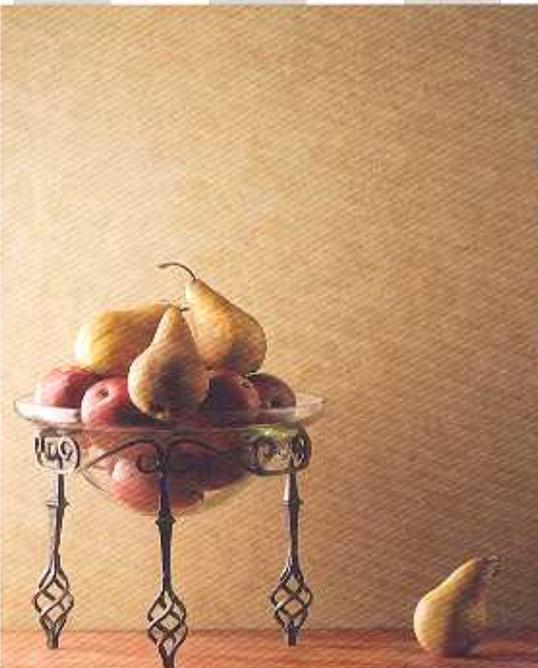


# Mold

## Cause, Effect and Response

### A Study of Wallcovering Products



Visit the WA Website at [www.wallcoverings.org](http://www.wallcoverings.org) or the CFFA website at [www.chemicalfabricsandfilm.com](http://www.chemicalfabricsandfilm.com) for updates/errata to this document.

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# Executive Summary

In response to concerns about mold growth in building and home interiors, the Wallcoverings Association (WA) and the Chemical Fabrics & Film Association (CFFA) offer this 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 homes and buildings, particularly with respect to wallcoverings. The publication also discusses various strategies for minimizing or eliminating the potential for mold growth, by abolishing the moisture source, by carefully selecting wallcoverings, by taking into account the climate and design features of homes and buildings, and by adhering to good practices in preparing wall surfaces and installing wallcoverings. It concludes with a discussion of why homes and buildings fail and a summary of a model of how to prevent and solve problems, such as mold and mildew growth, at each stage of the design and construction process.

**Although they are often cited in connection with mold and mildew growth in building interiors, wallcoverings do not cause mold to grow. In virtually all cases, the mold and mildew is due to excessive moisture. To prevent or eliminate mold, the source of the moisture must be identified and eliminated. If the moisture source is not found and corrected, mold will continue to grow.**

This publication is intended for the wallcoverings industry, including manufacturers, distributors, professional installers, interior designers, building owners and managers, homeowners, and end users. 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. Every effort has been made to equally represent commercial and residential wallcovering products.

The Wallcoverings Association is an industry organization dedicated to promoting the best interests of the industry and its end users and serving as a conduit for ongoing communications for and between all business segments. To that end, the WA stays abreast of current topics of concerns impacting the wallcoverings industry and provides sound information on products, services and issues to architects, designers and end users to support the choice of wallcoverings as a viable, cost-effective decorating option.

The Chemical Fabrics & Film Association is an international trade association representing manufacturers of polymer-based fabric and film products used in building and construction, automotive, fashion and many other industries. Chemical fabrics and films can be found in hundreds of applications, including commercial and residential wallcoverings; automotive upholstery, instrument and door panels, and convertible tops; upholstery for furniture; and home décor.

Please see the next page for the WA's and CFFA's position statement on the relationship between mold, mildew and wallcoverings. An overview of mold and mildew as it relates to chemical and film products also is available from CFFA.

To obtain additional copies of this publication or to learn more about the Wallcoverings Association, please contact:

Wallcoverings Association  
401 N. Michigan Avenue; Chicago, Illinois 60611  
Phone (312) 644-6610 Fax (312) 527-6705  
[www.wallcoverings.org](http://www.wallcoverings.org)

To obtain a copy of this publication, CFFA's *Mold & Mildew: An Overview/Wallcovering* or learn more about the Chemical Fabrics & Film Association, please contact:

Chemical Fabrics & Film Association  
1300 Sumner Avenue; Cleveland, Ohio 44115-2851  
Phone (216) 241-7333 Fax (216) 241-0105  
[www.chemicalfabricsandfilm.com](http://www.chemicalfabricsandfilm.com)

**Also, please visit the WA or the CFFA's websites for updates/errata to this document.**

The Wallcoverings Association and the Chemical Fabrics & Film Association gratefully acknowledge the generous contribution to this publication by the Foundation of the Wall and Ceiling Industry (FWCI), whose publication, *Mold: Cause, Effect and Response*, was used as source material in the development of this publication. To obtain a copy of this publication or learn more about FWCI, please contact:

Foundation of the Wall and Ceiling Industry  
803 West Broad Street, Suite 600; Falls Church, VA 22046  
Phone (703) 534-8300 Fax (703) 534-8307  
[www.awci.org](http://www.awci.org)

# Position Statement for the WA and CFFA Regarding the Relationship Between Mold and Mildew and Wallcoverings

The Wallcoverings Association (WA) and the Chemical Fabrics & Film Association (CFFA) recognize that issues concerning mold and mildew are gaining increased attention from both residential and commercial property owners as well as the public at large. Although wallcoverings are often cited in connection with mold and mildew growth, it must be understood that wallcoverings do not cause mold and mildew. In virtually all cases, the mold and mildew growth is due to excessive moisture. In order to prevent or eliminate mold and mildew one must identify and eliminate the source of the excessive moisture. In unusual cases, where moisture or moisture infiltration from the wall cavity cannot be eliminated or sufficiently reduced, use of wallcoverings with higher permeability ratings should be considered.

This statement serves to communicate the WA and CFFA's position regarding the relationship of mold and mildew to our industry's products. It is intended to provide one industry voice and to aid in presenting fact and structure in our response to this growing issue. Additional materials will serve to support our position statement and further detail our efforts to provide educational and corrective procedures in relation to mold in residential and commercial properties. For simplicity, all the issues are referred to as mold. Wallcovering discoloration or wall deterioration

caused by mold is an indication of a moisture problem. The WA and CFFA recommend that the source of the water or excessive moisture should be found immediately and eliminated. The control of moisture vapor and its relationship to different types of wallcovering construction must be communicated to specifiers, installers, architects and property owners.

For preventive measures, the WA and CFFA stresses that it is important that any wallcovering professional (specifier, architect, designer, installer or user), homeowner or commercial property owner should conduct ongoing evaluation and be aware of any potential construction problems that may cause excessive moisture.

The Wallcoverings Association and the Chemical Fabrics & Film Association's members agree that it is necessary to educate and inform wallcovering professionals about the prevention and detection of mold, proper removal, wall surface treatment and product selection, and the proper process for wallcovering installation. The Wallcoverings Association and the Chemical Fabrics & Film Association will make every effort to communicate corrective measures and provide educational tools to guard against mold as it relates to wallcovering products.

***This position statement is intended to provide one industry voice and to aid in presenting fact and structure to the WA and CFFA response to this growing issue.***

# Introduction

## FACT OR FICTION - RECENT MEDIA HEADLINES

***Ridding Hilton of mold may cost \$20 million***

***Mold plagues school***

***How household mold gets a grip***

***A growing problem: Toxic mold is eating away at homes and homeowners insurers' profits***

***Tales of rampant toxic mold get plenty of attention but science tells a less dramatic story***

***Is your office killing you?***

***Are toxic molds giving you headaches, asthma — or worse?***

These recent news headlines reflect increasing interest and concern about how mold affects indoor environments and building occupants. Are these media reports based on fact or fiction?

Mold as a potentially major building maintenance issue, particularly in hotels and motels in hot and humid climates, is nothing new. According to a 1990 survey of the hotel and motel industry, mold cost American Hotel and Motel Association members approximately \$68 million each year in lost revenues and damage repair. In a follow-up survey, 70 percent of respondents said that their rooms smelled stale, a condition often created or aggravated by odors emitted by mold.<sup>1</sup>

A more recent development is the prolific growth of mold in single-family homes and in other

commercial, institutional and residential buildings and fears of adverse health effects. Seventy-five percent of Americans are concerned that the quality of air in their homes and workplaces could have an adverse impact on health, with mold, dust mites, allergens and particles in the air topping their list of concerns.<sup>2</sup>

Are these concerns justified? Who is at most risk for having health problems as a result of mold? Are all molds toxic? What species of mold are considered toxic? Where and when does mold grow in buildings, what role do wallcoverings play, 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?

The wallcoverings industry sold more than \$940 million of wallcovering products in the U.S. market in 2000, with approximately one-half of the total volume being for commercial buildings.<sup>3</sup> With this large annual customer base, the incidence of mold-related complaints has been low, but is still of concern as it is rising.

In response to this concern, this publication offers a review of a variety of scientific, technical, and medical resources to answer these questions and to educate readers about the complex and often controversial issues surrounding mold growth in buildings, particularly with respect to wallcoverings. As noted in the executive summary, 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 issues when they do occur and practice good risk management. Every effort has been made to equally address both commercial and residential wallcovering products.

# Section 1. Who, What, Where, When, Why's of Mold

The first step in answering the questions posed in the Introduction is to realize that mold growth in homes and buildings and its relationship to health effects is not as simple as presented in news reports and litigation. It also requires looking at why mold is becoming a more prevalent problem, where mold grows and why, and what is it about mold that has prompted so many concerns. "Mold", "mildew" and "fungi" are used interchangeably throughout this publication. They are different names for the same thing.

## 1.1. 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 home or 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 home or building.
2. Building component(s) and material(s) can be affected to more or lesser degrees. Often the term "substrate" is used when referring to the surface on which mold can grow. This occurs because in the construction industry, the term "substrate" means a surface that sits beneath or underneath a building material. In the wallcoverings industry, however, the term specifically refers to the backing of a wallcovering. To avoid confusion in this publication, the term "substrate" will be used exclusively to describe the backing of a wallcovering.

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 there is repeated water damage; the amount of water content or activity in or on the surface of the building component(s) or material(s) for long enough to support mold growth; and the nutrition source available in or on the component or material's surface. Some mold species such as *Stachybotrys chartarum*, for example, will grow on carpet backings and materials containing cellulose, including gypsum wallboard. Other species such as *Penicillium chrysogenum*, *P. exapnsuum* or *Scopulariopsis sp.* grow behind wallcoverings, whereas *Wallemia sp.* grows primarily on textiles, and *Phoma sp.*, another common mold found indoors, grows on painted walls. *Acremonium sp.* and *Aspergillus versicolor* seem to favor growing on ceramic products, paints and wallcovering adhesives. Other species that may grow behind wallcoverings include *Aspergillus niger*, *Penicillium funicolosum*, *Chaetomium globosum*, *Trichoderma sp.* and *Aureobasidium pullulans*. It is also possible to have more than one species of mold growing in the same area.
4. Exposure to mold may cause health effects to greater or lesser degrees. 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, microbial volatile organic compounds (MVOCs) or other potentially toxigenic components, such as mycotoxins that can produce adverse health symptoms, are being produced.
- Some people may develop an adverse health reaction when exposed to mold and some people may not. Also some people may be more prone to having worse health reactions than others.
- It is quite likely that purported health effects are not attributable to mold exposure or may be attributable only in extreme cases. See Section 1.6, Are Molds Really Toxic?, for more details.

## 1.2. Overview of Mold in Building and Home Interiors

Homes and buildings are dynamic environments, affected by geographic location; climate; heating, ventilating and air-conditioning (HVAC) system design and operation; types of materials used in construction, finishing and interior design; moisture intrusion; pest colonization; and human activities. Mold and mildew are a form of fungi, which are *ubiquitous* – in other words – they are everywhere and exist as a natural part of indoor and outdoor environments. They also are one of the basic mechanisms of the earth’s ecosystem for recycling plant material.<sup>1</sup>

In order to grow, mold needs four things:

1. A nutrient source.
2. Appropriate temperature.
3. Moisture.
4. Source of mold spores.

A “Mildew Square” developed by James Kimbrough, Ph.D., and Virginia Peart, Ph.D., of the University of Florida, provides an effective illustration of these requirements. Stopping mold growth requires eliminating one or more of these essential elements. Unfortunately, in a normal comfortable human environment – homes or commercial, educational or institutional buildings – eliminating spores, warmth and a food source is almost impossible. The one element that can be removed, however, is moisture.<sup>1</sup>

Figure 1.1. Mildew Square.



This section takes a closer look at these elements and their relationship to supporting mold growth throughout a home or building. Section 1.3, Wallcoverings and Mold: A Function of Moisture Levels and Permeability, focuses specifically on why mold potentially grows on or behind wallcoverings, and Section 1.4, Mold, Mildew, Fungi – What’s the Difference?, concentrates on sources of mold spores. Section 4.1, Eliminate Sources of Moisture, discusses in detail how to control and/or eliminate moisture sources.

**NUTRIENT SOURCES.** There are numerous sources in today’s homes and buildings to satisfy the nutritional needs of mold, including materials containing cellulose, such as found in some wallcoverings, gypsum wallboard, paint, wood paneling, plywood, oriented strand board (OSB), pre-cast panels and ceiling tiles, fabrics, 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. While wallcoverings and adhesives/primers contain biocides (also called mildewcides), some adhesives may also contain starch, which may provide a potential food source for mold.

Some traditional construction and finishing materials contain natural chemicals that retard biodegradation; for example, the heartwood of some tree species contains terpenes and other substances that inhibit fungal growth. Man-made products such as ceiling tiles, wallcoverings, 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 antimicrobial compounds and provide a nutrient source.<sup>4</sup>

Typically, antimicrobials are added to these products during the manufacturing process to make them resistant to mold growth.

Also important is keeping the area and building and finishing materials such as wallcoverings clean during and after installation as dirt, dust and other organic materials can become trapped behind the wallcovering and/or in the wall cavity and provide a food source for mold. See Section 4.4, Good Practices – Keep Materials and Work Area Clean, for more details.

**TEMPERATURE.** Homes and 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 species of mold, 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 homes and buildings requires sufficient moisture for a long enough period of time to support growth. There are primarily four factors that influence the amount of moisture available for mold growth:

1. Building tightness, which does not allow moisture to escape to the outside or to be removed from the inside air through dehumidification.
2. Liquid water infiltration from the outside as a result of a leaky building envelope or structural failure.
3. Moisture condensation on or near mold-susceptible building materials or components, which originates from water vapor inside or outside the home or building.
4. Moisture generation within the home or building by the occupant and the occupant’s activities.

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, homes and buildings are built much tighter than their counterparts in the first half of the 20<sup>th</sup> century. A typical home and 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.<sup>5</sup> In response to the energy crises in the 1970s, tightening up homes and buildings to save energy became the mantra of all commercial, institutional and residential building construction.

Efforts to save energy have been successful. For example, even though the number of commercial buildings and the amount of commercial floor space has increased since 1979, total energy consumption has remained flat.<sup>6</sup> 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.

In addition, the amount of air exchanged between conditioned indoor (HVAC) spaces and the outdoors diminished as buildings became tighter, resulting in significantly less dilution of moisture and indoor pollutants, such as formaldehyde, volatile organic compounds (VOCs) and carbon dioxide. This trend occurred concurrently with the introduction of metal and plastic window frames, glass wall systems that do not permit natural ventilation, and new synthetic materials and

products for building furnishings, finishings, wall-coverings, flooring and cleaning.<sup>5</sup>

**WATER INFILTRATION.** Any opening in the building envelope (whether a residential or other type of structure) may permit liquid water and water vapor to penetrate the home or building and accumulate on mold-susceptible materials or components. These sources include:

- Leaky windows and door openings.
- Roof leaks.
- Missing, inadequate or poorly designed flashing.
- Lack of gutters.
- Foundation leaks.
- Plumbing leaks.
- Tuckpointing, particularly where the cement between bricks has worn thin.
- 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. Liquid water also can travel along beams and piping and show up as a leak in another part of the home or building. 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 pronounced impact.

Moisture also can enter the building envelope through *capillary action*; that is, a natural wicking force that will draw water from one source into the building envelope cavity. This primarily occurs at the base of exterior walls.<sup>7</sup> Capillary action also can occur when building components that transmit water are exposed to drenching conditions, such as excessive rainfall.

The fundamental principle of rain and ground water control is to shed water by layering materials in such a way that water is directed downward out of or away from the structure. In short, drainage is the key. Drainage applies to everything – building foundation, walls, roofs, doors, windows, skylights, balconies, decks, railings and dormers to name a few.<sup>8</sup> Regardless of the cause, entry of liquid water into any building structure must be prevented. See Section 4.1, Eliminate Sources of Moisture, for more information.

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; for example, oriented strand board (OSB) and other press-wood products, ceiling tiles and gypsum wallboard that are allowed to get wet from rain and/or other sources.<sup>7</sup> Improper storage of building materials also can result in the materials getting and staying wet while waiting installation.

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.<sup>4</sup>

**WATER CONDENSATION: A MATTER OF DEW POINTS, HUMIDITY.** Mechanical HVAC systems became popular in the mid-1960s and really gained momentum in the 1970s. In a cooling (hot and humid) climate, as the building envelope becomes tighter, any depressurization of conditioned spaces (the indoor environment is at a negative pressure as compared with the outdoor environment) may increase infiltration of water vapor from the outside. Similarly, in a heating (mixed or cold) climate a pressurized building can cause warm moisture-laden air from inside the building to 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.<sup>5</sup>

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 sp.*, *Trichoderma harzianum* and *Paecilomyces variotii* were frequently found in external walls of affected homes.<sup>9</sup> 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.<sup>4</sup>

Condensation occurs when warm air, which holds higher amounts of moisture than cold air, travels through a wall to the colder side. As the warm air begins to cool, it is forced to release moisture. This is referred to as the dew point. When there is a significant temperature drop across the wall cavity, the dew point will occur somewhere within that cavity.

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 sheathing. Internal humidity sources in pressurized homes and 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.<sup>4</sup>

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, outdoor humidity and building pressurization. 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.

Moisture also can enter a building as a result of air leakage, such as through or around windows or roof flashing, movement of humid air into the interior through cracks or loose construction of the building envelope, and diffusion of water vapor from the outside toward the cooler interior. In structures with either crawl space or attic, air leakage in the HVAC duct system into these areas may cause a negative pressure in the occupied areas. Any air that has leaked from the duct system would have to be made up from outside air. As noted, the diffusion or infiltration of air is caused by the home or building's interior being at a negative pressure with respect to the outdoor environment.<sup>1,4</sup> High amounts of air infiltration, which can bring in high amounts of moisture, can result in mold growth on all interior walls.

The Hospitality Lodging & Travel Research Foundation's landmark report on mold and mildew in hotel and motel guestrooms in hot and humid climates cited three primary causes for water vapor infiltration due to negative pressure in many hotel and motel properties:

- Fan effect from air being exhausted from bathroom fans without sufficient make-up air being added.
- Stack effect from the pressure of warm air rising in a building.

- Wind effect from the pressure of wind and varies with wind direction.<sup>1</sup>

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 fungi 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 [building] material [or building component] and is expressed as a decimal. For example, animal cells require  $a_w$  near 0.99 or 1.00, which is essentially saturation."<sup>10</sup> 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. 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.<sup>11</sup> Rooms can have hot and cold spaces and thus different relative humidity levels. What this means is surface condensation is not always necessary for mold growth to occur.<sup>12</sup>

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 building material contains the appropriate nutrients and no inhibitors, some fungi will be able to grow and possibly reproduce. Humidity levels at the surface of the building material must be maintained long enough for fungi to become established, usually about 48 hours. For example, if 80 percent relative humidity is present more than half the time, mold risk increases rapidly. The more water that is available, the more fungi there are that can colonize a surface.<sup>4, 11, 12</sup>

**MOISTURE GENERATION.** As noted, building occupants and their activities are a significant source of moisture in home and building interiors. Activities that can add moisture include operating showers without bathroom ventilation to the exterior, cooking without ventilation of steam to the exterior and drying clothes without venting the unit to the exterior, or using kerosene heaters or ventless gas appliances. Ventless gas appliances are a significant source of indoor moisture. They add 1 oz. of moisture for every 1,000 BTU rating per hour. For example, unvented gas stoves or ovens can generate 8 oz. to 75 oz. (one cup to more than one-half gallon) of moisture per hour.<sup>13</sup> In hotel and motel rooms in hot and humid climates, up to 28% of interior moisture can come from building occupants and their activities.<sup>14</sup>

**SPORES.** As discussed, mold is found everywhere in the indoor and outdoor environment. Section 1.4, *Mold, Mildew, Fungi – What’s The Difference?*, provides a comprehensive discussion on how mold grows and the various sources of mold spores in indoor environments.

### **1.3. Wallcoverings and Mold: A Function of Moisture Levels and Permeability**

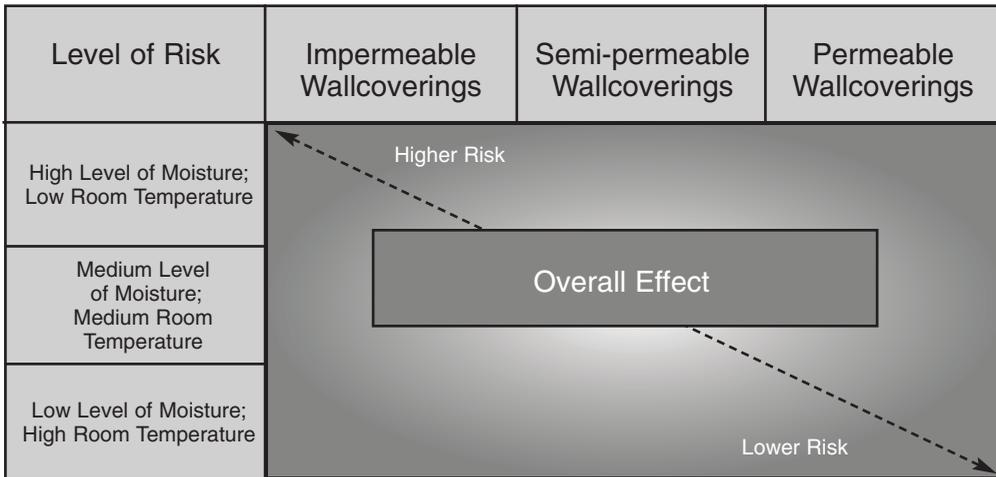
As noted in the previous section, warm humid air infiltrating into a wall cavity condenses when the dew point is reached inside the wall cavity as a result of the warm moist air coming into contact with the cool temperature of the wall surface. When this condition prevails, the backside of the wallcoverings and the wallboard to which the wallcovering is attached become an ideal place for mold growth.<sup>1, 4</sup> In existing homes and build-

ings, an effective line of defense is to first and foremost eliminate the source(s) of moisture and air infiltration, and second is to ensure that water vapor in the wall cavity can escape to the building’s interior through the wall surface. In new homes and buildings, the key is to design and build the structure to prevent favorable conditions for mold growth in the first place. In both cases, choosing the right wallcovering in terms of its permeability is vital. See Appendix C, NIST Personal Computer Model (MOIST) for information on a computer model developed by the National Institute of Standards and Technology (NIST) for evaluating moisture content of different building materials in different settings as a function of time.

Figure 1.2 illustrates the relationship of moisture level, room temperature and wallcovering permeability along with the level of associated risk for mold growth. For example, if a home or building has a high level of moisture intrusion into the wall cavity and an impermeable wallcovering is used, the risk for mold growth is very high as was the case for the buildings cited in The Hospitality Lodging & Travel Research Foundation’s report on mold in hotel and motel guestrooms in hot and humid climates.<sup>11</sup> On the other hand, if there is a low level of moisture intrusion into the wall cavity and a permeable wallcovering is used, then the risk for mold growth is very low. Selecting a permeable wallcovering can lower the risk for mold growth in a building with a high level of moisture and low indoor room temperature from air conditioning. See also Sections 4.1, *Eliminate Sources of Moisture*; Section 4.2, *Select Materials and Finishes to Prevent Mold*; and Section 4.3, *Build It Right in the First Place*, for more details.

**Figure 1.2. Risk of Mold Growth as a Function of Moisture Level in the Wall Cavity, Room Temperature and Wallcovering Permeability – Cooling Climate\***

Description of Wallcoverings, for more detailed descriptions of wallcoverings products and federal specifications for wallcovering physical properties.



**DECORATIVE LAYER.** In most cases, this layer is the thinnest and consists of the inks applied to the top of the intermediate layer. The decorative layer provides the design and color and is usually the major reason a wallcovering is chosen. The design is printed using various methods such as gravure, flexography, surface and screen. Also, texturing of the surface may

\* See Figure 4.1, in Section 4.1, Eliminate Sources of Moisture, for a map of areas in the U.S. that the U.S. Department of Housing and Urban Development has designated as a cooling climate.

The previous section provided an overview of how moisture can enter a building and become trapped in the wall cavity and condenses. The following discussion looks at the other essential factor in this equation: the permeability of wallcoverings. In short, how permeable a particular type of wallcovering is depends on its composition and the porosity of the materials used in its construction.

**WALLCOVERINGS CONSTRUCTION.** The majority of wallcoverings have three layers, which can be made of a variety of materials depending on the design and desired effect. See Appendix B,

increase the wallcovering’s permeability. This layer may also have a protective polymer coating to provide added performance characteristics. For residential wallcoverings, the decorative layer may be thicker than the balance of the wallcovering’s construction for some special products, such as expanded patterned PVC, paintables and high gravure. This thicker decorative layer typically does not interfere with permeability because the designs are discrete areas and do not fully cover the surface.

**INTERMEDIATE LAYER.** This layer, also called the ground, provides the surface on which the decorative layer is printed. It also provides the background color, which is often white but can be any color depending on the design. The intermediate layer can range in thickness from less than 1 mil to as much as 20 mils as in the heavier solid vinyl products.

**SUBSTRATE OR BACKING.** This is the layer that is adhered to the wall. The substrate, which is important in determining which wallcovering product will be used in a particular application, can be made of a wide variety of materials, including:

- Paper backings, which are used on paper-backed vinyls, vinyl-coated papers and specialty products. Strippable residential paper backings, which offer wet strength to allow activation of prepaste by immersing the product in water, are wood-free bleached cellulose pulp that is saturated with acrylic latex and then groundcoated on the print surface for improved print and scrubability.
- Coated woven fabric backings, which are commonly referred to as scrim or osnaburg. Scrim is used primarily in light construction and osnaburg in medium to heavy usage areas such as commercial building corridors.
- Coated non-woven fabric backings, which often improve wallcovering-printing techniques compared with woven fabrics while maintaining physical strength qualities necessary for commercial installations.
- Latex acrylic backings, which are used on textile-faced wallcoverings to make them more stable and improve hanging qualities.<sup>15</sup>

The substrate or backing also may provide a food source for mold as paper contains cellulose and woven fabrics may trap dust, allergens and organic materials in their weaves. In addition, pre-mixed adhesives used to adhere the wallcovering to the wall may contain starch, which is a nutritional source for mold. For this reason, these adhesives contain a mildewcide to prevent mold growth on the backside of wallcoverings. See Section 4.2, Select Materials and Finishes to Prevent Mold, for more details.

**MATERIALS.** Vinyl is used in many types of commercial and residential wallcoverings, because it is more durable, stronger and easier to clean than other wallcovering materials such as papers, linens, foils or grass cloth. While vinyl is the most widely used material for commercial and residential wallcoverings, other natural and synthetic materials are used to achieve a particular appearance, texture or performance characteristic. These materials include strippable paper, string effects, natural and synthetic textiles, polyester and olefin, cork and cork veneer and wood veneer. See Appendix B, Description of Wallcoverings, for details about the materials used in wallcoverings.

**PERMEABILITY RATINGS.** Building materials can be separated into three general classes depending on their permeability as shown in Table 1.1. While there are no standard industry permeability ratings for wallcoverings, Table 1.1 also shows results from internal vapor transmission testing conducted by a major wallcovering manufacturer, which is suggestive of what these ratings might be. These values, along with the following discussion, offer a helpful comparison with other building materials.

*The substrate, which is important in determining which wallcovering product will be used in a particular application, can be made of a wide variety of materials.*

As there are several recognized test methods for water vapor transmission, disclosing which method was used when discussing permeability of wallcoverings and building materials is important to avoid confusion about the testing results. The values in Table 1.1 were derived using ASTM E96-95, *Standard Test Methods for Water Vapor Transmission of Materials*, wet cup method at 73.4 degrees F (23 degrees C) and 50 percent relative humidity outside the dish.

It is important to note that other test methods are commonly used. Also of note is a U.S. Department of Housing and Urban Development (HUD) standard for manufactured housing that has proposed a waiver on permeability for the wall composite from 1 to 5 perms to achieve mold resistant exterior wall construction in all climates without the use of vapor barriers. The values in the HUD proposed waiver were derived using the dry cup method.<sup>16</sup>

The permeability of a particular type of wallcovering varies depending on the weight and porosity of the materials used. For example, a Type I vinyl wallcovering weighing 12 oz to 19 oz may have a perm rating of 1 (semi-permeable), whereas a Type II vinyl wallcovering weighing 20 oz and higher has a perm rating of less than 1 (impermeable). Some manufacturers have introduced “microvented” wallcoverings that feature approximately 135 very tiny holes per square inch in the vinyl wallcovering. These holes allow water vapor to escape. Even though most wallcoverings can be “microvented,” care should be taken, as “microventing” is not recommended for vinyl-coated paper, paper backed vinyl wallcoverings or vinyl wallcoverings with a non-woven substrate. “Microvented” wallcoverings have a permeability rating of between 8 and 12, which qualifies them as permeable.<sup>17, 18</sup>

***As there are several recognized test methods for water vapor transmission, disclosing which method was used when discussing permeability of wallcoverings and building materials is important to avoid confusion about test results.***

Table 1.1. Building Materials, Wallcoverings Permeability

<b>General Classes<sup>19</sup></b>		<b>Wallcoverings</b>	
Classification	Building Materials	Type	Estimated Perm Rating
Vapor impermeable – referred to as vapor barriers	Rubber membranes, polyethylene film, glass, aluminum foil, sheet metal, oil-based paints and foil-faced insulating sheathings	Type II vinyl Mylar or Foil, PET laminated to Non-woven	Less than 1*
Vapor semi-permeable – referred to as vapor retarders	Plywood, OSB, unfaced expanded polystyrene (EPS), fiberfaced isocyanurate, heavy asphalt impregnated building papers, some latex paints and bitumen facing on most fiberglass batt insulation	Untextured vinyl  Textured vinyl  PVC Liquid- coated non-woven	1 - 3  2 - 10  2 - 15
Vapor permeable – referred to as breathable	Unpainted gypsum board and plaster, unfaced fiberglass insulation, cellulose insulation, unpainted stucco, lightweight asphalt impregnated building papers, asphalt impregnated fiberboard, exterior gypsum sheathings, cement sheathings, and “housewraps”	“Microvented” vinyl wallcovering  Non-woven (Composition variation)  Woven fiberglass  Paintable paper Residential Simplex & Duplex wallpaper (non-vinyl coated)  Prepasted paper  Saturated paper Strippable Paper  Textiles  Paintable residential paper  Natural products	8 - 2*  4 - 100*  ~10 or higher  8 - 20*  2 -30  2 -30**  ~10 - 100  10 or higher***  15 - ~100

\* Testing conducted in accordance with CFFA 19 Procedure B (ASTM E96-95, *Standard Test Methods for Water Vapor Transmission of Materials*, wet cup method at 73.4 degrees F (23 degrees C) and 50 percent relative humidity outside the dish). Other methods can be used.

\*\* Prepasted wallcovering should be tested with prepaste removed or not added to the paper. Various constructions of wallcoverings will give a wide variation in perm values.

\*\*\* The type of paint and number of coats of paint can cause significant variation in perm values.

Typically, non-woven wallcoverings are made of polyester and wood cellulose, which allows for transmission of moisture. Perm ratings for non-woven wallcoverings may range as low as 4 to as high as 100. This wide range depends on how tightly the wallcovering is compressed. Plain wallcovering papers, on the other hand, are less porous and may have a perm rating of about 8 to 20. Saturated paper is comprised of a latex binder that holds wood-free pulp of cellulose and polyester fibers together, which gives the wallcovering strength. The advantage is it can look like a vinyl wallcovering, but unlike vinyl wallcoverings it has a higher perm rating of 2 to 30. Added treatments to the decorative layer tend to make this type of wallcovering less permeable.

Textiles also known as woven wallcoverings typically are made from synthetic fibers such as polypropylene (generic term is polyolefin). Because there is more space between the fibers, this type of wallcovering would likely have a relatively high perm rating of about 10 to 100 or higher.

Woven fiberglass wallcoverings are made of fiberglass that appears to be woven. Usually, this type of wallcovering is white and, once applied to wall, is painted. The perm rating varies depending on type of paint used and number of coatings applied to the surface; for example, enamels or epoxy coatings. In general, the rating is 10 or higher.

Natural products, such as grass cloth, are not often used in commercial applications in the US as they lack the durability and strength needed to withstand day-to-day abuse. Because they have a very loose composition, these products have very high perm ratings. In general, the rating is 15 to 100.

Permeability also depends on whether a protective coating is applied to the design layer, which

would tend to make the wallcovering less porous. Paper or non-woven wallcoverings may have filling agents, which are used to get better quality of print and to create a more even appearance. Coatings made from clays and calcium carbonates are used to achieve printing performance characteristics similar to vinyl. Acrylic and other emulsion polymers can be formulated to make a wallcovering coating that is porous. The effect is similar to “microvented” wallcoverings. Wallcoverings with this type of coating have the advantage of being more permeable but are less durable than vinyl.

#### **1.4. 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.<sup>20</sup> *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.

Although mentioned earlier in this publication, it bears repeating that mold is found everywhere in both indoor and outdoor environments. And as described in Section 1.2, Overview of Mold in Building and Home Interiors, in order for mold to grow it needs a nutrient source, appropriate temperature, moisture and a source of mold spores. To keep mold from growing indoors requires eliminating one of these four elements, which is not easily done. The key is moisture. By eliminating moisture, mold growth can be prevented. See Section 4.1, Eliminate Sources of Moisture, for more information.

Not all species of mold are destructive to building materials or may cause adverse health effects. A number of varieties are essential to every day life and are beneficial to health. Fungi, for example, can be commonly found on grocery store shelves, such as button mushrooms or more exotic varieties for the gourmets at heart. Fungi are used in the making of common foods; for example, related species and strains of *Saccharomyces cerevisiae* (yeast) are commonly used in baking and for some types of fermentation, including alcoholic beverages. Yeast also is often taken as a vitamin supplement because it is 50 percent protein and is a rich source of B vitamins, niacin and folic acid.<sup>21</sup> Different strains of *Penicillium* are used in making Stilton, Buxton and blue cheese to name a few.<sup>22</sup>

In addition, fungi are a valuable resource for commonly used medicines; for example, cyclosporine, an important immune suppressant drug used with organ transplant surgery, is made from the fungus *Tylocladium inflatum*. *Isopenicillin N*. is the fungus from which penicillin antibiotics are derived. In fact, fungi are the second largest microbial producers of antibiotics behind a specific type of bacteria.<sup>23</sup>

Unlike bacteria and algae, fungi cells are *eukaryotes*; that is, they have a nuclear envelope.<sup>24</sup> The majority of species, including those most abundant in the environment are *saprobies*, 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.<sup>25</sup>

Fungal spores germinate to produce hyphae, which grow and branch within or on the building materials or components, typically producing a colony that eventually forms a new generation of spores.<sup>25</sup> Fungi also can spread if a fragment of broken hyphae is transplanted to an area with adequate warmth, moisture and nutrient source.<sup>15</sup> 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.<sup>25</sup> Fungi spores also can survive for many years in dry or hot environments, requiring only moisture and available organic matter in order to germinate.<sup>26</sup>

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.<sup>20, 26</sup>

***Not all species of mold are destructive to building materials or may cause adverse health effects.***

## 1.5. 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.<sup>25</sup> 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, including wallcoverings. *Zygomycetes* 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.<sup>10</sup>

The University of Minnesota Department of Environmental Health and Safety's website features a fungal glossary on its indoor fungal resources page, including species-specific information derived from an extensive review of available scientific literature. The following discussion of *Cladosporium sp.*, *Phoma sp.*, *Rhodotorula sp.* and *Stachybotrys* is from that glossary.<sup>27</sup>

*Cladosporium sp.* is the most commonly identified outdoor fungus. The outdoor numbers are lower in the winter and often higher in summer. It is also found often 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 the species level 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 cooling coils and drain pans. In some countries, *Rhodotorula sp.* is the most common yeast genus in indoor air.

*Stachybotrys 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. Until very recently, researchers believed that *Stachybotrys* was rarely found in outdoor air samples, and was usually difficult to find in indoor air samples unless it is physically disturbed or 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.

*Aureobasidium pullulans* is one of several genera of "black yeasts", characterized by mostly slow-growing, black, pasty colonies. This yeast-like fungus is commonly found on caulk or damp window frames in bathrooms.

A more recent study of indoor/outdoor mold ratios across the US, however, identified *Stachybotrys chartarum* in 6 percent of indoor air and 1 percent of outdoor air of the buildings studied. These researchers concluded that *Stachybotrys* is a normal component of airborne fungi and detection of this mold species is not as rare as was previously thought.<sup>28</sup>

Table 1.2 lists some of the common molds and locations found in indoor environments.<sup>20, 27</sup>

## 1.6. Are Molds Really Toxic?

Although much has been made in news reports and in recent litigation about 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 species of fungi can produce *mycotoxins*, which are considered to be toxic to humans and animals.

Table 1.2. Common Indoor Molds

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

Specifically, data are lacking to support threshold limit or dose-response relationship for exposure. As of this writing, the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH) and 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.

Systemic infections, which are also caused by mold, 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.<sup>20, 30</sup> A rare, but much more serious immune-related condition, hypersensitivity pneumonitis, may follow exposure (usually occupational) to very high concentrations of fungal and other microbial proteins.<sup>29</sup>

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 MVOCs are released into the air and inhaled, physically contacted (dermal exposure) or ingested.<sup>31</sup>

**VOLATILE ORGANIC COMPOUNDS.** Volatile organic compounds, also called microbial volatile organic compounds (MVOCs), are responsible for the musty odors characteristic of mold growth. In the process of degrading building materials and components 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.<sup>32</sup> 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.<sup>20</sup>

***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.”<sup>10</sup>***

***In its position statement on adverse human health effects associated with molds in the indoor environment, the American College of Occupational and Environmental Medicine reaffirms that “current scientific evidence does not support the proposition that human health has been adversely affected by inhaled mycotoxins in home, school or office environments.”<sup>29</sup>***

**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. Researchers estimate that 10 percent of the population has allergic antibodies to fungal antigens and only one-half of these 10 percent, or 5 percent, are expected to show clinical illness. Symptoms can range from mild to transitory responses such as watery eyes, runny nose, throat irritation, coughing and sneezing to chronic illnesses such as sinusitis and asthma. An important note is that indoor mold allergens probably affect fewer people than do allergens from cats, mites and cockroaches or outdoor molds. Also of note is a significant proportion of people with asthma (10 percent to 32 percent) are sensitive to mold.<sup>20, 29</sup>

**MYCOTOXINS.** A wide variety of molds can produce mycotoxins, and some of these compounds are toxic to humans and animals.<sup>24</sup> 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 *Fusarium*, *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.<sup>20</sup>

Among the health effects attributed to mycotoxins are mucous membrane irritations, including eye, nose and throat, from exposures at high levels.<sup>20, 33</sup> 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.<sup>20, 30</sup> Other symptoms attributed to mold mycotoxins include headache, dizziness, dermatitis, diarrhea and impaired or altered immune function.<sup>34</sup>

***Allergic reactions are the most common responses to mold. Indoor mold allergies probably affect fewer people than do allergies from cats, mites and cockroaches or outdoor molds.***

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.”<sup>35</sup> 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.<sup>36, 37</sup> Mycotoxin production for a given species is highly dependent on growth conditions, such as nutrient availability, temperature and humidity. Ronald E. Gotts, 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.”<sup>38</sup>

#### ***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 micro-biological 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.<sup>39</sup>

***“Just because a toxigenic mold is found in an indoor environment, it does not necessarily mean that the mold is producing mycotoxins,” said Ronald E. Gotts, M.D., Ph.D.***

## Section 2. How to Tell if a Mold Problem Exists

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 also to identifying the source of the problem, what type of mold is 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 mold problems and recommend a remediation plan. For these reasons, the wisest course of action is to call an expert!

### 2.1. 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.
- Industrial hygienists or your state health department.

**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:
  - ✓ How many mold-related jobs has your firm done and when was the first one? Look for experience prior to 1997.
  - ✓ 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.
  - ✓ What certifications does your firm bring? Certifications such as a professional engineer (PE), a certified industrial hygienist (CIH), a certified indoor air quality professional (CIAQP), a certified indoor environmentalist (CIE) and a certified mold remediator (CMR) are helpful if they have experience, useless if not.

### 2.2. 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 Appendix A, List of 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. Most mold problems, however, occur on either the interior of the outside wall or the adjacent wall that connects to the outside wall.<sup>1</sup> 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.<sup>40</sup> These interviews can also help establish a hypothesis or several hypotheses, which provides a focus for the investigation.<sup>41</sup>

***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.<sup>42</sup> 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.<sup>43</sup>

Visible stains (red, pink, yellow and black) on the front side of the wallcovering can be indication that mold is growing behind the wallcovering. Some species of mold can produce by-products as a part of their digestive process, which can migrate or diffuse to the front surface of wall coverings and produce these colored stains.<sup>77</sup>

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.<sup>31</sup>

Carpeting and other flooring, textiles, ceiling tiles, gypsum wallboard and ceilings, cardboard, press-wood products, paper and other cellulosic surfaces are also inspected. The inspector will look both inside and outside the building 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.
- Negatively pressurized building.

**FIBEROPTIC EQUIPMENT.** 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.<sup>42, 43, 44</sup>

**MOISTURE METERS.** Moisture meters that detect, measure and locate moisture in buildings materials are rapidly becoming an important diagnostic tool for mold remediation and prevention.<sup>31</sup> Basically, there are two-types of moisture meters: pin-type resistance meters and impedance, pinless or pad-type meters. Both measure the way moisture affects the electrical properties of the material being tested.<sup>45</sup>

The most accurate results may be obtained from the use of the pin-type moisture meters. The 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. They also can detect if there is a loss of adhesion of the loose wallcovering.<sup>46</sup> As the pins are removed the wallcovering will bulge or puff out to follow the pins being removed.

The pin-type resistance meters work on the principle of direct current (DC) resistance measurement. For most porous materials, an increase in moisture content will result in a decrease in electrical resistance. The resistance measurement meter has pin electrodes connected to it. When the pins are inserted into the material being tested, the DC current passes in a single line from one pin to the other, measuring the decrease in the resistance. The higher the moisture content, the lower the resistance. This change is translated into a moisture-related reading and displayed on a moving coil or digital or diode display.<sup>45</sup> These meters must be calibrated for each type of

building material or component, for example, plywood, studs or gypsum wallboard.<sup>46</sup> Other meters feature multiple scales. The Delmhorst BD-2100, for example, includes a scale for gypsum wallboard in addition to a wood scale and a reference scale:

- Wood Scale – 6 percent to 40 percent moisture range. Useful for flooring and building material such as wood studs, floor joists and subfloors.
- Reference Scale – reads from 0 to 100 on a relative basis. Used on non-wood materials such as concrete, plaster, and insulation.
- Gypsum Scale – 0.2 percent to 6 percent moisture range. Used on gypsum wallboard.<sup>41</sup>

Visit [www.delmhorst.com](http://www.delmhorst.com) for more information.

The impedance, pinless and pad meters operate on the principle of electrical impedance, in which the electrical impedance of a material varies in proportion to its moisture content. Pinless meters use radio frequency signals to penetrate the material being tested rather than pins. To measure and detect moisture, the two co-planar conductive rubber electrodes mounted on the base of the instrument case are pressed onto the material being tested. The instrument measures the electrical impedance of this material by creating a low frequency alternating electric field between the electrodes. The very small alternating current flowing through the field is proportional to the impedance of the material. The instrument detects this current, determines its amplitude and displays the computed moisture value on the moving coil pointer meter or LCD display material. The field penetrates the material being tested to a depth of up to approximately 1 1/4 inch (30 mm) for the pocket size instrument and up to 3 inch (75 mm) for larger impedance meter.<sup>45, 46</sup>

As there is a wide variation in the nominal electrical impedance of different material types, a good

quality moisture meter of this type should provide at least three selectable scales that are optimal for testing materials such as wood, timber; dry-wall, roofing; and plaster, brick. In addition to these materials, one of these sensitivity scales should be suitable for the detection and location of elevated moisture in or behind a range of covering materials such as wall, floor, and ceiling tiles, siding, carpet tiles and laminated floor coverings.<sup>45</sup>

The impedance, pinless and pad meters are not always accurate, but they can be useful for quick, qualitative surveys to identify wet versus dry spots in walls and floors over a large area. They also can help determine if further testing is required in certain spots. These meters are particularly susceptible to misinterpretation when working with laminated composites.<sup>40, 46</sup>

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.<sup>47</sup>

**OTHER TYPES OF METERS.** 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.<sup>40, 46</sup>

**SAMPLING.** The strategy for collecting samples involves developing hypotheses (as noted above) and then designing a plan that will allow testing of the hypotheses.<sup>31, 32</sup> 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<sup>43</sup>

One word of caution with respect to sampling: Nearly all indoor air quality experts in the U.S. recommend spending only a minimal effort in collecting and analyzing mold samples. One reason is that mold is everywhere in the environment and relying on sampling results alone to clarify the problem rarely helps. Further, air sampling is notoriously susceptible to "false negative results," meaning that non-detection does not indicate that mold does not exist. In short, if mold is visible, there is a problem that needs to be promptly addressed.<sup>48</sup> With that being said, the following further details source and air sampling, the two primary methods used to evaluate mold problems.

**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.<sup>31</sup> These samples are analyzed under a microscope. Surface sampling is less destructive than bulk sampling, which requires removing a piece of the building material or component on which the mold is growing.

**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.<sup>31, 40</sup> 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.<sup>32</sup>

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.<sup>32</sup> *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.<sup>30, 49</sup>

**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<sup>50</sup> or glucan concentrations as estimates of fungal biomass. In addition, immunoassays are under development for measuring some specific fungal allergens.<sup>32</sup>

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.<sup>51</sup> 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.<sup>52</sup> As of this writing, the test kit for *Stachybotrys chartarum* is just making its way to the commercial market.<sup>53</sup>

***Conventional testing and analysis methodologies rely heavily on human evaluation and are dependant on the degree of the analyst's expertise and experience.***

**SEASONAL VARIATIONS.** When assessing a mold problem, the inspector also should be aware of the potential effects of seasonal variations on the building. For example, inspection and testing may find a great deal of moisture in the drywall or wall cavity during the cooling months but may find the opposite is true during the heating months. If the assessment is done during the heating months, there is a temptation to assume that moisture intrusion is no longer a problem and all that needs to be done is cleaning up any visible mold. Do not be fooled! Even though testing may not demonstrate high moisture levels at that exact moment, evidence of mold is sufficient proof that at some point during the year there is enough moisture for a long enough period of time to support mold growth. The source of that moisture must be found and corrected in order for any remediation efforts to be successful. See Section 1.2, Overview of Mold in Building and Home Interiors, for details on sources of moisture condensation.

### **2.3. Testing Criteria and Results**

Also as of this writing, there are no government standards or guidelines for interpreting microbial testing results so there is no way to deem definitely that a building is either “safe” or “unsafe” for building occupants.<sup>48</sup> 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.<sup>54</sup> 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](http://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.<sup>54</sup>

**INDOOR/OUTDOOR RATIOS.** A comparison of concentrations and species composition of the collected samples is used to assess indoor/outdoor ratios. 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.<sup>40</sup>

*If the assessment is done during the heating months, there is a temptation to assume moisture intrusion is no longer a problem.*

***Don't be fooled!***

Indoor fungal growth 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 *Clado-sporium 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 *Clado-sporium sphaerospermum* indoors, with the latter indicating an indoor source.<sup>32</sup>

According to a recent study, the most common culturable airborne fungi, both outdoors and indoors, and in all seasons and regions in the US, were *Cladosporium*, *Penicillium*, nonsporulating fungi and *Aspergillus*. As noted in Section 1.5, Different Types of Indoor Molds, the researchers conclude that *Stachybotrys chartarum* is a normal

component of airborne fungi and detection of this mold species is not as rare as previously thought. This study also offers comparative information on common culturable airborne fungi in the US that can be used to better interpret bioaerosol samples. It is the largest study of airborne indoor and outdoor fungal species and concentrations conducted with a standardized protocol to date.<sup>28</sup>

**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.<sup>32</sup>

***Researchers have concluded the Stachybotrys chartarum is a normal component of airborne fungi and detection of this mold species is not as rare as previously thought.***

## Section 3. How to Get Rid of Mold

Successful remediation and restoration of a building or home with mold can be accomplished without taking drastic steps as reported by some news media. See Section 2, How to Tell if a Mold Problem Exists, and Section 4.1, Eliminate Sources of Moisture, for more information.

***First and foremost, the source of moisture must be found and eliminated.***

Even though it is tempting to clean up mold

without the help of an expert – don't, especially if the area is larger than 10 sq. ft. Mold can look dead, but in actuality the spores are still very capable of spreading and colonizing other building materials. Without proper containment and removal, the risk of spreading mold spores throughout the building is very high, not to mention an increased risk to the workers cleaning up the mold infested area of inhaling sufficient number of mold spores that may possibly cause health problems.

While there are no set standards, a number of organizations have provided guidelines (see Appendix A, List of Guidelines and Resources for the Assessment and Remediation of Fungal Contamination). According to 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.”<sup>31</sup>

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 than 10 sq. ft. (see Section 2.1, Finding a Qualified Expert).<sup>31, 55</sup> 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 4.1, Eliminating Sources of Moisture, for more information.
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 2.2, 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 addressed as soon as possible.

# Section 1. Who, What, Where, When, Why's of Mold

## 3.1. 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 outlined in the guidelines and resources listed in Appendix A, List of Guidelines and Resources for Assessment and Remediation of Fungal Contamination.

***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.***

Wallcoverings per se are not specifically addressed in these guidelines. The safest course is to follow guidelines for removing mold from porous materials.

The New York City Department of Health Guidelines on Assessment and Remediation of

Fungi in Indoor Environments identify 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. Contaminated wallcovering, whether porous or not, should be removed, bagged, and taken to the landfill. If the mold growth is not extensive – that is, less than 10 sq. ft. of the wall surface is affected, and the mold has not infiltrated or degraded the wall surface – then the wall surface 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. Another recommended cleaning solution is comprised of two cups of household bleach per one gallon of water. A diluted bleach solution, however, is **not recommended** for the initial wash of wall or wall surface, because the spores may be bleached and become difficult to see, and as a result they may not be removed. Wash the wall area with a detergent solution first, then, wash with the bleach solution. Once cleaned, the area should then be monitored for mold growth.

***An important reminder: If the moisture source is not eliminated, mold growth will reoccur.***

***Caution: Do not mix cleaning solutions as hazardous gases may be generated. Also, diluted bleach or other cleaning solutions may discolor flooring or carpeting; therefore, care should be taken to protect adjacent surfaces.***

If the walls are wet or extremely damp, will not dry or have become soft from water damage, the wallboard with the wallcoverings attached should be removed to limit mold spore exposure. In severe cases, studs and insulation may have to be replaced. Replacement of drywall will eliminate the need to wash and bleach the wall. It also will provide a new, sound surface for reinstallation. A respirator or protective facemask should be worn during wallcovering and/or drywall removal. See Section 3.2, Specific Personal Protection and Containment Guidelines, for additional details.<sup>56</sup>

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.<sup>55</sup>

#### ***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 building material or component. 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.<sup>55</sup>

***HVAC SYSTEM.*** By and large, the procedure for remediation is the same for HVAC systems as for the rest of the home or 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.<sup>55</sup>

#### ***BIOCIDES AND ANTIMICROBIAL AGENTS.***

Biocides are chemical or physical agents that kill or inactivate microorganisms, and antimicrobial agents are compounds used to suppress microbial growth.<sup>35</sup> 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.<sup>31</sup>

- Some agents are designed to treat certain groups of microorganisms and not others. Suppression of one species may give others an advantage.<sup>57</sup>
- 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.<sup>57</sup>

**BIOCIDES, ANTIMICROBIAL AGENTS AND WALLCOVERINGS.** Manufacturers of wallcovering adhesives and primers typically incorporate biocides and antimicrobial agents into their formulas to protect walls and the wallcoverings from mold growth. These biocide systems, also called fungicides or fungistats, are designed to prevent microbial contamination and mold infestation “in-the-can” and/or in the dried adhesives.

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 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.<sup>58</sup> While the cost of this new technology is very expensive, it is being reviewed by wallcovering manufacturers. Vinyl wallcovering manufacturers incorporate a biocide (mildewcide) into the vinyl formulation of their wallcovering.

Another strategy being offered by primer manufacturers is a primer that creates a barrier between the wall and wallcovering backing, which the mold cannot overcome. Primers also help to protect the drywall face when wallcoverings are removed. Regardless of the type of wallcovering, proper wall preparation and application of a primer is essential not only for quality wallcovering installation but also for preventing mold growth. See Section 4.2, Select Materials and Finishes to Prevent Mold, for more about preparing the wall for a wallcovering.

***An important note: Any use of biocides (mildewcides) and antimicrobial agents, whether they be stand-alone products or incorporated into wallcovering adhesives and primers, should complement proper water and moisture control and regular cleaning and maintenance, not replace them.<sup>57</sup> If the moisture source is not eliminated, mold will grow.***

### 3.2. 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.<sup>59, 60, 61</sup> 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.<sup>55</sup>

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. As wallcoverings are removed from the wall, carefully roll inward (mold area inside) so that the mold-infested area is contained and worker exposure is minimized. Removed wallcoverings can then be bagged and taken from the building. These products can then be added to a landfill.<sup>56</sup>
- 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.

### **3.3. Verifying Successful Remediation**

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

- Visual inspection to ensure all of the contaminated building material or component 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 mold from re-establishing colonies.*

## Section 4. 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 building material or component, fungal spores that settle on the building material or component, and moisture, usually 70 percent relative humidity or higher at the surface of the building material or component. For all practical purposes, all of these conditions, except moisture levels, are met in nearly every home and building.<sup>62, 63</sup>

In existing homes and buildings, an effective line of defense is first and foremost to eliminate the source(s) of moisture and air infiltration, and second is to ensure that water vapor in the wall cavity can escape to the building's interior through the wall surface. In new homes and buildings, the key is to design and build the structures to prevent favorable conditions for mold growth in the first place. In both cases, choosing the right wall-covering in terms of its permeability and properly preparing the wall surface can strengthen these lines of defense in cooling climates.

### 4.1. Eliminate Sources of Moisture

Trying to clean up a mold problem without first solving the fundamental cause of the moisture problem will prove to be both futile and costly. The primary places to look for the cause of moisture intrusion is the building's HVAC and envelope (roof and wall) systems. Insurance company records clearly show that these two building systems comprise the majority of all post-construction litigation claims against design teams, especially those related to moisture intrusion problems.<sup>48</sup>

As described in Section 1.2, Overview of Mold in Building and Home Interiors, the following are the four 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 cold surfaces of building materials or components, which originates from water vapor inside or outside the building.
4. Moisture generated within the building by the occupant and the occupant's activity.

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.
- Positive pressure is preferred to negative pressure.
- 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 home or building can typically overcome leakage, these areas should be sealed. A tightly sealed home or building will minimize air leakage and reduce the amount of air required by the HVAC system to maintain positive

pressures, which saves energy.<sup>7</sup> There are less common conditions where positive building pressurization would not be desirable, such as homes or buildings with a high internal moisture load, but that is not typical. This publication addresses only typical homes and 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, which 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.<sup>64,65</sup>
- 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 measure

ment 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. It 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), wallcoverings (11 percent) and soft wood (17 percent).<sup>64, 66</sup>

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 surface of the building material or component not the ambient relative humidity in the room. 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 building material or component to exceed 70 percent.<sup>66</sup>

Relying on relative humidity 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.<sup>67</sup> Seasonal variations and day-to-day variations, in some cases, can cause fluctuating growth periods for the mold. The best guidance is to maintain indoor relative humidity consistently below 60 percent.

**VAPOR AND AIR BARRIERS.** Effectively controlling condensation within wall systems requires understanding how condensation occurs in different climates and in different seasons. Effective control also requires designing the wall system and implementing appropriate strategies to accommodate the climate and change of seasons. It is suggested that a current moisture control handbook be consulted to inform the reader of the latest ideas for moisture control. Typically, wall systems consist of the exterior wall, metal or wood stud framing, air barrier, vapor barrier (if used), insulation, gypsum sheathing, gypsum wallboard and a wallcovering 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 wallcovering or paint. See Section 4.2, Select Materials and Finishes to Prevent Mold, for more information.

**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. See Appendix D, Standard Test Method and Calculation of Permeability, for a discussion of computer modeling of wall construction. Moisture trapped between two materials that act as vapor barriers cannot escape and thus condenses inside the ceiling or wall at the cold surface. If a vapor barrier is used, extreme care should be taken in determining which method to use.
- Use a permeable wallcovering or permeable paint on internal surfaces.
- The HVAC system must maintain a net positive pressure with respect to the outdoors to keep unconditioned outdoor air out of the home or building.
- Avoid excessive cooling of interior spaces below the average, monthly, outdoor dew point for the area in which the home or 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.<sup>7, 63, 65, 68, 69</sup>

**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 home or 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:

- 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.<sup>65, 68, 69</sup>

**MIXED CLIMATES.** Many parts of the U.S. may be categorized as being in a mixed climate: cold and dry in the winter and hot and humid in the summer. Placement of the vapor barrier follows the advice for cold climates; that is, on the warm, winter side of the wall assembly.<sup>13</sup>

Conventional vapor barriers may provide effective

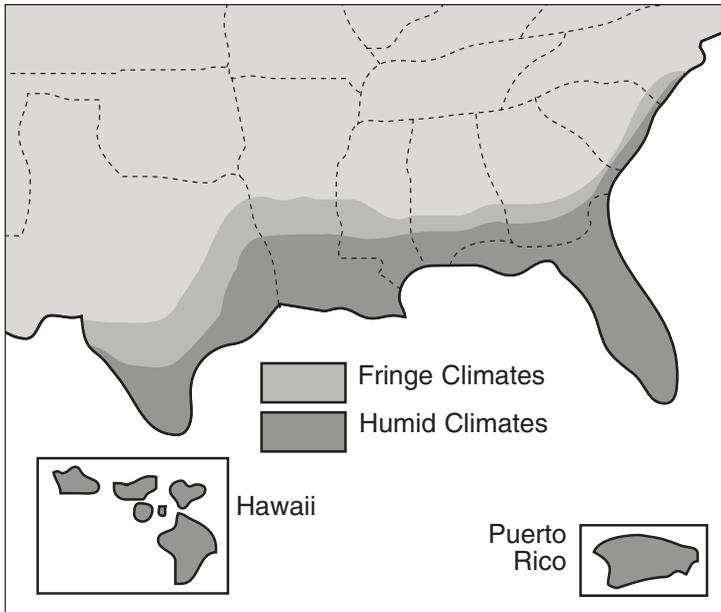
protection against condensation during the heating season by reducing the vapor diffusion into the wall assembly to an acceptable minimum. But in the cooling season, the low vapor permeability of the vapor barrier reduces drying potential and as a result may trap moisture in the wall assembly.

This dilemma has resulted in the development of innovative vapor barriers or retarders, which are now just emerging and may not yet be commercially available. These barriers and retarders may provide more flexible water vapor control than traditional materials. For example, the “smart” retarder (a nylon film 50 µm or 2 mil in thickness) takes advantage of the inversion of temperature and humidity levels from winter to summer. In winter, the air is warmer and more humid inside the building and in summer, the air is warmer and more humid outside. When the ambient humidity rises outside, the “smart” retarder adapts its vapor permeability by opening its pores when good drying conditions prevail. It accomplishes this by absorbing water from the air, which then opens its molecular pores.<sup>70</sup>

The “smart” vapor retarder does have limitations, however, and may not be as effective in hot, humid climates where high outdoor humidity levels prevail. The higher humidity may increase the “smart” vapor retarder’s permeability to such an extent that it may not be able to reduce vapor diffusion sufficiently. The same may be true in all climates for buildings with exceptionally high indoor humidity levels, such as an indoor swimming pool. Short peaks of high indoor relative humidity, such as may occur in kitchens and bathrooms, do not affect the “smart” retarders performance.<sup>70</sup>

Figure 4.1 shows a map of the areas in the U.S. that the U.S. Department of Housing and Urban Development has designated as a cooling (humid and fringe) climate.

Figure 4.1 Humid and Fringe Climate Map<sup>16</sup>



**HVAC SYSTEM.** As described in Section 1.2, Overview of Mold in Building and Home Interiors, improper interaction between the HVAC system and the building envelope can be a major player in creating favorable conditions for mold growth. While the HVAC system itself is not a source of moisture, its design and how well it is operated and maintained has a direct bearing on its effectiveness in preventing moisture intrusion and condensation. The following are some general guidelines:

- Design the room air conditioning supply air grille or outlet so cool air does not blow directly on the wall or ceiling, thereby maintaining the temperature of the wall surface as high as possible and minimizing the possibility of moisture condensation on or behind the wallcovering.

- Design the system to supply sufficient pre-conditioned and filtered air to remove excess humidity and contaminants such as mold spores from make-up air and to prevent intrusion of outside air through the building envelope.
- Design the system to properly manage moisture loads.
- Design the system to properly to maintain the building at a slightly higher pressure relative to the outside, which will force air to flow out of the building through joints and cracks rather than allowing outside air to flow into the building.<sup>7, 71</sup>

#### 4.2. Select Materials and Finishes to Prevent Mold

Although much of the recent attention has been focused on how molds possibly can harm people, mold 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, wallcoverings, HVAC system components and furnishings can lead to increased maintenance and operation costs.<sup>64</sup>

Today, an effective strategy for controlling condensation and preventing mold growth is to design wall systems and 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.<sup>63</sup>

A key component of this strategy is selecting the proper wallcovering that balances performance characteristics and permeability. Here are some guidelines:

- Any wallcovering covering can be installed in a dry building.
- Questionable walls should use a permeable (breathable) wallcovering or perforated (“microvented”) wallcovering.

***As a compromise, the interior surface of the exterior walls in cooling climates should be installed with permeable (breathable) or microvented vinyl and interior walls with any variety of wallcoverings. See Section 4.1, Eliminate Sources of Moisture, for more information.***

Also, using high-quality materials and finishes are 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 1.2, Overview of Mold in Building and Home Interiors), 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.<sup>72</sup>

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).<sup>72</sup>

### **4.3. Proper Surface Preparation**

Proper surface preparation is not only essential for quality wallcovering installation but also for preventing mold growth regardless of whether the building is new or existing. The wall surface should be clean, dry, structurally sound and free of mold, grease and other stains. In new construction, ideally sufficient time should be allowed for the building to dry out before drywall and wallcoverings are installed. The actual moisture of the drywall may vary with relative humidity in the area. Moisture content of a new drywall may be as high as 15 to 18 percent as measured by a moisture meter in a hot and humid climate during

the cooling season.<sup>56</sup> In other areas of the country, normal moisture content is typically under six percent. Care should be to ensure that high moisture content in the wallboard is due to relative humidity and not a leaky building or improperly stored building material.

In existing buildings, careful inspection of the wall surface should be made and any mold should be cleaned or removed in accordance with mold removal guidelines. If the area is less than 10 sq. ft., then the area may be thoroughly cleaned. If the area is greater than 10 sq. ft., proper removal protocols should be followed. See Section 3.1, Cleaning, Removing Building Materials, for details. Also, if the walls are wet or extremely damp, will not dry or, have become soft from water damage, then the wallboard should be removed and new drywall installed.<sup>56</sup> After the wall surface has been cleaned, any mold stains should be sealed with a good quality stain killer primer/sealer.

Any mold stains should be sealed with a good quality stain killer primer/sealer. If the area is greater than 10 sq. ft., proper removal protocols should be followed. Again, see Section 3.1, Cleaning, Removing Building Materials, for details.

***Wallcoverings should never be installed on a wet wall.***

***Any mold stains should be sealed with a good quality stain killer primer/sealer.***

Each type of surface needs to be treated accordingly:

***NEW DRYWALL.*** Make sure the drywall is free of contaminants such as dust, dirt and mildew and has had enough time to dry out. Joints and spackled areas should be thoroughly cured and sanded smooth. Best results are obtained when the moisture content of the drywall is minimized. Apply a good quality wallcovering primer.

***NEW PLASTER.*** Allow at least 60 to 90 days for new plaster to completely cure. Best results are obtained when the moisture content of the plaster is minimized. If waiting for total curing is not possible, the newly plastered walls should be washed with a zinc sulfate solution to neutralize the lime (two to four pounds of zinc sulfate per gallon of water) then prime the wall. Best results will be obtained if a pigmented, acrylic wallcovering primer is used to decrease the porosity of the plaster and form a good surface to bond the wallpaper to the wall.

***PAINT.*** Test painted surfaces for moisture sensitivity. Hold a wet sponge or cloth to the paint surface for 15 seconds and then rub the surface vigorously with a cloth. If little or slight amount of paint is removed, the paint should be sound. If all or a large quantity is removed, the surface is moisture sensitive, which may result in failure. If the wall is found to be moisture-sensitive, it should be sanded or washed with ammonia to remove the paint. All painted walls should be primed with a good quality wallcovering primer.

***MASONRY.*** Wall surfaces should not exceed 5.5 percent moisture as measured by a moisture meter. It is best to seal the concrete with a waterproof sealer before applying a wallcovering primer and hanging the wallcovering. Surfaces should be sanded smooth and irregular surfaces smoothed with drywall compound, plaster or other materials. Liner paper may be required.

***OLD WALLCOVERING HAS BEEN REMOVED.***

Old adhesives can act as a food source for mold and make bonding to the wall surface uneven and difficult. They should be removed by sanding or by use of an adhesive remover. Rinse the wall and allow it to dry. If the wall shows any signs of existing mold, it should be washed with a water/detergent solution, rinsed with a water/household bleach solution and then allowed to dry as described in Section 3.1, Cleaning, Removing Building Materials. As noted, if the area in question is larger than 10 sq. ft., then proper removal protocols should be followed. Repair the wall as necessary, and prime with a good quality wallcovering primer.

Wallcoverings can then be reinstalled using conventional methods and the recommendations noted above under New Drywall. Since, the dry-wall may have been wet, the surface may have a greater tendency to peel or release some of the paper when a double cut is made. Dry hanging, cutting the seam shortly after the wallcoverings has been applied to the wall or both seem to help with this problem. In addition, a thin coating of adhesive in the peeled area seems to provide satisfactory results.<sup>56</sup>

***PANELING.*** Sand or chemically remove all surface contaminants. Follow this step with a good quality adhesion promoting primer. Grooves should be filled then primed and/or an appropriate wall liner should be used. Most wallcoverings will require additional priming of the wall liner before installation. See wall liner instructions for priming, installation and adhesive recommendations.<sup>17</sup>

Specific installation instructions for any type of surface may be obtained from the wallcoverings manufacturer.

#### **4.4. Good Practices - Keep Materials and Work Area Clean**

Keeping the work area and the wallcoverings clean is vitally important for preventing mold growth. For example, the water used to install wallcoverings should be potable water; that is, water that is clean enough to drink. Only water that is brought onsite by installers or obtained from a secure source should be used.

Bringing water onsite or obtaining it from a secure source may at first blush appear to be very demanding; however, invisible fungi and bacteria are everywhere. As described in Section 1.2, Overview of Mold in Building and Home Interiors, and Section 1.4, Mold, Mildew, Fungi – What’s the Difference?, mold can grow and multiply in moist and warm environments that provide organic nutrients.

Because spores are invisible, installers should take extra precautions to avoid using contaminated tools, water or materials. Even experienced installers have been known to keep water contaminated with traces of adhesive from application rollers that have been soaking overnight or even over a weekend. This contaminated water becomes a good culture broth and a warm room becomes an incubator. Application rollers can become grossly contaminated, and if these rollers are used, or if contaminated water is used to dilute adhesives, problems may occur.

In most jobs, being unaware of potential problems with the wall or wall surface or being careless will not cause damage to the wall from mold growth since the adhesive dries quickly. The same handling, however, will contribute to problems with

walls that do not allow water or moisture to dissipate and with wall surfaces that prevent fast drying of adhesives. The difference is the walls' ability to absorb and retain moisture (see Section 1.2, Overview of Mold in Building and Home Interiors, and Section 4.3 Proper Surface Preparation). Any source of excess moisture should be corrected before installing or re-installing wallcoverings (see Section 4.1, Eliminate Sources of Moisture).

The following suggestions will minimize or eliminate problems:

- Remove any old wallcovering and any residual adhesive. Wash any areas with visible mold with a water and detergent solution. Wash again with a water/household bleach solution. See Section 3.1, Cleaning, Removing Building Materials, for details and wall surface limitations. Allow the washed wall to dry. Before installing the wallcovering, the wall surface should be dry, free of grease, staining markers and mold. Also, the wall should be structurally sound with no excessive moisture or condensation.
- If any wall area is not dry or structurally sound for installation, then do not install the wallcovering. Alert the drywall contractor, general contractor, building owner or homeowner as appropriate, and wait until the problems in the area have been corrected before either starting or continuing with the wallcovering installation.
- Any dark stained areas should be treated with a stain killing/blocking primer to prevent stains from coming through the wallcovering at a later time.
- Use a primer with a biocide. Follow the manufacturer's instructions for application. Note that some manufacturers require two coats of a primer for mold protection.
- Apply the primer from factory-sealed containers, and use new rollers and trays.
- Use a good quality wallcovering adhesive that contains biocides.
- Apply the adhesive from factory-sealed containers, and use new rollers. Alternatively, a pasting machine may be used instead of rollers.
- Do not soak rollers in water. Leave the rollers in the primer or adhesive or use a new roller each day.
- Use new sponges. Wash them completely in running water and leave them to dry overnight.
- Change the wash water frequently to limit possible contamination.
- Use dry sponges and clean, dry pails for fresh water each morning. (Caution: Bleach may cause natural sponges to deteriorate).
- Paper expands when it is immersed in water. Consequently, residential paper-backed products require booking; that is, folding the wallcovering such that wet side is against wet side, in order to allow the paper to expand and reach a steady state. If the wallcovering is not allowed to expand then seam overlapping will occur. The best way to determine if a wallcovering should be booked, or not, is to follow the installation instructions.
- Use the minimum quantity of adhesive that can do the job. Do not book non-woven and fabric-backed products, unless stated otherwise in the manufacturers directions, and leave the pasted wallcoverings open to evaporate water. Since mold can grow on the wet adhesive, the less adhesive and water on the wallcovering and the faster it dries, the better.
- Pasting the wall with adhesive for vinyl wallcovering and non-wovens may be an option. Pasting the wall for paper products is not recommended.
- Pasting machines are routinely left "loaded" overnight. Ideally, they should be cleaned at the end of the workday to limit contamination or spoilage, especially if there is a high risk for contamination at the installation site.

## 4.5. Design and Build It Right in the First Place

The focus of this publication 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 homes and buildings. Going forward, the ultimate prevention of mold contamination is to design and build homes and buildings right in the first place.

As emphasized through this publication, controlling moisture is the key to preventing mold problems. The key to controlling moisture is understanding how building systems interact, and designing and constructing homes and buildings to utilize 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.

Looking at why homes and buildings fail may prove useful in determining what is required to design and build a successful building. Failures can be attributed to following three factors:

- Building and home owners' unrealistic expectations of success and reliance on the contracting process and building codes to protect their buildings from failure. In addition, many building designers and contractors believe that following established building codes and using strategies they have used before is enough to guarantee success.
- Complexity of the building construction process and the failure of the design and construction team to recognize the interrelationships between various technical disciplines.

***Buildings and homes, especially in hot and humid climates, fail because satisfying building codes alone does not ensure that the combination of design features selected for a particular structure and past strategies work together to prevent moisture and mold problems. Often more design features than are specified in building codes and new strategies are needed.***

- Contradiction among fundamental forces, such as cost, schedule and quality, which influences decision makers throughout the design and construction process. During the design phase, cost is typically the biggest concern. Very often, the design team has little or no input into developing the budget, yet the team may be contractually obligated to redesign the project at the team members' expense if their design exceeds the construction budget. During the construction phase, the primary concern is scheduling, since controlling the schedule is directly linked to controlling the project's final cost. The general contractor is often contractually obligated to finish a project by a specific date or face assessment of damages. Only at the punch list phase does quality become a consideration and by then changes become too costly or require too much time to complete. Consequently, problems may not be corrected.<sup>5</sup>

To be successful, the building and home owner and all members of the design and building team, including interior designers, drywall contractors and wallcovering installers, must be aware of these factors and work together to mitigate them, by being involved in the planning, design, construction, finishing and commissioning of the building. David Odom and his colleagues at CH2M Hill and Disney Development Company developed a model to address and resolve indoor air quality problems at each project stage, which can be summarized as follows:

- Establish specific design and construction guidelines at project inception.
- Use periodic peer reviews throughout the design and construction process to compare results against original construction guidelines.
- Implement proper startup technique for the HVAC system to verify correct operation of the building before it is occupied.<sup>7</sup>

**DESIGN.** Regardless of what some design and building professionals might say, design practices and principles are not the same for all parts of the U.S. For example, when design principles that are appropriate for a mixed climate are applied to a building in a hot, humid climate, the results can be disastrous. A case in point is the HVAC system. Good design practice dictates providing certain levels of outside air into occupied spaces based largely on occupant density and space usage. However, in hot and humid climates, the highest priority is to maintain proper humidity at all times both during occupied and unoccupied periods.<sup>7</sup> The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) in its *Handbook Fundamentals* cautions that different climates

present different problems, and buildings should be designed and operated accordingly.<sup>73</sup>

During the design phase, the architect, the interior designer, the drywall contractor and the mechanical engineer should collaborate closely to identify and address critical design issues that will impact not only energy usage but also control of moisture intrusion and humidity within the building, especially within the wall systems. Issues such as exterior and interior wall finish permeability, vapor retarder (if used) type and location, air barrier type and location, and weather barrier type and location must be balanced with the method of maintaining positive building pressurization, conditioning and controls for the interior space, ventilation methods, and the effects of energy management systems.<sup>7</sup>

Appendix C, NIST Personal Computer Model (MOIST), describes a computer model developed by the National Institute of Standards and Technology (NIST) for predicting the moisture content of the various construction materials as a function of time. In this model, the type and placement of building materials can be varied. It also can be used to evaluate the effect of various paints and wallcoverings on moisture accumulation. By comparing predicted results with and without a vapor barrier, the model can be used to determine whether a vapor retarder is needed and, if so, where it should be placed. In addition, the model allows users to electronically “move” a wall or ceiling to different U.S. and Canadian cities to investigate the effect of climate on moisture accumulation. Hourly weather data for six U.S. cities are provided with the model. Weather data for 40 other U.S. and five Canadian cities are available from ASHRAE.

**CONSTRUCTION.** The critical elements during the construction phase are sequencing of construction and quality of assembly. Building materials and components that are susceptible to water and moisture damage must be protected from the weather during transport to the job site, while waiting installation and after installation. In addition, a preconstruction conference should be held between the general contractor, supervisors and subcontractors to ensure everyone is clear and to address any scheduling issues, such as installing

the drywall and wallcoverings prior to the building being dried in, while cement or sprayed on fire proofing in other parts of the building are still curing/drying, and/or before the water piping has been tested.

Also critical is the quality of construction or assembly building components. Many quality-related issues can be dealt with through open communication through interactive, informed and cooperative inspections.<sup>74</sup>

# Appendix A. List of Guidelines and Resources for Assessment and Remediation of Mold Contamination

<i>Organization</i>	<i>Title or Resource</i>	<i>Web Site</i>
American Conference of Governmental Industrial Hygienists.	Bioaerosols Assessment and Control	<a href="http://www.acgih.org">www.acgih.org</a>
American Industrial Hygiene Association	Report of the Microbial Growth Taskforce	<a href="http://www.aiha.org">www.aiha.org</a>
American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) ANSI/ASHRAE	Standard 62-2001, Ventilation for Acceptable Indoor Air Quality	<a href="http://www.ashrae.org">www.ashrae.org</a>
California Department of Health Services	California Indoor Air Quality Program Information Sheets and Links	<a href="http://www.cal-iaq.org/iaqsheets.htm">www.cal-iaq.org/iaqsheets.htm</a>
California Research Bureau Reports	Molds, Toxic Molds and Indoor Air Quality	<a href="http://www.library.ca.gov/crb/01/notes/v8n1.pdf">www.library.ca.gov/crb/01/notes/v8n1.pdf</a>
Health Canada	Indoor Air Quality in Office Buildings: A Technical Guide	<a href="http://www.hc-sc.gcca/ehp/ehd/catalogue/bch_pubs/93ehd166.htm">www.hc-sc.gcca/ehp/ehd/catalogue/bch_pubs/93ehd166.htm</a>
Indoor Air Quality Association	Mold Resources and Links	<a href="http://www.iaqa.com/mold_resources.htm">www.iaqa.com/mold_resources.htm</a>
Indoor Environmental Standards Organization	Standards of Practice for the Assessment of Indoor Environmental Quality, Volume I: Mold Sampling and Assessment of Mold Contamination	<a href="http://www.iestandards.org">www.iestandards.org</a>
International Society of Indoor Air Quality and Climate	Control of Moisture Problems Affecting Biological Indoor Air Quality. ISIAQ Guideline TFI-1996	<a href="http://www.ie.dtu.dk/isiaq">www.ie.dtu.dk/isiaq</a>
International Society of Indoor Air Quality and Climate	Guidelines for IAQ in Schools (task force)	<a href="http://www.isiaq.org">www.isiaq.org</a>
Minnesota Department of Health	Indoor Mold: Health Hazard Identification and Control	<a href="http://www.health.state.mn.us/divs/eh/indoorair/mold/hazardid.html">www.health.state.mn.us/divs/eh/indoorair/mold/hazardid.html</a>
National Institute of Science and Technology	A Computer Analysis of Wall Construction in the Moisture Control Handbook	<a href="http://fire.nist.gov/bfrlpubs/build95/PDF/b95011.pdf">http://fire.nist.gov/bfrlpubs/build95/PDF/b95011.pdf</a>

<i>Organization</i>	<i>Title or Resource</i>	<i>Web Site</i>
New York City Department of Health	Guidelines on Assessment and Remediation of Fungi in Indoor Environments	<a href="http://nycdoitt.ci.nyc.ny.us/html/doh/html/epi/moldrpt1.html">nycdoitt.ci.nyc.ny.us/html/doh/html/epi/moldrpt1.html</a>
Sheet Metal and Air-Conditioning Contractors National Association (SMACNA)	Duct Cleanliness for New Construction Guidelines	<a href="http://www.smacna.org">www.smacna.org</a>
University of Minnesota, Department of Environmental Health and Safety	Fungi in Buildings  Fungal Abatement Safe Operating Procedure  Managing Water Infiltration Into Buildings	<a href="http://www.dehs.umn.edu/iaq/fungus/">www.dehs.umn.edu/iaq/fungus/</a>  <a href="http://www.dehs.umn.edu/iaq/sop.html">www.dehs.umn.edu/iaq/sop.html</a>  <a href="http://www.dehs.umn.edu/iaq/flood.html">www.dehs.umn.edu/iaq/flood.html</a>
US Centers for Disease Control and Prevention	Molds in the Environment  Questions and Answers About <i>Stachybotrys chartarum</i> and other molds	<a href="http://www.cdc.gov/nceh/airpollution/mold/moldfacts.htm">www.cdc.gov/nceh/airpollution/mold/moldfacts.htm</a>  <a href="http://www.cdc.gov/nceh/airpollution/mold/stachy.htm">www.cdc.gov/nceh/airpollution/mold/stachy.htm</a>
US Environmental Protection Agency	Indoor Air Quality Tools for Schools  Building Air Quality Handbook  Mold Remediation in Schools and Commercial Buildings  Mold Resources	<a href="http://www.epa.gov/iaq/schools/tools4s2.html">www.epa.gov/iaq/schools/tools4s2.html</a>  <a href="http://www.epa.gov/iaq/iaqinfo.html">www.epa.gov/iaq/iaqinfo.html</a>  <a href="http://www.epa.gov/iaq/pubs/moldresources.html">www.epa.gov/iaq/pubs/moldresources.html</a>
Washington State Department of Health	Got Mold? Frequently Asked Questions  Is Indoor Mold Contamination a Threat to Health?	<a href="http://www.doh.wa.gov/ehp/ts/IAQ/Got_Mold.html">www.doh.wa.gov/ehp/ts/IAQ/Got_Mold.html</a>  <a href="http://www.doh.wa.gov/ehp/oehas/mold.html">www.doh.wa.gov/ehp/oehas/mold.html</a>

## Appendix B. Description of Wallcoverings

Commercial wallcoverings are produced in a wide variety of designs specifically for use in homes, hotels, apartment buildings, office buildings, schools and hospitals. They are manufactured to meet or surpass minimum physical and performance characteristics as set forth in federal guidelines such as Federal Specification CCC-W408-D. Residential wallcoverings meet or surpass specification set forth in ASTM F793. The guidelines contain requirements for flammability, tear strength, abrasion resistance, washability, scrubability and stain resistance. Following these product descriptions is a chart (Table B-1) that lists wallcovering product specifications for both commercial and residential wallcoverings. It is a composite of specifications found in the CFFA-W-101-D and ASTM F793 documents.

**VINYL WALLCOVERINGS.** Vinyl wallcoverings consist of one or more layers of vinyl plastic with a polyester, polyester-and-cotton blend woven fabric, non-woven fabric or paper backing. There are several categories of vinyl wallcoverings, each with specific performance characteristics:

- **Vinyl coated paper** (residential wallcovering) has a paper substrate on which the decorative surface has been sprayed or coated with an acrylic type vinyl or polyvinyl chloride (PVC). Although more resistant to grease and moisture than plain paper and suited for residential kitchens and bathrooms, it does not resist excessive or prolonged exposure to grease, moisture or abuse. Thus, it is not suitable for commercial applications.
- **Paper backed vinyl/solid sheet vinyl (PBV)** (residential and commercial wallcovering) has a paper (pulp) substrate laminated to a solid decorative surface. This type of wallcovering is very durable as the decorative surface is a solid sheet of vinyl. It is classified as scrub-
- **Fabric backed vinyl (FBV)** (residential and commercial wallcovering) features a solid vinyl intermediate layer that is laminated to woven or non-woven fabric substrate. The vinyl layer can vary from 2 mils to 35 mils in thickness. The woven fabric substrate may be either a scrim fabric with a weight range of 0.75 oz. per sq. yd. up to 1.3 oz. per sq. yd. for Type I or an osnaburg fabric with a weight range of 1.75 oz. per sq. yd. to 2.6 oz. per sq. yd. for Type II. Non-woven fabric may vary in weight from 1.5 oz. per sq. yd. to 3.0 oz per sq. yd. Lighter weight fabric is typically used for Type I and a higher weight for Type II. Type I (light duty commercial or heavy duty residential) can be used in homes, offices, hospital patient rooms and hotel rooms, and Type II (medium duty) can be for used in all other areas including foyers, lounges, corridors and classrooms. Typically, commercial vinyl wallcovering must meet the specification for wallcovering as stated in one of the wallcovering specification documents: Federal Specification *Wallcovering, Vinyl Coated* CCC-408 A-D, ASTM Designation F 793-93, *Standard Classification of Wallcovering By Durability Characteristic*; or CFFA-W-101-D, *CFFA Quality Standard for Vinyl Coated Fabric Wallcovering*. See the chart following these descriptions for a more complete breakdown of properties and construction of commercial wallcoverings.
- **Rigid vinyl sheet** (commercial wallcovering) is a solid sheet wallcovering that is used in commercial applications where there is a potential for high-impact damage. This type of wallcovering does not usually have a backing and is installed with special contact adhesive.

**NON-VINYL WALLCOVERINGS.** The following are examples of wallcoverings that are not made with vinyl. All of these wallcoverings can be used as residential or as commercial wallcovering.

- **String effects** have very fine vertical threads laminated to a paper substrate.
- **Natural textiles** are usually laminated to a backing to enhance dimensional stability and to prevent the adhesive from coming through to the surface. These backings are usually acrylic or paper. Textiles are constructed of natural fibers and can be finely designed or coarse, depending on the desired look.
- **Polyolefin/synthetic textiles** are woven and non-woven and were developed to give the aesthetic appearance of a natural textile while adding an increased value in stain and abrasion resistance. Many are comprised of polyolefin yarns, which are made from polymers and copolymers of propylene. These products generally have an acrylic or paper backing.
- **Heavy weight paper and saturated paper** may be used in commercial applications. Heavy weight saturated paper may have the same weight and physical strength of some vinyl wallcoverings. Heavy weight paper also may have the appearance of a heavy weight liner paper but the surface can be decorated. Products consist of wood pulp and varying amounts of latex depending on the manufacturer of the product.
- **Non-woven wallcoverings** are typically made from cellulose and polyester blends along with latex binders. There is a large variation in weight, decoration, permeability, performance, functionality and composition of various non-woven products. Non-woven wallcoverings can be used in many of the same areas as residential and commercial wallcoverings.
- **Acoustical wallcoverings** are used on vertical surfaces, panels, operable walls and any place sound reduction is a primary factor such as

meeting rooms, offices, theaters, auditoriums, restaurants, corridors and elevator lobbies.

They are predominately made of man-made polyester and olefin fibers and are tested for special sound absorption rating known as a noise reduction coefficient (NCR) rating. The higher the number, the more noise absorption.

- **Cork and cork veneer** have variegated texture with no definite pattern or design. Cork veneer is shaved from cork planks or blocks and laminated to a substrate that may be colored or plain.
- **Wood veneer wallcoverings** are mostly laminated to fabric backings. Due to environmental and grain matching issues, wood veneers are used primarily in offices or conference rooms and other specialty areas such as large columns.
- **Underliner** is a blank stock-type wallcovering that can be used on almost any wall surface, such as plaster, drywall, paneling and cinder block, to provide a smooth surface for installing wallcoverings. It comes in light, medium or heavy weights, and it can be plain paper stock or a non-woven material.
- **Fiberglass wallcoverings** may have a variety of woven appearances. The product is typically installed as a white wallcovering. The surface is painted to achieve the final desired color. Fiberglass wallcoverings are sold in different weight and textures. This product has good permeability and a natural fire resistance.

**Adapted from *Introduction to Commercial Wallcoverings, Wallcoverings Association, July 1999.***

**Table B-1. Wallcovering Characteristics vs. CFFA, ASTM and Federal Specifications**

Substrates	Natural Kraft, Natural Cork	Residential Groundwood, Residential No. 1 Wallcovering Hanging Stock, Residential Wet Laid Two Ply Peelable Paper, Residential Duplex	All Bleached Cellulosic Wet Strength Strippables, Solid Vinyls (Plastisol Coated Groundwood w/wo a top coat), Blown Vinyls on Two Ply Hanging Stock	Residential and Commercial 10-19.5 oz./lin. yd. Calendared or Extruded Vinyl on Sheetting or Nonwoven Fabric, Patent Finished PVC on Woven or Nonwoven Fabric, Metallized PET Laminated to PVC Coated Nonwoven Fabric	Commercial 19.6-32 oz./lin. yd. Calendared Vinyl on nonwoven or Osnaburg Woven Fabric	Commercial 33-and-up oz./lin. yd Calendared Vinyl on Heavy Osnaburg or Broken Twill Woven Fabric
	Category I per ASTM F793	Category II per ASTM F793	Category III per ASTM F793	Category IV per ASTM F793	Category V per ASTM F793	Category VI per ASTM F793
Commercial Classification				Type I by CCC-W-408D Type I by CFFA-W-101D	Type II by CCC-W-408D Type II by CFFA-W-101D	Type III by CCC-W-408D Type III by CFFA-W-101D
Serviceability	Decorative only	Decorative with medium serviceability	Decorative with high serviceability	Decorative with commercial serviceability	Medium commercial serviceability	High commercial serviceability
Colorfastness (hours)		23	46	200	200	200
Washability (cycles)		100	100	100	100	100
Scrubbability (cycles)			50	200	300	500
Abrasion Resistancy (cycles)				200	300	1000
Breaking Strength (lbs. of force) (MD x CMD)				40 x 30	50 x 55	100 x 95
Crock Resistance (cycles)			Good	Good	Good	Good
Stain Resistance			Good - Reagents 1-9	Good - Reagents 1-9	Good - Reagents 1-12	Good - Reagents 1-12
Tear Resistance (scale reading) (MD x CMD)				12 x 12	25 x 25	50 x 50
Block Resistance (point scale)				2	2	2
Coating Adhesion (lbs. of force per 1" strip)				2	3	3
Cold Cracking Resistance				No change	No change	No change
Heat Aging Resistance				Pass	Pass	Pass
Flame Spread (maximum)		25	25	25	25	25
Smoke Development (maximum)		50	50	50	50	50
<b>Shrinkage (% maximum)</b>						
MD Machine Direction				2	2	2
CMD Cross Machine Direction				1	1	1.5
Mold Resistance by ASTM G21 ASTM F793			rating 0 or 1	rating 0 or 1	rating 0 or 1	rating 0 or 1
Minimum Weight per CFFA (oz per linear 54" wide yard)				10.5	19.5	33

## Appendix C. MOIST Personal Computer Model

The body of this publication references a more conservative wall surface relative humidity of 70 percent or higher for the onset of mold growth in the wall cavity.<sup>60</sup> The National Institute of Standards and Technology (NIST), however, has developed a personal computer model, called MOIST, for predicting the transient moisture and heat transfer within building envelopes that shows that the onset of mold growth may not begin within the wall cavity until wall surface relative humidity reaches 80 percent.<sup>75</sup> A description of the MOIST model and the results of analyses using MOIST are offered here for interested readers.

The computer model permits users to easily define a wall or ceiling and predict the moisture content of the various construction materials as a function of time. The type and placement of building materials can be varied. By comparing predicted results with and without a vapor barrier, the model can be used to determine whether a vapor retarder is needed and, if so, where it should be placed. It also can be used to evaluate the effect of various paints and wallcoverings on moisture accumulation. In addition, the model allows users to electronically “move” a wall or ceiling to different U.S. and Canadian cities to investigate the effect of climate on moisture accumulation. Hourly weather data for six U.S. cities are provided with the model. Weather data for forty other U.S. and five Canadian cities are available from the American Society of Heating, Refrigerating and Air-Conditioning Engineers in Atlanta, Georgia. The Society’s website is [www.ashrae.org](http://www.ashrae.org).<sup>75</sup>

The results of comprehensive laboratory experiments verified the accuracy of the MOIST computer model in the hygroscopic regime. Three different multilayer wall specimens were installed in a calibrated hot box. The exterior surfaces of the wall specimens were first exposed to both steady

and time-dependent winter conditions, while their interior surfaces were maintained at 70 degrees F (21.1 degrees C) and 50 percent relative humidity. These boundary conditions caused moisture from the interior environment to permeate into the wall specimens and accumulate in their exterior construction materials. Subsequently, when the exterior air temperature was elevated to 90 degrees F (32.2 degrees C), the exterior construction materials lost moisture to the interior environment.<sup>75</sup>

The moisture content within the exterior construction materials and the heat transfer rate at the inside surface of the wall specimens were measured and compared with MOIST predictions. The moisture and heat transfer properties for the construction materials comprising the wall specimens were independently measured and used as input to the MOIST computer model. The agreement between predicted and measured moisture contents was within 1.1 percent moisture content.<sup>76</sup>

For the cooling climate (Southeastern United States), one wall that was tested had risk of mold and mildew growth behind an interior vapor retarder, which was cooled by the indoor air conditioning. During the summer, moisture from the outdoor environment permeated inwardly through this construction and accumulated at the interior vapor retarder, and the surface relative humidity approached and rose above the critical 80 percent level for mold and mildew growth.<sup>75</sup>

Several of the walls for a cooling climate contained an exterior vapor retarder, which decreased moisture transfer to the interior construction layers. The relative humidity behind interior vapor retarders was decreased below 80 percent. However, during the winter, moisture from the indoor environment permeated outwardly through the wall construction and accumulated at exterior vapor retarders where the relative humidity rose above 80 percent.<sup>75</sup>

For a cooling climate, the MOIST model was used to find another good performing wall construction. A permeable wall (without vapor retarding layers and low-permeability materials) was found to perform satisfactorily. During both winter and summer periods, moisture passed through the wall construction and did not significantly accumulate within the construction layers. The analysis presented in this report was limited in that it did not include moisture transfer by air movement and it did not include cyclical rain wetting. Figures C-2 and C-4 illustrate condensation temperature in individual layers of the wall construction.<sup>75</sup>

The results of analysis for walls with vinyl wallcoverings show acceptable performance year-round for heating and mixed climates. In the humid climates during the winter, there is a problem of condensation if an impermeable membrane or non-permeable wallcovering is installed on the interior surface of the exterior walls. Other than in hot and humid and fringe climates, the results of the MOIST computer model of wall construction demonstrate that non-permeable vinyl wallcovering show acceptable performance year-round when used on interior surfaces of exterior walls.<sup>13</sup>

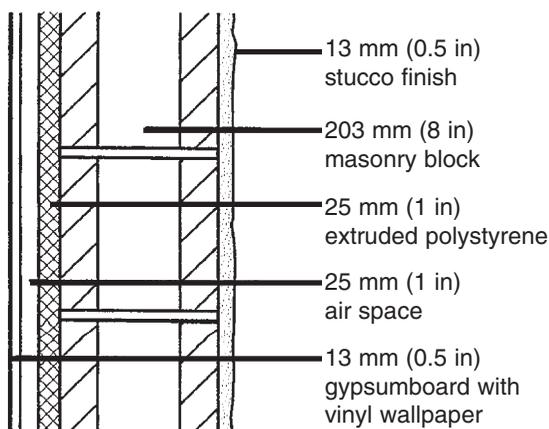


Figure C-1. A non-permeable wall in a cooling climate.

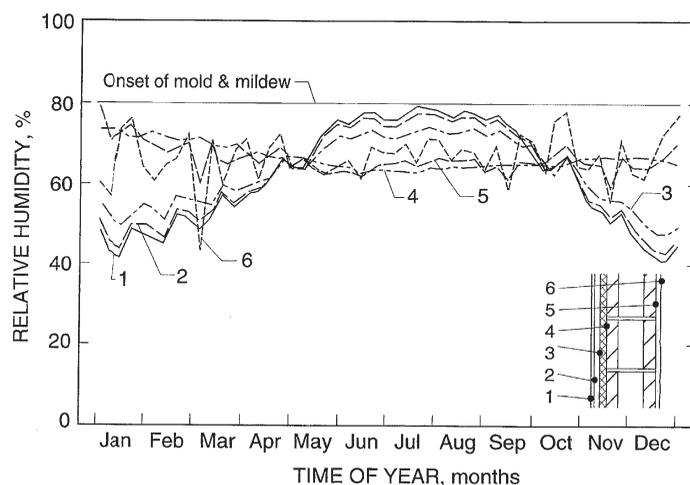
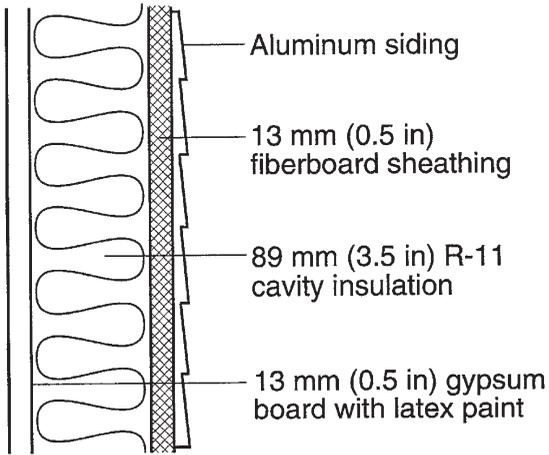
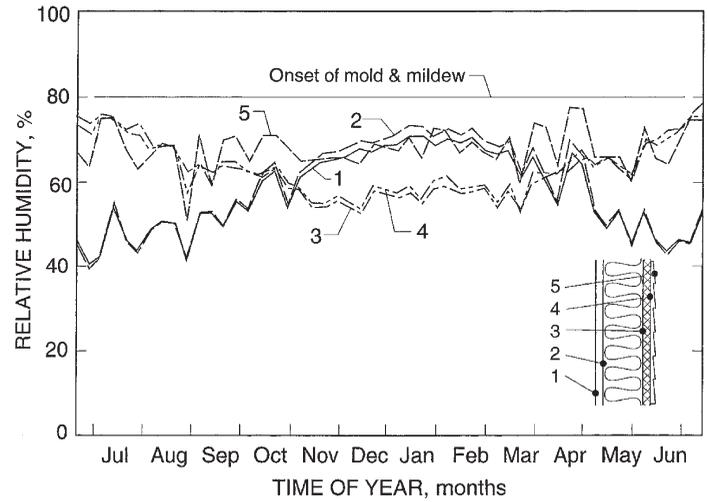


Figure C-2. Relative humidity at layer surfaces versus time of year for Figure C-1 of cooling climate (indoor relative humidity of 50 percent).



**Figure C-3.** A permeable wall for cooling climate.



**Figure C-4.** Computer simulation of permeable wall construction for a cooling climate.

# Appendix D. Standard Test Method and Calculation of Permeability as Prescribed in ASTM E 96-95, Standard Test Methods for Water Vapor Transmission of Materials\*

This test measures the transmission of water vapor through samples of materials less than 1 1/4 in thick. The test can be run in two very different configurations that help to characterize the sample in distinctly different environments. In one method, Wet Cup, water is placed in the cup and water vapor lost through the membrane is measured. The other method, Dry Cup, has a desiccant placed in the cup that pulls moisture from any water vapor that passes through the membrane. Because of the different driving force, values measured by different methods are not expected to agree or to correlate. The test method selected for the measurement should be selected as closest to the conditions the material is expected to experience in field service.

## *Definition of Terms*

- Water vapor permeability – the time rate of water vapor transmission through a unit area of flat of unit thickness induced by a unit vapor pressure difference between two specific surfaces, under specified temperature and humidity conditions.
- Water vapor permeance – the time rate of water vapor transmission through a unit area of flat material or construction induced by a unit vapor pressure difference between two specific surfaces, under specified temperature and humidity conditions.
- Water vapor transmission rate – the steady water vapor flow in unit time through unit area

of a body, normal to specific parallel surfaces, under specified temperature and humidity conditions at each surface.

## *Sample Limitation and Characterization*

- Sample components that react with water, such as water-activated prepaste, must be eliminated before testing.
- Embossed samples must be measured for thickness in the center of the exposure area to the nearest 1/1,000 inch.
- Embossed samples overall thickness shall be at least five times the sum of the maximum pit depth and its tested permeance shall not be greater than 5 perms.
- Because time to reach equilibrium varies as the square of the thickness, thicker products will be tested until they reach a constant rate that may take 60 days.

## *Calculation*

By weighing the sample and plotting the loss the moisture vapor transmission rate (mvt) can be determined by drawing a straight line with at least six point and determining the line's slope as the sample's mvt. This evaluation requires experience to draw the correct line and is best conducted by laboratory people who routinely run this test.

**The test can be run in two very different configurations — dry cup or wet cup — that can help characterize the sample in distinctly different environments.**

### Water Vapor Transmission

$$WVT = G/tA = (G/t)/A$$

Where:

In inch-pound units:

- G = weight change, grains (from the straight line)
- t = time during which G occurred, h
- G/t = slope of the straight line, grains/h
- A = test area (cup mouth area), ft<sup>2</sup>
- WVT = rate of water vapor transmission, grains/h-ft<sup>2</sup>

In metric units:

- G = weight change (from the straight line), g
- t = time, h,
- G/t = slope of the straight line, g/h,
- A = test area (cup mouth area), m<sup>2</sup>, and
- WVT = rate of water vapor transmission, g/h-m<sup>2</sup>

### Permeance

$$\text{Permeance} = WVT/\Delta p = WVT/S(R_1 - R_2)$$

Where:

In inch-pound units:

- $\Delta p$  = vapor pressure difference, in. Hg
- S = saturation vapor pressure at test temperature, in. Hg.
- R<sub>1</sub> = relative humidity at the source expressed as a fraction (the test chamber for desiccant method; in the dish for water method), and
- R<sub>2</sub> = relative humidity at the vapor sink expressed as a fraction

In metric units:

- $\Delta p$  = vapor pressure difference, mm Hg (1.333 X 10<sup>2</sup> Pa)
- S = saturation vapor pressure at test temperature, mm Hg (1.333 X 10<sup>2</sup> Pa)
- R<sub>1</sub> = relative humidity at the source expressed as a fraction (the test chamber for desiccant method; in the dish for water method)
- R<sub>2</sub> = relative humidity at the vapor sink expressed as a fraction

Example – In a desiccant test that ran 288 hours (12 days) on an exposed area of 100 in.<sup>2</sup> (0.0645 m<sup>2</sup>), it was found that the rate of gain was substantially constant after 48 h and during the subsequent 240 h, the weight gain was 12 g. The controlled chamber conditions were measured at 89.0 degrees F (31.7 degrees C) and 49 percent relative humidity.

Required: WVT and permeance

Calculation (inch-pound units):

$$G/t = 12 \text{ g} \times \frac{15.43 \text{ grains}}{\text{g}} \div 240 \text{ h} = 0.771 \text{ grains/h}$$

$$A = 100 \text{ in.}^2 \times \frac{1 \text{ ft}^2}{144 \text{ in.}^2} = 0.695 \text{ ft}^2,$$

$$S = 1.378 \text{ in. Hg (from standard references tables),}$$

$$R_1 = 49\% \text{ (in chamber)}$$

$$R_2 = 0\% \text{ (vapor sink), and}$$

$$WVT = 0.771 \text{ grains/h} \div 0.694 \text{ ft}^2 = 1.11 \text{ grains/ft}^2 \text{ h.}$$

$$\text{Permeance} = WVT/\Delta P = WVT/S (R_1 - R_2)$$

$$= 1.11 \text{ grains/ft}^2 \text{ h} \div 1.378 \text{ in. Hg (0.49 - 0)}$$

$$= 1.64 \text{ grains/ft}^2 \text{ h in. Hg} = 1.64 \text{ perms}$$

Calculation (metric units):

$$G/t = 12 \text{ g}/240 \text{ h} = 0.05 \text{ g/h,}$$

$$A = 0.0645 \text{ m}^2,$$

$$S = 35 \text{ mm Hg (from reference tables),}$$

$$= 35 \text{ mm Hg} \times 1.333 \times 10^2 \text{ Pa/mm Hg} = 46.66 \times 10^2 \text{ Pa,}$$

$$R_1 = 49\% \text{ (in chamber),}$$

$$R_2 = 0\% \text{ (vapor sink), and}$$

$$WVT = 0.05 \text{ g/h} \div 0.0645 \text{ m}^2 = 0.775 \text{ g/h} \cdot \text{m}^2$$

$$\text{Permeance} = WVT/\Delta P - WVT/S (R_1 - R_2)$$

$$= 0.775 \text{ g/h m}^2 \times 1 \text{ h}/3600\text{s} \div 46.66 \times 10^2 \text{ Pa} \times (0.49 - 0)$$

$$= 9.42 \times 10^{-8} \text{ g/Pa} \cdot \text{s} \cdot \text{m}^2$$

\* "Adapted, with permission, from E 96-95 - Standard Test Methods for Water Vapor Transmission of Materials", copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from the ASTM, phone: 610-832-9585, fax: 610-832-9555, e-mail: service@astm.org, website: www.astm.org .

## Appendix E. Frequently Asked Questions

*What are mold and mildew and where are they found?*

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. Mold is EVERYWHERE, both in the indoor and outdoor environments. Many species of mold are essential to every day life and are beneficial to health, although there are a few species that can be destructive to building materials and may cause some adverse health effects. See Section 1.4, Mold, Mildew, Fungi – What’s the Difference; Section 1.5, Different Types of Indoor Mold; and Section 1.6, Are Molds Really Toxic?, for more information.

*How can I be exposed to mold and mildew?*

Everyone is exposed to mold and mildew every day, as they are EVERYWHERE, both in the indoor and outdoor environments. When a moldy material becomes damaged or disturbed, spores and parts of the mold colony called, hyphae, can be released into the air. Exposure can occur if airborne spores are inhaled. Exposure also can occur if moldy materials are directly handled without proper protection. See Section 1.4, Mold, Mildew, Fungi – What’s the Difference, and Section 3.2, Specific Personal Protection and Containment Guidelines, for more information.

*What are mold spores?*

Mold spores are like seeds. When they germinate they form hyphae, which is the primary component of a mold colony. Spore and hyphae can break free from the colony and travel to another area and start a new colony. Spores may travel in several ways, including being passively moved by a breeze or water drop, mechanically disturbed by

a person or animal passing by, or actively discharged by the mold, usually under moist conditions or high humidity. Although they are always microscopic, spores contain one to many cells and differ greatly in size, shape, color and method of formation. Mold spores can survive for many years in dry or hot environments, requiring only moisture, the right temperature and an available food source in order to start growing. See Section 1.4, Mold, Mildew, Fungi – What’s the Difference, for more information.

*What are mycotoxins?*

Some species of mold produce substances called mycotoxins, some of which may be poisonous to humans and animals. Mycotoxin production for a given species depends a lot on growth conditions, such the availability of food, the right temperature and enough moisture. 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. See Section 1.6, Are Molds Really Toxic?, for more information.

*What does permeability mean?*

Permeability is a measure of the amount of air or water vapor that can pass through a membrane in a certain amount time. It is usually measured in the number of grams that can pass through a membrane in a 24-hour period. Because residential wallcoverings do not need to be as strong or durable as commercial wallcoverings, their structure tends to be more permeable than commercial wallcoverings. At this time, however, there are no standard industry permeability ratings for wallcoverings and many product labels do not contain ratings of this sort. This publication provides estimates of permeability ratings for wallcovering

materials. These values, along with the discussion in Section 1.3, Wallcoverings and Mold: A Function of Moisture Levels and Permeability, offer a helpful comparison with other building materials.

*How can I get rid of mold or mildew in a home or building?*

The most effective solution is to eliminate all sources of unwanted moisture within the home or building. There are primarily four sources of moisture, including: building tightness, which does not allow moisture to escape to the outdoors; liquid water infiltration from outside as a result of a leaky building envelope or structural failure; moisture condensation on cold surfaces, which originates from water vapor inside or outside the building; and moisture generated within the building by the occupant and the occupant's activity such as operating showers without bathroom ventilation to the exterior, cooking without ventilation of steam to the exterior and drying clothes without venting the unit to the exterior. See Section 1.2, Overview of Mold in Building and Home Interiors, and Section 4.1, Eliminate Sources of Moisture, for more information.

*My home or office has a musty odor, but I do not see any signs of mold or mildew on the walls. Where does the odor come from?*

The odors are a byproduct of mold and mildew growth. Mold or mildew may be growing underneath the wallcovering or inside the wall cavity where you cannot see it. The odor may be entering the room through the electrical outlets. Mold also may be growing in the HVAC system or in a nearby area that is using the same HVAC system, with the odors entering the room through the air ducts. See Section 1.2, Overview of Mold in Building and Home Interiors, and Section 1.4,

Mold, Mildew, Fungi – What's the Difference, for more information.

*I removed some wallcovering in August and my walls were damp. I removed additional wallcovering in January and the walls were dry. I had about the same amount of mold in both places. What is going on?*

During the summer (cooling season), condensation can occur on the backside of wall, which causes the wallboard to be damp. During the winter (heating season), the wallboard tends to dry out as condensation (if any) may occur on the interior side of the building envelope rather than the backside of the wall itself. The temptation is to assume that moisture intrusion is no longer a problem and all that needs to be done is to clean up any visible mold. *Do not be fooled!* Evidence of mold is sufficient proof that at some point during the year there is enough moisture in the wall cavity for a long enough period of time to support mold growth. The source of that moisture must be found and corrected in order for any remediation efforts to be successful. See Section 1.2, Overview of Mold in Building and Home Interiors, and Section 4.1, Eliminate Sources of Moisture, for more information.

*If I bleach the walls after removing the wallcovering, have I killed all of the mold?*

If mold was present when the wallcovering was removed and even though the wall was thoroughly cleaned, if no effort was made to correct any moisture problems then the mold will probably return. Any moisture problem should be corrected before replacing the wallcovering. See Section 3.1, Cleaning, Removing Building Materials; Section 3.3, Verifying Successful Remediation; and Section 4.1, Eliminate Sources of Moisture, for more information.

*I found mold on a sidewall rather than an exterior wall. The moldy area was approximately 5 feet from the floor and 1 foot from the ceiling and about 4 feet from the sides of the wall. How can mold grow in the center of the wall without a water leak of some type?*

Likely, the HVAC system is blowing cool air onto a sidewall causing localized cooling of the wall surface. Moisture from the warm moist air in the wall cavity will condense on the cooled wall surface much like water droplets forming on a glass of ice water. The condensation can eventually saturate the wallboard, providing enough moisture for mold to grow. See Section 1.2, Overview of Mold in Building and Home Interiors, for more information.

*I have a large area of wallcovering with mildew. What should I do?*

If the area is larger than 10 sq. ft., contact an expert who can assess the problem, determine the source of moisture and recommend steps to eliminate the moisture and clean up the mold. Areas smaller than 10 sq. ft. can be cleaned or removed without the help of an expert. In any case, the source of the moisture must be found and fixed in order for any remediation effort to be successful. See all of Section 2, How to Tell If a Mold Problem Exists, for more information. Also, Appendix A, List of Guidelines and Resources for Assessment and Remediation of Fungal Contamination, features a list of additional resources for information about mold, assessment, remediation and removal.

*How do breathable wallcoverings keep my wall from growing mold?*

Breathable (or permeable) wallcoverings allow moisture to pass through the wallcovering surface or membrane. The HVAC system then removes the moisture from the air. As a result, insufficient moisture is present in the wall to allow mold to grow. Because residential wallcoverings do not need to be as strong or durable as commercial wallcoverings, their structure tends to be more permeable than commercial wallcoverings. See Section 1.2, Overview of Mold in Building and Home Interiors, and Section 1.3, Wallcoverings and Mold: A Function of Moisture Levels and Permeability, for more information.

*How can I tell whether a wallcovering is breathable (permeable) or not?*

Most wallcovering products do not contain permeability ratings on their labels. Contact your supplier or distributor to find out the permeability rating of a specific product. For more information, see Section 1.3, Wallcoverings and Mold: A Function of Moisture and Permeability.

*Can I blow air through a breathable (permeable) wallcovering?*

High permeable wallcoverings such as textiles will readily allow air to pass. Low permeable wallcoverings, however such as perforated vinyl wallcovering, paper or non-woven wallcoverings will allow water vapor or moisture to pass but air movement will not be readily noticeable. See Section 1.3, Wallcoverings and Mold: A Function of Moisture Levels and Permeability, for more information.

*Should I use breathable (permeable) wallcovering in a kitchen, bath or sauna area?*

Since the warm, moist air from the kitchen, bath or sauna could penetrate the breathable (permeable) wallcoverings, non-breathable (impermeable) wallcoverings such as vinyl would be a better choice in the bath/sauna area. See Section 1.3, Wallcoverings and Mold: A Function of Moisture Levels and Permeability, for more information.

*What if I just cut a hole in my wall to let the warm, moist air out of the wall cavity? Wouldn't that dry my wall out?*

Putting a hole in the wall would allow more moist air into the room and it also would increase the airflow and condensation on the back of the drywall. In other words, it would make matters a lot worse. Finding and eliminating the source of moisture is vitally important for preventing mold growth. See Section 1.2, Overview of Mold in Building and Home Interiors, and Section 4.1, Eliminate Sources of Moisture, for more information.

*Does perforation affect the fire rating for wallcovering?*

No, fire ratings are the same as non-perforated wallcoverings. This publication does not specifically address fire ratings.

*Does perforation affect the physical values of wallcovering?*

Perforating or microventing woven backed wallcoverings does not change their physical characteristics. Perforating or microventing non-woven backed wallcoverings, however, will weaken them. See Section 1.3, Wallcoverings and Mold:

A Function of Moisture Levels and Permeability, for more information about perforating or microventing wallcoverings, especially as these techniques relate to permeability.

*If I hang a non-breathable (or impermeable) wallcovering over an existing mildewed wallcovering, will the first layer of wallcovering keep the top layer of wallcovering from mildewing and changing colors?*

The color changes in the first layer will eventually occur with the second layer as well. Also, the first layer may become loose and delaminate from the wall as a result of the increased weight and the continued mold growth under the first layer. Installing wallcovering over existing wallcovering also will increase the flame, smoke and toxicity of the flame in the event of a fire. In short, it is not at all a good idea. See Section 3.1, Cleaning, Removing Building Materials, for more information.

*I had a severe mold problem caused by a leaky roof. I installed perforated wallcovering, but the mildew returned. What happened?*

Breathable (or permeable) wallcoverings such as perforated or "microvented" wallcoverings may not be able to overcome the amount of water leaking from the roof. In order to prevent mold from returning, the source of the leaks must be identified and fixed. Water leaks provide moisture needed for mold growth and building deterioration regardless of whether wallcoverings are present or not or what type of wallcoverings are used. See Section 1.2, Overview of Mold in Building and Home Interiors; Section 3.1, Cleaning, Removing Building Materials; and Section 4.1, Eliminate Sources of Moisture, for more information.

*What is a positively pressurized home or building, and what is the advantage of having a positively pressurized home or building?*

When a home or building is positively pressurized, the air pressure inside is at a slightly higher pressure than outside the structure. The advantage is cool, dry air inside the home or building pushes its way into cracks and crevices and into air cavities or inside wall cavities in the building. The cool, dry inside air also does not condense inside the wall cavities and any infiltration of warm, moist air from outside would be stopped. Other sources of water or moisture from structural or plumbing leaks will not be affected. As a result, these sources of moisture must be independently corrected. See Section 1.2, Overview of Mold in Building and Home Interiors, and Section 4.1, Eliminate Sources of Moisture, for more information.

*Can mildew grow within a positively pressurized building?*

If sufficient moisture from a roof leak, pipe leak or any other moisture source builds up in an area then

mold can grow. The area would tend to be localized to the leaky area and typically not wide spread over an entire building as it would be in a negatively pressured building, although water can travel along pipes and duct work to other areas of the building. See Section 1.2, Overview of Mold in Building and Home Interiors, and Section 4.1, Eliminate Sources of Moisture, for more information.

*How dry does the air in a home or building need to be and can people live comfortably in a positively pressurized home or building?*

A home or building maintained at about 50 percent humidity and 72 degrees F will be comfortable for most people. At a relative humidity of 60 percent or higher, mold will grow. A positively pressurized building will usually go unnoticed except when entering the home or building. The air would flow out instead of into the entrance. Proper maintenance of the HVAC system will provide comfortable surrounding indoor environment in which to live or work. See Section 1.2, Overview of Mold in Building and Home Interiors, and Section 4.1, Eliminate Sources of Moisture, for more information.

## Appendix F. Glossary

**Allergen** – A substance that elicits an allergic reaction. Fungal allergens are proteins found in either the mycelium or spores. Only a few fungal allergens have been characterized, but all fungi are thought to be potentially allergenic.

**Allergenic** – Able to produce an allergic reaction.

**Biocides (also known as Fungicides)** – Chemicals that limit the growth or kill microorganisms such as fungi.

**Black Mold (also known as Toxic Black Mold or Toxic Mold)** – A poorly defined term that usually has been associated with the species of mold known as *Stachybotrys chartarum*. While there are only a few mold species that are truly black, there are many that can appear black. Not all molds that appear black are *Stachybotrys*.

**Building envelope (also known as Exterior Envelope)** – The part of the building that consists of all of the elements protecting the interior from the outside weather elements, including roofing, siding, windows, exterior doors, porches, flashing trim, caulking, waterproof decking, venting systems, chimneys and other elements which relate to the exterior surfaces of the structure.

**Colony** – An organized area of mold growth.

**Drywall (also known as Gypsum Wallboard, Sheetrock™ or Plasterboard)** – A wall component consisting of a manufactured panel made out of gypsum plaster and encased in a thin cardboard or paper. It is usually 1/2 to 3/4 inches thick and 4 ft. by 8 ft., 4 ft. by 9 ft. or 4 ft. by 12 ft. in size. The panels are nailed or screwed onto the framing and the joints are taped and covered with a joint compound. Green board type drywall has a greater resistance to moisture than regular (white) plasterboard.

**Ethanol** – A compound produced by mold as a metabolic byproduct, which is often useful for determining if there is active mold growth.

**Ergosterol** – A compound produced by mold as a metabolic byproduct, which is often useful for determining if there is active mold growth.

**Fascia** – A vertical wood member, such as a cedar, 1 in. by 6 in., nailed to the ends of the rafters. It is often the backing of the gutter.

**Flashing** – A building component used at the interface of portions of a roof, deck, or siding material to another surface such as a chimney, wall or vent pipe. It is often made of various metals, rubber or tar and is mostly intended to prevent water from entering a building or home.

**Fungi** – 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. Approximately 69,000 species of fungi have been described in the scientific literature and estimates for the total number exceed 1.5 million.

**Hidden Mold** – Mold growth on building components and materials that is not easily seen, including the areas above drop ceilings, within a wall cavity (the space between the inner and outer structure of a wall), inside air handlers or within the ducting of an HVAC system.

**Hypersensitivity** – Great or excessive sensitivity.

**Hypha (plural Hyphae)** – An individual fungal thread or tubular filament of connected cells, which represent the individual parts of the fungal body. Appears as a branching structure with cell

walls. Mold spores germinate to produce hyphae, which grow and branch within or on the surface on which they are growing. They typically produce a colony that eventually forms a new generation of spores. Mold also can spread if a fragment of broken hyphae is transplanted to an area that has adequate moisture, warm enough temperatures and a nutrient source.

*Immunocompromised* – Individuals whose immune systems are weakened and susceptible to opportunistic diseases or infections. People who are classified as immunocompromised include but not limited to those with AIDS, certain cancers, the very old, the very young or those undergoing immunosuppressive drug therapy.

*Microbial Volatile Organic compounds (MVOCs)* – Chemicals fungi produce as a result of their metabolism. Some MVOCs are responsible for the characteristic moldy, musty or earthy smell of fungi. 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.

*Mold and Mildew* – Generic terms used to describe essentially the same types of fungi, with mold used to describe fungi growing on surfaces and mildew to describe fungi growing on fabrics.

*Mycelium* – A mass of hyphae making up a colony of fungi.

*Mycotoxin* – Chemical compounds produced by some fungi, some of which may be toxic to humans or animals. By convention, the term “mycotoxin” excludes mushroom toxins. Fungi that produce mycotoxins are called “toxigenic fungi”. 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.

*Mycology* – The study of fungi.

*Nonsporulating* – Fungal colonies that do not produce spores.

*Opportunistic Pathogen* – Any organism capable of causing disease only in a person whose resistance is lowered. Fungi occasionally act as pathogens when conditions unusually favorable for infection arise; for example, in people who have AIDS, certain cancers, the very old, the very young or those undergoing immunosuppressive drug therapy.

*Oriented Strand Board (OSB) (also known as Chip Board or Wafer Board)* – A manufactured wood panel composed of 1- and 2-inch wood chips and glue. It is often incorrectly used as a substitute for plywood.

*Pathogen* – An organism that causes disease.

*Remediate (or Remediation)* – Simply means to fix a problem. As it relates to mold, remediation includes fixing the water/moisture problem and the cleaning, removal and/or replacement of damaged or contaminated building materials.

*Saprobies* – Organisms that use non-living organic materials to grow and reproduce.

*Sensitization* – Repeated or single exposure to an allergen that results in the exposed person becoming hypersensitive to the allergen.

*Sheathing* – The plywood, board, OSB or other material used as the base for the roofing.

**Soffit** – A small ceiling-like space, often out of doors, such as the underside of a roof overhang.

**Spore** – General term for a reproductive structure in fungi, bacteria and some plants. Mold spores can survive for many years in dry or hot environments, requiring only moisture, the right temperature and an available food source in order to start growing. Spores may travel in several ways, including being passively moved by a breeze or water drop, mechanically disturbed by a person or animal passing by, or actively discharged by the mold, usually under moist conditions or high humidity.

**Sporulating** – Fungal colonies that produce spores.

**“Toxic” Mold** – A term that has no scientific meaning, as mold itself is not toxic. The metabolic byproducts of some molds may be toxic, however (see mycotoxin). The term was coined by the

news media and is used most often in reference to *Stachybotrys chartarum* and the alleged severe health effects associated with exposure to this type of mold.

**Toxigenic Fungi** – Fungi that can produce mycotoxins.

**Treated Lumber** – A wood product impregnated with chemicals to reduce damage from wood rot or insects. Often used for the portions of a structure likely to be in ongoing contact with soil and water such as a deck. Wood may also be treated with a fire retardant.

**Visible Mold** – Mold growth that can be easily seen.

**Water Activity ( $a_w$ )** – A measure of water within a building material or component that an organism can use to support growth.

***Adapted from the American Industrial Hygiene Association’s The Facts About Mold: A Glossary, which can be viewed at <http://www.aiha.org/GovernmentAffairs-PR/html/mold-glossary.htm>, and Start Remodeling.com glossary, which may be viewed at [http://www.startremodeling.com/construction\\_glossary.htm](http://www.startremodeling.com/construction_glossary.htm). Also, Stedman’s Medical Dictionary, 27<sup>th</sup> edition. Lippincott, Williams & Wilkins. Philadelphia, Pennsylvania. 2000.***

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**The Wallcoverings Association**  
401 N. Michigan Avenue; Chicago, Illinois 60611  
Phone (312) 644-6610 Fax (312) 527-6705  
[www.wallcoverings.org](http://www.wallcoverings.org)



**Chemical Fabrics & Film Association**  
1300 Sumner Avenue; Cleveland, Ohio 44115-2851  
Phone (216) 241-7333 Fax (216) 241-0105  
[www.chemicalfabricsandfilm.com](http://www.chemicalfabricsandfilm.com)

# Mold

## Cause, Effect and Response

### A Study of Wallcovering Products



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