The Pennsylvania Housing Research Center

Mold and Buildings

Builder Brief BB0301

Wally Kowalski and Eric Burnett

Introduction

As one of the most ancient life forms on our planet, mold has always been with us. Yet in the past 20 years or so the growth of mold in buildings has become a major public health issue. It's even been referred to as a "creeping catastrophe." What is mold? Where does it come from, and how dangerous is it? This brief seeks to answer these questions and to give builders some background information on this contentious issue.

What is Mold?

The term mold refers to the various kinds of fungi, or spore-bearing micro-organisms, that grow on animal and vegetable (organic) matter. The term is also commonly used to refer to the furry or downy coating formed by the growth of these fungi. When mold grows on textiles, paper or leather, the coating or discoloration it creates is called mildew.

When we see mold on a surface, what we are seeing is the growth that results from the germination of mold spores, which are microscopic "seeds." The end product of the mold growth cycle is more spores, that become airborne at the slightest disturbance and are dispersed by air currents.

Molds thrive at the lowest levels of the food chain. Given favorable temperatures, air, some trace elements and moisture, most organic components will enable mold spores to be fruitful and multiply. Since some common building materials are organically based, they serve as a food source.

Outdoor air is filled with the spores of hundreds of species of fungi. Their concentration and mixture vary over the seasons. Many of these species are relatively harmless to most people in normal outdoor concentrations, but up to 20% of people have allergic reactions to common fungal spores. The most serious problems occur when indoor concentrations rise to levels far above those found outdoors.

Common Indoor Molds

As Figure 1 shows, the four most common molds account for about 80% of the molds normally found indoors. The remaining 20% consists of any or all of the molds shown in the associated table.

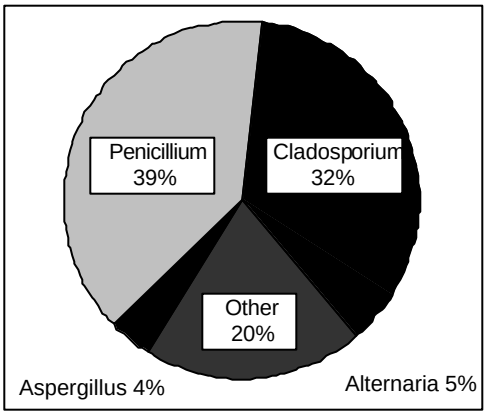

Figure 1: Most Common Indoor Molds

Other Common Indoor Molds

(Allergenic Fungi by Genus)

Absidia	Mucor
Acremonium*	Paecilomyces*
Aureobasidium	Phialaphora
Botrytis	Phoma
Chaetomium*	Rhizomucor
Cryptococcus	Rhizopus
Emericella	Rhodoturula
Epicoccum*	Scopulariopsis
Exophiala	Stachybotris*
Eurotium*	Trichoderma*
Fusarium*	Ulocladium
Geomyces	Wallemia

*(includes toxigenic species)

Concentration Levels

If a building were completely open to the outdoors, the level of airborne spores would be about the same as that of the outdoor air. In buildings that are naturally ventilated, the spore levels in the indoor air would be typically lower than those outdoors because the spores tend to settle on surfaces in the relatively calm air. With mechanical ventilation (fans) buildings the spore levels would be even lower, since some of them plate out on the ventilation equipment.

Air conditioning may actually remove spores from the air. When condensation occurs in the coils, the spores are washed out of the air. Figure 2 shows the effects of the three types of ventilation systems—natural ventilation (no fans), forced air distribution (ducts and fans) and air conditioned (with cooling coils)—and how they influence spore levels indoors compared to the outdoor air. These results were reported in the *California Healthy Buildings Study* in 1997.

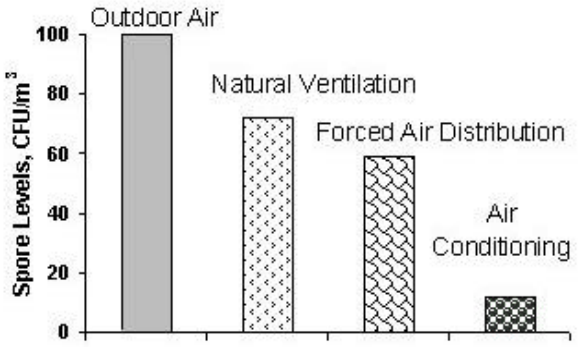

Figure 2: Effect of Ventilation Systems on Indoor Spore Levels

Potential Risks and Costs

Mold can harm the people occupying buildings in which mold is present, as well as damaging the buildings themselves. Understandably, it is the damage to people rather than the damage to buildings that gets the headlines.

A couple with a sick infant son were recently ordered to move out of their VA home in Florida because the mold called *Stachybotris* was present. It had saturated everything from the walls to the clothes and furniture. *Stachybotris* is perhaps the most dangerous fungus in the US today; the toxin it produces is suspected of causing bleeding lung disease in infants. Unable to afford a cleanup, the couple had to resign themselves to their house being burnt down by the fire department.

The threat to human health often leads to expensive efforts to eliminate the source of the mold and to change the conditions that permit its growth. The cost of remediation, however, may be much less than the cost of a lawsuit especially if the plaintiff is found to have suffered serious health damage as the result of mold contamination. Even if the plaintiff does not win the case, the social and economic costs of litigation are often substantial.

Mold problems are not confined to any one material or to houses. Some high profile mold related problems have occurred in hotels, schools and hospitals. Some of the larger builders have however had to deal with multiple claims and class action lawsuits and this has captured the attention of the media.

Mold and Health Problems

Indoor mold may cause health problems that include infections, induced asthma, toxic reactions, and respiratory irritation. Respiratory infections are rare, but they can occur with some species of molds and can affect those with impaired immune systems.

Molds may also produce allergic reactions in susceptible individuals. The exact amount of any of these allergens required to cause reactions is at present unknown, and so no standards or limits can be set. The *California Healthy Buildings Study* suggests that a lower limit for mixed spores of 100 CFU/m^3 characterizes healthy buildings. One Canadian study shows that indoor levels of *Aspergillus* above 50 CFU/m^3 are associated with various ailments.

Asthma, once thought to be an inherited condition, has been steadily increasing for the past 20 years or more, especially among younger males. Asthma can

be caused by chronic exposure to molds and other respiratory irritants or allergens.

The toxins produced by molds are biological poisons that can cause a variety of serious health problems. In small quantities they may cause mild illness. Only a dozen of the common molds are capable of producing toxins (toxigenic), but they include the four most common molds shown in Figure 1 plus those shown with an asterisk in the associated table. However, not every species of toxigenic mold within each identified genus produces toxins, and even toxigenic species produce toxins only under certain conditions.

Certain molds secrete toxins into their immediate surroundings, thereby wiping out competition for limited nutrients or moisture. These toxins are often as dangerous to humans as they are to other microbes. So human beings may become, in effect, the accidental victims of biological warfare being waged among competing fungi.

Volatile organic compounds (VOCs) and other gases can be produced by molds. Certain VOCs can irritate nasal passages, the lungs, the eyes, or even the skin. Gases produced by fungal growth may not do any damage but can create unpleasant odors and even nausea.

Some 15-30% of cases of sick building syndrome (SBS) or building-related illness (BRI) have been associated with molds, and particularly with those molds that produce toxins. In general, problem buildings often have higher levels of some mold species indoors than occur naturally outdoors.

Prerequisites for Mold Growth

Since fungal spores are present everywhere in the environment, they constantly infiltrate into buildings. They enter with the outside air through the ventilation system or through other openings. They may be carried in on clothing, furniture, or with other materials, including plants. Once inside, air currents or other disturbances may redistribute them. The indoor environment contains everything fungi need to grow: moisture, nutrients, warmth, and air.

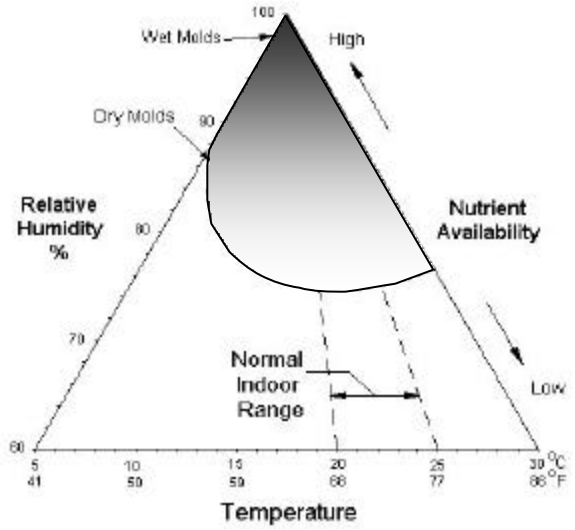

Figure 3: Growth Triangle for Indoor Molds

Figure 3 shows the three primary factors influencing the growth of indoor molds: RH%, temperature, and nutrient availability. In general, a humidity level above approximately 75% can sustain mold growth, as shown in the figure. Some molds, like *Stachybotris*, prefer relatively moist conditions; they are called wet molds. Molds that grow well in relatively low humidity, like *Aspergillus*, are called dry molds. Other molds fall between these two extremes. Note that molds will grow over a much wider temperature range than is normally found indoors.

Figure 3 also shows the general nature of the relationship between nutrient availability and mold growth. When nutrients are abundant, growth will be sustained. When only trace nutrients are present, growth will be minimal. A complicating factor is that bacteria that can exist on non-organic surfaces like stone or steel may provide enough nutrients for mold to grow.

Moisture is Critical

For existing spores to germinate, all it may take is a little flood damage, a leak in a roof or a pipe, or water vapor condensing to form water. The result could be a major mold problem.

The trigger for mold growth is almost always moisture or high humidity, especially humidity above 95%. High humidity alone may not be sufficient to cause mold growth, but it often results in condensation on cool surfaces, including walls, windows, and duct insulation. The condensed moisture may cause mold to grow.

Condensation commonly occurs in winter and most often in the kitchen and the bathroom because of the high levels of moisture produced by the activities that take place in those rooms. Condensation is also common in the summer when the interior space is conditioned. Human beings also produce moisture. Besides moisture generation, the occurrence of condensation also depends on ventilation, heating, thermal insulation, and surface absorption.

Condensation Management

Since moisture is such a critical component and condensation is the major source of building moisture, controlling the incidence, location and amount of any condensation is often the key to preventing mold growth.

Thermal insulation is used to keep internal surfaces above the dewpoint temperature, thus preventing condensation. Inadequate or damaged insulation may result in condensation and subsequent mold growth, so repairing or improving insulation may solve the problem. The table below lists further options.

Remediating Condensation Problems
1. Inspect or adjust heating system
2. Unblock or increase ventilation
3. Clean duct and open air registers
4. Clear combustion air inlets on equipment
5. Retrofit windows with double pane glass
6. Vent laundry driers to outside
7. Install dehumidifiers

Once mold has grown and materials are saturated with mold, they can be cleaned with a variety of bleaches and cleaning agents. Sometimes, however, removing the contaminated material is the only option.

Damage to Building Materials

In addition to causing health problems for building occupants, mold can also cause building materials to deteriorate. Mold-induced degradation affects wood and wood products, latex paint, non-synthetic textiles, leather, rubber products, and some plastics. Mold may also cause damage to any of the materials listed in the table below. In addition, long-term mold growth may weaken non-organic materials such as gypsum, concrete, and even stone.

Where Mold Growth may Occur	
Materials	**Locations**
organic building materials	air conditioners
carpet dust	cooling coils
dust in ductwork	evaporative coolers
filters	fans
floor dust	fiberglass insulation
gypsum-based finishes	humidifier water
wet carpet	moist walls
wet walls	metal ductwork
latex painted surfaces	refrigerator coils

Nutrient availability can be controlled to some degree by selecting appropriate building materials. And, although it may not be possible to restrict all materials to those that don't support mold growth, it may be possible to control the moisture on or around these materials. This is where the quality of construction and supervision come into play. The building enclosure, the water and the air barriers, and the vapor retarders must receive close attention during both design and construction. Sound maintenance practices are important too. Poor design, poor construction, and poor maintenance all contribute to the mold problem.

www.engr.psu.edu/phrc

PHRC
219 Sackett Building
University Park, PA 16802
Telephone: (814) 865-2341
Fax: (814) 863-7304