and carbon dioxide, were some of the most commonly measured air pollutants in schools. The survey cites water damage leading to mold contamination as the second most frequently reported building-related problem, with the root cause of many of the problems being inadequate and/or deferred maintenance of school buildings and HVAC systems.[22]

How to Tell If a Mold Problem Exists

If you are called in about a mold growing on gypsum wallboard, ceilings or behind wallpaper or if you are called about mold growing inside a wall cavity, what should you do? The presence of mold, water damage or musty odors in a building should be addressed immediately. Assessing complaints about mold infestation in buildings is critical to not only confirming that a problem exists, but identifying the source of the problem, what type of fungi are present, recommending a remediation plan and developing a strategy to prevent the problem from recurring. Only specially trained personnel who understand how buildings work and how to find sources of moisture should assess potential mold problems and recommend a remediation plan. For these reasons, the wisest course of action is to insist the building owner/manager call an expert!

Finding a Qualified Expert

Let the Buyer Beware. Finding a qualified expert is a challenging problem as there are relatively few real experts in the field of assessing, remediating and controlling mold in buildings. In response to news reports and litigation, many firms, staffed with former asbestos experts, have suddenly appeared claiming they have expertise. Many of these firms can be found in the Yellow Pages or on the Internet. The following are several starting points for finding a qualified expert:

- Referrals from people who have successfully addressed mold problems.
- Authors of articles and booklets.
- Bibliographies of scientific and medical literature on mold. The works of leading experts are typically published, and many of them work in firms with good reputations.

You Get What You Pay For. Although the cost of a high-level expert in mold may seem very high, the cost of hiring a less competent firm usually turns out to be higher, with more testing costs, more remediation costs and more legal entanglements being the likely outcome. Here are some questions to ask, followed by tips about what to look for in the answers:

- Find out how long a firm has been doing indoor air quality–related work.
- Review the credentials of the team and supporting experts available through the firm.
- Ask the prospective expert the following questions:
  - How many mold-related jobs has your firm done and when was the first one? Look for experience prior to1997.
  - How many and what kind of samples do you typically take on your first inspection? As a starting point, good firms rely on visible inspections and use surface and source sampling only to identify visible molds.

- How much of your work involves representing plaintiffs? In short, less is better.

- What certifications does your firm bring? Certifications such as PE, CIH, CIAQP, CIE and CMR are helpful if they have experience, useless if not.

What the Expert Will Do to Assess the Problem

Assessing a potential mold problem at the minimum requires a visual inspection, source sampling and when indicated, air sampling. The following discussion focuses on situations other than water damage caused by floods and other catastrophic events. It applies to commercial, institutional and residential construction.

While there is no national standard governing fungal assessment and remediation, several organizations and government agencies have developed guidelines *(see the appendix, Guidelines and Resources for Assessment and Remediation of Fungal Contamination).* The scope of the assessment will vary depending on whether there is already visible mold growth, if a musty smell is detectable and if building occupants have complained about health effects. The following outlines the steps usually taken during a mold contamination assessment.

Building Occupant Interviews. Often the site of the water damage is not obvious as it may be hidden behind walls. Talking with building occupants and the building owner or manager can provide valuable clues before a visual inspection of the entire building and mechanical systems is done.[23] These interviews can also help establish a hypothesis or several hypotheses, which provides a focus for the investigation.[24]

Visual and Olfactory Inspection. The visual and olfactory inspection of building systems, components and materials for mold growth and water damage is the cornerstone of the diagnostic process, particularly in seeking to identify pathways of water or moisture entry and the location and number of sites within the building that have mold growth.[25] Such inspections must be thorough, consistent and based on experience and knowledge of where mold grows, what conditions lead to mold growth, and what mold growth looks like and smells like.[26]

During the visual inspection, carpeting and other flooring, textiles, wall coverings, ceiling tiles, gypsum wallboard and ceilings, cardboard, press-wood products, paper and other cellulosic surfaces are inspected. The inspector also will look both inside and outside for signs of mold growth and water penetration, condensation and damage, for example:

- Landscaping appropriate for limiting water intrusion and dampness.

- Roof condition and design (flat or pitched).

- Water stains near skylights, around ceiling fans, on ceiling tiles, in carpeting and on walls.

- Leaking pipes.

- Loose or leaking toilet flanges.

- Leaks at windowsills, wall penetrations and deck attachments.
- Missing, improper or improperly installed flashings.
- Breaches in the roof, fascias, chimneys, and skylights.
- Windows and doors not properly flashed.
- Building cladding or trim not properly installed.
- Wood touching the ground, allowing it to wick up moisture.
- Negative drainage around the foundation.

Fiberoptic equipment, such as a boroscope, which has a high intensity light, may be used to view spaces behind ductwork or behind walls. If there is active mold growth, often the inspector will be able to detect the characteristic musty smell. The HVAC system also is checked for damp filters and conditions as well as overall cleanliness.[25, 26]

A moisture meter is another tool that is used to measure moisture content in building materials.[14] These probes are not always accurate, but they can be useful for qualitative surveys to identify wet versus dry spots. They are particularly susceptible to misinterpretation when working with laminated composites. Some investigators also use sound meters and infrared sensors to measure air leakage, on the assumption that where air is free to enter a building so is water or moisture.[23] The most accurate results may be obtained from the use of a "probe" style moisture meter, which measures the moisture content of building materials by measuring the electrical resistance between two pins. These pins read only at their uninsulated pin tips, which allow the investigator to drive the pins into material at various depths and note readings at each level of penetration. These meters must be calibrated for each substrate, for example, plywood, studs or gypsum wallboard. "Pinless" meters, which require no pin intrusion into the surface of the substrate material, use radio frequency signals to penetrate the material being tested. These types of meters are useful to quickly identify wet areas in walls and floors. They offer the convenience of testing a large area quickly, and help determine if further testing is required in certain spots.[27]

A recent study explored the association of moisture measurements and microbial levels. The results showed that when water damage was ongoing during the investigation, moisture measurements are sufficient to estimate the risk of fungal contamination and growth. However, if drying of moisture damaged-materials has begun, or moisture conditions in the materials are varying in a wide range over time, then direct-counting methods for spores are most appropriate for assessing the level of biocontamination.[28]

Visible growth on interior surfaces is clear evidence that fungi have colonized. In most cases, the discovery of visible mold growth warrants immediate cleanup and identification of the underlying reasons for the growth. Generally, if visible mold is present, additional air sampling is not necessary.[14, 15]

Sampling. The strategy for collecting samples involves developing hypotheses (as noted above) and then designing a plan that will allow testing of the hypotheses.[14, 15] Agreement on the hypotheses and plan should be achieved prior to sampling and is usually part of developing a scope of work for the remediation process *(see Section 3, How to Get Rid of Mold Once It's Found).* Sampling is done to confirm the following:

- The identity of visible fungal growth.
- Release of aerosols.
- Active mold growth.
- Success of remediation procedures.[26]

Source Sampling. Source sampling is useful to document that discoloration or deposits on surfaces actually represent fungal growth or spore accumulation and is done to confirm olfactory indications of mold growth. These samples are usually collected from visibly moldy surfaces by scraping and cutting materials with a clean tool and putting them into a clean plastic bag. Surface samples are usually collected by wiping a measured area with a sterile swab or by stripping the suspect surface with clear tape.[14] These samples are analyzed under a microscope. Surface sampling is less destructive than bulk sampling, which requires removing a piece of the mold substrate.

Air Sampling. Air sampling often is employed to document what type(s) and amount(s) of mold spores or hyphae are in the air, to assess the cause of symptoms reported by building occupants or to gauge the level of contamination throughout the building if there is evidence from the visual inspection or bulk sampling that the HVAC system has been contaminated.[14, 23] Air sampling for fungi particles is complicated by their diversity in size, shape, density and surface features. This form of sampling also is prone to false positives. The ACGIH emphasizes the importance of a well-designed sampling protocol, reliance on carefully collected baseline data for comparison, and collecting a sufficient number of samples to ensure results are not due to random chance.[15]

Most common airborne mold spores are collected using impaction into agar or an adhesive-coating transparent surface (spore trapping). Culture-based analyses tend to underestimate actual fungal concentration because many spores are either not viable or are unable to grow on the culture medium. Spore trapping allows accurate counting of total fungal spores and identification of some spores, but many spores such as *Penicillium sp.* and *Aspergillus sp.* cannot be identified by microscope.[15] *Stachybotrys chartarum* also is not easily captured in air samples, as its spores when wet are sticky and not easily aerosolized. Further, its inability to compete with other mold and bacteria may result in its being killed off by other organisms in the sample.[13, 29]

Sample Analyses. The primary methods of evaluating the samples of fungi are to isolate the fungi in a laboratory culture and examine the culture by microscope. Other approaches also are used, such as analysis of mold metabolites ethanol, ergosterol[30] or glucan concentrations as estimates of fungal biomass. In addition, immunoassays are under development for measuring some specific fungal allergens.[15]

Conventional testing and analysis methodologies rely heavily on human evaluation and are dependent on the degree of the analyst's expertise and experience. In addition, techniques such as cultivation are time-consuming, while others such as microscopy are labor-intensive and subjective. Polymerase Chain Reaction (PCR) is a new technology that holds great promise for speeding up and increasing the accuracy of identifying microbial organisms by keying in on the organisms' DNA.[31] A recent study demonstrated that PCR is useful for directly detecting *Stachybotrys chartarum* on gypsum wallboard without intermediate cultivation, and that it might be possible to distinguish between toxin and non-toxin producing strains.[32] As of this writing, the test kit for *Stachybotrys chartarum* is just making its way to the commercial market.[31]

Testing Criteria and Results

Also as of this writing, there are no government standards or guidelines for interpreting microbial testing results. The reasons include the absence of exposure baseline data for various types of mold and other microorganisms in indoor environments; the absence of epidemiological data relating bioaerosol exposure to adverse health effects; the sheer number of microbial agents in the air, with some being viable and others non-viable (dead spores, toxins and submicron particulate antigens); and susceptibility to microbial agents varies widely among humans.[33]

Analysis and microscopic identification of mold spores and colonies requires considerable expertise and should be done only by a qualified microbial laboratory with specific expertise and experience in identifying fungi. The American Industrial Hygiene Association (AIHA) offers accreditation to microbial laboratories. The AIHA's list of accredited labs is available at www.aiha.org.

The presence of a few or trace amounts of fungal spores in bulk/surface sampling should be considered background. Air samples in particular are evaluated by looking at the indoor/outdoor ratios of mold levels and types, and the presences of indicator species in the indoor environment. Keep in mind that even with excellent assessment and consulting with epidemiological and medical experts, the relationships between sampling data and adverse health effects are difficult to determine.[33]

Indoor/Outdoor Ratios. Indoor/outdoor ratios are assessed by comparing concentrations and species composition of the collected samples. In indoor environments without a mold problem, the number and types of mold found in the indoor air are similar to the outdoor environment. This means that the source of mold inside the building is the outdoor environment. If fungal concentrations indoors are consistently and significantly higher than outdoors, or if there is significant evidence of species in the indoor samples that are not found in the outdoor samples, then an indoor source is indicated.[23]

Indoor fungal growth also may also be present where the indoor concentrations are less than or equal to the outdoors. Thus it is important to look at the composition of the sample, that is, what species of mold are found in the samples. Proper identification requires identifying the type of mold to the species level. For example, limiting a report of *Cladosporium sp.* to the genus level may lead investigators to assume the levels indoors are the similar to outdoors, with no particular indoor problem present. If the samples were identified to the species level, the investigators would have found *Cladosporium herbarum* to be dominant outdoors and *Cladosporium sphaerospermum* indoors, with the latter indicating an indoor source.[15]

Indicator Organisms. Fungi whose presence is indicative of excessive moisture and a potential health hazard—for example, a species with known allergenic, irritant or toxigenic properties that is uncommon in outdoor environments—are called *indicator organisms*. The mere presence of a few spores should be interpreted with caution, but it does not necessarily indicate that the building occupants are exposed to sufficient levels to cause health effects. Further, indicator species are not the only fungi that can cause problems for building occupants, so investigators should consider these findings as only an indication that there may be mold growth in the indoor environment.[15]

How to Get Rid of Mold Once It's Found

Successful remediation and restoration of a building or home with mold can be accomplished without taking drastic steps as reported by some news media. While there are no set standards, a number of organizations have provided guidelines *(see the appendix, Guidelines and Resources for the Assessment and Remediation of Fungal Contamination).* According the New York City Department of Health Guidelines for Assessment and Remediation of Fungi in Indoor Environments, the goal of a mold remediation is "to remove or clean any contaminated materials in a way that prevents emission of fungi and dust contaminated with fungi from leaving a work area and entering an occupied or non-abatement area, while protecting the health of workers performing the abatement."[14]

Before a remediation effort is started, proper assessment should be completed and a clear scope for the remediation work developed. Remediation procedures depend on the extent of the mold growth, including the following:

- Amount of water to be removed and extent of drying (if needed) in the case of structural leakage, water pipe breakage or failure of septic and other building systems.
- Type of materials on which the fungi is growing.
- Size of the area impacted.
- Degree to which the fungi have degraded the materials for use as a food source.

Only specially trained personnel should undertake remediation, especially with mold infestation affecting areas larger that 10 sq. ft. *(see Section 2, Finding a Qualified Expert).*[14, 34] Remediation also requires a great deal of professional judgment. Essentially, the process is accomplished in three steps:

1. Find the underlying cause of water intrusion and/or the moisture and eliminate or control it *(see Section 4, Eliminating Sources of Moisture).*
2. Remove porous materials on which the mold is growing, especially if the growth is extensive or the materials cannot be adequately cleaned.
3. Clean the surfaces of non-porous and semi-porous materials on which mold is growing as long as they are structurally sound.

As in *Section 2, What the Expert Will Do to Assess the Problem,* the following discussion focuses on situations other than water damage caused by floods and other catastrophic events. One note about water damage caused by these events, however, is that any water infiltration should be cleaned as soon as possible. An immediate response (within 24 to 48 hours) by a firm specializing in water remediation and a thorough cleanup, drying and/or removal of water-damaged materials will prevent or limit mold growth.

Cleaning, Removing Building Materials

Decisions about cleaning and removing building materials depend on the type and condition of the material (amount of degradation) on which the mold is growing and the extent of mold growth. Except where noted, the following discussion is a consensus of the steps outlines in the guidelines and resources listed in the appendix (page 36).

The *New York City Department of Health Guidelines on Assessment and Remediation of Fungi in Indoor Environments* identifies five levels of contamination:

- Level 1: Small isolated areas (10 sq. ft. or less), such as ceiling tiles and small areas on walls.
- Level 2: Mid-sized isolated areas (10 to 30 sq. ft.), such as individual gypsum wallboard panels.
- Level 3: Large isolated areas (30 to 100 sq. ft.), such as several gypsum wallboard panels.
- Level 4: Extensive contamination (greater than 100 contiguous sq. ft.).
- Level 5: HVAC system.

Porous Materials. Porous materials, such as gypsum wallboard, ceiling tiles, insulation, carpeting and textiles that have extensive mold growth must be removed. If the mold growth is not extensive—that is, less than 10 sq. ft. of its surface is affected, and the mold has not infiltrated or degraded the substrate—then these materials may be thoroughly cleaned by washing them with a dilute solution of biocide and detergent or vacuumed with equipment fitted with high efficiency particle air (HEPA) filters. The area should then be monitored for mold growth. In addition, porous materials not supporting active mold growth can still harbor mold spores and particles from other sources. Where appropriate, these materials also should be thoroughly cleaned and monitored. If porous materials have absorbed odors, removal may be necessary to complete the restoration of the building. Carpeting and drapes that can be removed for thorough cleaning and drying may be salvageable. Valuable books and papers sometimes can be rescued by fumigation, followed by freeze-drying and vacuuming the residual particles.[34]

Non-Porous and Semi-Porous Materials. Non-porous materials (metal ductwork, metal studs, vinyl flooring, glass, fiberglass and plastics) can be readily cleaned. Slightly porous or semi-porous materials (wood and wood-pressed products, stone and concrete) that have visible mold growth may be reusable depending on the depth the mold growth has penetrated the substrate. Cleaning is accomplished by vacuuming using equipment with HEPA filters or direct air exhaust to the outdoors, washing with a dilute solution of biocide and detergent, or cleaning, thorough drying and repainting. Mold growth on furniture may be removed by refinishing.[34]

HVAC System. By and large, the procedure for remediation is the same for HVAC systems as for the rest of the building. Application of biocides as a substitute for removing microbial growth and settled biological materials is not acceptable. Contaminated porous materials in the HVAC system must be removed down to the bare (underlying) metal and appropriately discarded. Full containment procedures should be implemented when removing extensive areas of porous materials.[34]

Biocides and Antimicrobial Agents. Biocides are chemical or physical agents that kill or inactivate microorganisms, and microbial agents are compounds used to suppress microbial growth.[35] Although they may be useful in removing and preventing fungal contamination, their use should be carefully considered; for example:

- The use of gaseous ozone or chlorine dioxide for remedial purposes is not recommended, as both compounds are highly toxic, contamination of occupied spaces may pose a health threat and the effectiveness of these treatments is not certain.[14]

- Some agents are designed to treat certain groups of microorganisms and not others. Suppression of one species may give others an advantage.[35]

- Most disinfectants and sanitizers are approved for use on previously cleaned rather than solid surfaces, but for thoroughly cleaned surfaces, a biocide may not be needed, as killing mold does not necessarily destroy their antigenic or toxic properties.[35]

Antimicrobial agents to protect building materials from fungal growth are now incorporated into a variety of consumer products. Some agents also can be applied to existing materials. If an antimicrobial agent is used, it should complement proper water and moisture control and regular cleaning and maintenance, not replace them.[35]

Specific Personal Protection and Containment Guidelines

Before any remediation work is begun, appropriate personal protection and containment protocols should be established. The larger the area of fungal contamination, the more stringent personal protection and containment requirements should become.

Personal protective equipment (PPE) may include gloves, eye protection, protective clothing covering both head and shoes, and respiratory protection in accordance with OSHA's respiratory protection standard (29 CFR 1910.134). Many states also have their own respiratory protection standards under State-operated OSHA plans. For example, California, Oregon and Washington each have requirements that exceed those of OSHA, but only apply to work in those states. Respiratory protection may range from disposable respirators to full-face respirators with HEPA cartridges. Few data are available on exposures occurring during remediation.[36, 37, 38] Decisions on what PPE will adequately protect workers requires experience and professional judgment and may be obtained from occupational physicians, toxicologists, respiratory protection experts, and health and safety professionals.[34]

One of the most important goals is to minimize in the case of minimal contamination and, in the case of moderate and extensive contamination, prevent the dispersal of dust and mold spores. The ACGIH identifies three levels of containment:

- Source containment for minimal contamination requires no special isolation of the area. Removal is straightforward and relatively simple, such as placing a moldy ceiling tile into a plastic bag, sealing the bag and removing the bag from the building.

- Local containment involves constructing an enclosure with two layers of polyethylene film supported on a wood-stud frame. A HEPA vacuum nozzle is used to create sufficient negative pressure within the enclosure to ensure containment of bioaerosols.

- Full-scale containment is commensurate with an asbestos abatement program and consists of a critical barrier to isolate the contaminated area from the clean or occupied area of the building; negative pressure created with a HEPA air filtration device, such as a negative air machine; and a decontamination unit for entry and exit of the remediation area. Contaminated debris is double bagged and passed through this area for HEPA vacuuming before being disposed.

Bagged debris, even from extensive fungal contamination, can be disposed of in a landfill as if the contents were moldy compost. Also, dust that may have settled outside the containment area should be removed with HEPA vacuuming and damp wiping followed by thorough drying.

Verifying Successful Remediation

Success of the remediation process can be judged by the following:

- Visual inspection to ensure all of the contaminated substrate is removed.

- Confirmed by sampling, including outdoor/indoor ratios. Results of surface sampling should be similar to other well-maintained buildings or on construction and finishing materials in the same geographic area.

- Ability of people to re-occupy the space without complaining of adverse health effects or physical discomfort.

If mold should begin to grow again, then likely the source of water or moisture has not been found or adequately controlled or eliminated. These sources must be addressed to keep fungi from re-establishing colonies.[34]

How to Keep Mold from Growing

In order for mold to grow, it needs optimal temperatures, usually between 40 degrees F and 100 degrees F (4 degrees C and 38 degrees C), nutrients in or on the substrate, fungal spores that settle on the substrate, and moisture, usually 70 percent relative humidity or higher at the surface of the substrate. For all practical purposes, all of these conditions, except possibly moisture levels, are met in nearly every building, so the answer to preventing mold growth is controlling moisture.[39, 40]

Eliminate Source of Moisture

As described in *Section 1, Overview of Mold in Construction,* the following are the three primary factors that influence moisture levels in buildings:

1. Building tightness, which does not allow moisture to escape to the outdoors.

2. Liquid water infiltration from outside as a result of a leaky building envelope or structural failure.

3. Moisture condensation on mold substrates, which originates from water vapor inside or outside the building.

These factors do not act independently of one another. In fact, there is a great deal of interaction. The keys to eliminating moisture sources include the following:

- Designing and constructing the building envelope and wall systems to prevent water and/or moisture from entering the building while at the same time providing a way for any accumulated water and/or moisture in a wall system(s) to either drain to the exterior of the building or evaporate.

- Knowing how and when to use vapor barriers.

- Properly managing air pressures and airflow inside the building.

- Maintaining indoor relative humidity below 60 percent.

Building Tightness. The most critical areas of the building envelope are gaps around the windows and doors, joint openings at roof, ceiling or floor lines, and soffit or wall vent systems. These areas are the most likely openings and are convenient pathways for air leakage and moisture intrusion into a building. Although good positive pressurization within the building can typically overcome leakage, these areas should be sealed. A tightly sealed building will minimize air leakage and reduce the amount of air required by the HVAC system to maintain positive pressures, which saves energy.[5] There are less-common conditions where positive building pressurization would not be desirable, such as buildings with a high internal moisture load, but that is not a typical building. This paper addresses only typical buildings.

Water Infiltration. Water infiltration from any of the many possible sources must be prevented. Here are some steps:

- Seal leaks in the building envelope and repair improperly installed and water-damaged building components.

- Install proper flashing where required (particularly roof penetrations, roof junctions, window and door assemblies, chimneys and deck attachments) in order to direct water away from the building and manage the flow of water near critical building elements.

- Install an effective rainwater barrier and drainage plain on the exterior side of the stud cavity. This can take a wide variety of forms and can be a part of the cladding system or a separate element of the wall assembly, depending upon design and building components.

- Improve the drainage around the foundation to prevent groundwater, including capillary water movement through the building materials, from entering the building.[41, 42]

- Use building–code compliant components that effectively refuse water and moisture entry.

- Ensure that good building practices are followed and that all building envelope systems are properly installed in accordance with code and manufacturer's recommendations.

Controlling Condensation. Although moisture activity is the best indicator of potential mold growth, there are presently no direct field measurement techniques to determine a_W. Many investigators try to use *moisture content* as a direct indicator, but this is related indirectly to a_W. Moisture content is the weight of water in the material divided by the weight of the material in a dry condition, and is expressed as a percentage. For example, water activity of 0.80, which is prime for mold growth, corresponds to the moisture contents of the following building products: brick (0.1 percent to 0.9 percent), gypsum wallboard (0.7 percent), cement (1 percent), wallpaper (11 percent), and soft wood (17 percent).[41, 43]

As a result of these difficulties, many advisory groups recommend using relative humidity to indicate microbial growth potential. The key, however, is to measure the relative humidity adjacent to the substrate not the ambient relative humidity. Although room relative humidity may keep most building materials fairly dry, it does not eliminate the possibility of microbial growth as cold spots or water intrusion may allow the relative humidity of air adjacent to the substrate to exceed 70 percent.[43]

Relying on relative humidity also has some limitations as well. There is only limited information available on the influence of fluctuating humidity on microbial growth in building materials. According to recent studies, durations of the wet and dry periods are critical for fungal growth in fluctuating conditions, because the time need for proliferation at high relative humidity is longer and the growth rate lower than on the constant favorable circumstances.[44]

The best guidance is to maintain indoor relative humidity consistently below 60 percent.

Effectively controlling condensation within wall systems requires understanding how condensation occurs in different climates. Effective control also requires designing the wall system and implementing appropriate strategies to accommodate the climate. Typically, wall systems consist of the exterior wall, metal or wood stud framing, an air barrier, vapor barrier (if used), insulation, gypsum sheathing, gypsum wallboard and a wall covering or paint. The primary variances in this structure that are dependent on the climate include the following:

- Location of the air barrier, which should be located on the warm side of the building. envelope, that is, adjacent to the exterior wall in warm, humid climates and adjacent to the interior wall in cold climates.

- Whether a vapor barrier is used and its location between the air barrier and insulation.

- Type of wall covering or paint.

Hot, Humid Climates. The goal is to keep moisture in the outdoor air from reaching the first cool surface inside the building envelope (referred to as the *first plane of condensation*). If the moisture is allowed to further enter the wall system, it will condense. In this climate, the air barrier should be located immediately adjacent to the exterior wall with the vapor barrier (if used, see discussion below) positioned between the air barrier and the insulation on the external portion of the building envelope. Other considerations and strategies follow:

- Install appropriate insulation to prevent large temperature differences between the air and surfaces.

- Whether or not to install a vapor barrier has been a point of confusion and debate not just among designers and builders but also among the various building codes. After considering the various opinions, the most effective approach appears to be not installing a separate vapor barrier. Moisture trapped between two materials that act as vapor barriers cannot escape and thus condenses inside the ceiling or wall at the cold surface.

- Avoid impermeable vinyl or other wall coverings and use permeable paints and wall coverings on the internal surface.

- The HVAC system must maintain a net positive pressure with respect to the outdoors to keep unconditioned outdoor air out of the building.

- Avoid excessive cooling of interior spaces below the average, monthly, outdoor dew point for the area in which the building is located. This may not be possible in some locations, especially in summer. At these times, proper insulation, correct location of air and vapor barriers (if used) and maintenance of pressure relationships are vital.[5, 40, 42, 45, 46]

Cold Climates. The goal is to keep warm, moist air in the indoor environment from flowing outward through cracks and holes in the building envelope. As the air nears the outer boundary of the building it cools, the relative humidity rises because cooler air has a lower moisture-holding capacity. The result is moisture condensation in the wall cavity. In this climate, the air barrier is located adjacent to the interior wall with the vapor barrier positioned between the air barrier and the insulation. Other considerations and strategies include the following:

- Install appropriate insulation to prevent large temperature differences between the air and surfaces. Make certain that insulation in exterior walls is adequate to prevent thermal bridging and to minimize the development of cold spots on internal surfaces.

- A vapor barrier should be installed in cold climates, but make sure it is installed on the warm side of the wall between the drywall and the studs. Carefully consider the materials used to make sure the vapor barrier has the proper resistance or moisture permeability to control moisture flow through the wall system.

- Use source control and dilution ventilation to reduce indoor moisture levels below those that allow condensation to occur. Provide good air circulation to keep interior surfaces at an even, warm temperature.[42, 45, 46]

Select Materials and Finishes to Prevent Mold

Although much of the recent attention has been focused on how molds possibly can harm people, fungi also can cause building materials, furnishings and the building structure itself to prematurely degrade and/or corrode. Premature failure or irreversible damage of the building envelope, interior walls, ceilings, floors, carpets, wall coverings, HVAC system components and furnishings can lead to increased maintenance and operation costs.[40]

In the late 1800s, the inventor of modern gypsum wallboard, Augustine Sackett, actually had a great solution for making wallboard waterproof. He used tar to bind the layers together, but the tar tended to melt in the sun or bleed through the wall covering in reaction to a heated room. To solve the problem, Sackett replaced the tar with plaster of Paris.[47]

Today, an effective strategy for controlling condensation and preventing mold growth is to select materials and finishes that allow air and moisture to move freely through the wall system. Using highly permeable materials on the cold side and low permeability materials on the warm side of the wall system maximizes vapor pressure diffusion from the wall, meaning that water vapor inside the wall system will migrate from the wall cavity into the interior space. Recall that operating a building with slightly positive pressure relative to the outdoors and using an external air barrier encourages dry indoor air to flow through the wall structure toward the outdoors. This has the advantage of lowering the relative humidity inside the wall structure. So, by combining these strategies, moisture is forced from the walls while dry air is encouraged to travel into the wall system toward the outside.[40]

Also, using high-quality materials and finishes is important because they generally will not degrade as quickly as lower quality products. Different building materials have different levels of susceptibility to fungal growth, depending on the amount of water activity the material can support *(see Section 1, Overview of Mold in Construction),* the amount of organic matter contained in or on the surface of the product, other structural properties, and the rate of degradation in the presence of moisture. Organic materials, such as binding agents and auxiliary substances, that are added to the inorganic materials provide a nutrient source. Structural properties of a building material's surface can be a factor as they have a tendency to change during the service life due to environmental factors, such as ultraviolet radiation and moisture. These changes make building materials more susceptible to mold growth, because as they degrade, their organic components become available as a nutrient source.[48]

A recent study looking at the response of different building materials to mold contamination at various relative humidity levels found that stone-based materials, including cement screed, gypsum wallboard and concrete, required longer exposure time at higher relative humidity for initial fungal growth than wood-based materials, including particleboard, fiberboard and plywood made of softwoods. Concrete was less susceptible to fungal growth, probably due to high alkaline properties in the material. The investigators also found that all building materials tested, which also included insulation products, were susceptible to mold growth at or above 90 percent relative humidity and temperatures at or above 59 degrees F (15 degrees C).[48]

One new technology of note that is just making its way to market is a preventive and remedial system that uses calcium hydroxide, a naturally occurring biocidal agent. This in and of itself is not unique, as calcium hydroxide has been used for years in this capacity. What is unique is this technology uses selected microencapsulating polymers to bind to the calcium hydroxide to keep it from rapidly degrading when the compound is exposed to ambient air. When applied to hard surfaces in a building, such as walls, ceilings and floors, or incorporated as a part of these building products during the manufacturing process, this new technology has the proven ability to kill infectious agents and fungi on contact and inhibit their spread for many years, while being safe for building occupants.[49]

Build It Right in the First Place–Resilient Buildings

The focus of this paper has been to provide an overview of what is involved in taking care of a mold problem once it has occurred and to prevent problems in existing buildings. Going forward, the ultimate prevention of mold contamination is to build resilient buildings that have proper water intrusion and moisture control measures. Resilient buildings are engineered so they can easily adapt to changes in operating conditions, occupancies, uses and level of maintenance, and can operate over long periods of time with minimal intervention of trained technical personnel. Its opposite, a brittle building, breaks down and fails to serve it occupants in response to changes or when maintenance is less than optimal.[50, 51]

Resilient engineering means thinking through the consequences of not only the design but also choice of materials and installation. It also involves not just the designer and general contractor, but also all those involved in construction.[50, 51]

As noted, controlling moisture is the key to preventing mold problems. The key to controlling moisture is understanding how building systems interact, and designing and constructing buildings to maximize that interaction to prevent water and moisture intrusion from the outdoor environment while maintaining a comfortable indoor environment with a constant relative humidity below 60 percent.

Risk Management and Insurance

The "Liability" and "Assignment" portions of Section 5 are adapted from materials published by the American Subcontractors Association. The "Insurance Coverage" section is adapted from materials published by Kirkpatrick & Lockhart LLP, a national firm that represents policyholders in insurance coverage disputes with their insurers.

Good risk management associated with mold damage liability follows the same strategy as good risk management associated with any potential failure or loss.

Liability

It is often the case that a wall and ceiling subcontractor does not create the conditions leading to the growth of mold within an indoor space. However, the wall and ceiling contractor may be liable for the damages and remediation if mold is growing on or in the drywall, if the wall and ceiling subcontractor signed a general contractor's proprietary subcontract with broad indemnity provisions that are common in the industry.

An overly broad indemnity clause may require the subcontractor to defend and pay for "all claims" that "arise out of the subcontract work, whether or not caused by any negligent act or omission of the general contractor, owner or another subcontractor." As the language itself suggests, a loss can be "caused by" somebody else and still "arise out of" the work of the wall and ceiling contractor. The mere fact that mold is growing on drywall that a wall and ceiling subcontractor installed may constitute a sufficient nexus to establish the subcontractor's obligation to indemnify a general contractor who gets sued for mold-related construction defects. This may be the case even though the general contractor was to blame for failing to properly coordinate trades, permitting work in progress to become wet, contracting for installation of flashing or caulking, failing to inspect completed work, or ensuring that good building practices were observed before the project was delivered to the owner.

A fair indemnity clause, like the clause appearing in the American Institute of Architects' Standard Form Subcontract A401-1997, limits the liability of the subcontractor for any claims "arising out of or resulting from performance of the subcontractor's work" with the following key phrase: "… but only to the extent caused by the negligent acts or omissions of the subcontractor … ." Without the expression, "caused by," "fault" is not relevant.

Assignment

A second risk management concern for subcontractors is insurance coverage. General contractors, even if unable to place fault on a subcontractor, can resort to the insurance secured by the subcontractor according to the terms and conditions of the policy, if the subcontractor's commercial general liability policy includes the general contractor as an "additional insured." As an "additional insured," the general contractor can typically make a claim against the subcontractor's general liability policy with respect to any liability "arising out of" of the subcontractor's work.

In most courts, insurance policies are broadly interpreted in favor of coverage. Thus, although the typical language of an "additional insured" endorsement extends coverage "with respect to liability arising out of your work," without any express statement concerning the "negligent acts or omissions" of an additional insured, the terms of the policy will nevertheless be construed so that claims caused by the partial, or even sole, negligence of an additional insured are included in the coverage, simply because the claims can be said to "arise out of" the subcontractor's work. As a result, the subcontractor's insurance policy may pay for the defense and settlement of a mold-related lawsuit filed against a general contractor if the general contractor is an "additional insured." In addition, as the "named insured" who pays the premiums, the subcontractor's loss experience is negatively affected when "additional insureds" make claims against the policy.

There is an alternative to additional insured coverage. There are general contractors who will accept an Owners and Contractors Protective Liability (OCP) policy in lieu of additional insured coverage. The "completed operations" are not covered in an OCP, but they are covered in the subcontractor's indemnity agreement. In order for the subcontractor to use an OCP, the subcontractor may have to buy the policy. Considering the relative cost of an OCP policy versus the added liability of an additional insured, it could be a very prudent investment.

Insurance Coverage

Depending on the facts and specific policy language at issue, policyholders may be able to protect themselves from mold claims by accessing their insurance coverage for both (1) bodily injury and property damage liability, and (2) personal injury liability.

Accessing Bodily Injury and Property Damage Liability Coverage. To determine whether insurance is available under bodily injury and property damage liability coverage, there are several key questions that must be addressed, including the following:

- What is the appropriate trigger of coverage?
- Were the damages expected or intended?
- Does the pollution exclusion apply?

Trigger of Coverage. The trigger-of-coverage issue involves the question of which policy period's insurance policies are responsible for covering a particular claim. Depending on the facts involved, the possibilities include those policies in force (1) when the initial exposure occurred, (2) during the entire period of exposure and (3) when the alleged injuries occurred. When determining which insurers are potentially responsible for covering these types of claims and which insurers should be placed on notice of the claim, consideration should be given to each of these trigger theories.

"Expected or Intended" Exclusion. In an effort to avoid their coverage obligations, insurers may contend that the injuries allegedly suffered by the claimants are excluded because the building owners, operators and contractors allegedly knew or should have known about the alleged presence of mold in their buildings. Contractors and subcontractors have two primary arguments that they should assert in response.

First, they can assert that the question is not whether they knew about the alleged presence of mold, but whether they knew that the condition would cause the specific bodily injury and property damage allegedly suffered by the claimants. Second, they can argue that an alleged loss is covered even if a court were to find that they reasonably *should have* known that the mold would cause damage, so long as they did not *actually* know that bodily injury or property damage would result.

Pollution Exclusion. In addition to asserting that the mold injury or damage at issue was expected or intended, insurers may raise the so-called "pollution exclusion," one version of which commonly provides that coverage is excluded for bodily injury and property damage "arising out of the discharge, dispersal, release or escape of irritants, contaminants or pollutants into or upon land [or] the atmosphere." Contractors and subcontractors can oppose the application of the pollution exclusion on two grounds. First, they may assert that, as a threshold matter, "pollution exclusions" apply, at most, only to instances of industrial environmental pollution and not to residential or office contexts. Second, even assuming that the exclusion applies in the non-industrial context, its terms are not satisfied by the typical claims of bodily injury and property damage arising out of mold.

Accessing Personal Injury Liability Coverage. In addition to coverage for bodily injury and property damage liability, contractors and subcontractors should look to their personal injury liability coverage to respond to mold claims. For example, personal injury coverage often insures injury arising out of "wrongful entry or eviction or other invasion of the right of private occupancy." Claimants may allege that the presence of mold has interfered with their use of a building or otherwise impaired their ability to occupy the building. In such cases, contractors and subcontractors should analyze whether their personal injury coverage is another source of protection from liability.

List of Guidelines and Resources for Assessment and Remediation of Fungal Contamination

Organization	Title or Resource	Web Site
American Conference of Governmental Industrial Hygienists	Bioaersols Assessment and Control	www.acgih.org
American Industrial Hygiene Association	Report of the Microbial Growth Taskforce	www.aiha.org
Health Canada	Indoor Air Quality in Office Buildings: A Technical Guide	www.hc-sc.gcca/ehp/ehd/catalogue/bch_pubs/93ehd166.htm
	Contamination of Indoor Air	www.hc-sc.gc.ca/english/iyh/indoor_air.htm
International Society of Indoor Air Quality and Climate	Control of Moisture Problems Affecting Biological Indoor Air Quality. ISIAQ Guideline TFI-1996	www.ie.dtu.dk/isiaq
	Guidelines for IAQ in Schools (task force)	www.isiaq.org
New York City Department of Health	Guidelines on Assessment and Remediation of Fungi in Indoor Environments	nycdoitt.ci.nyc.ny.us/html/doh/html/epi/moldrpt1.html
US Environmental Protection Agency	Indoor Air Quality Tools for Schools	www.epa.gov/iaq/schools/tools4s2.html

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