Mold, Housing & Wood

By Coreen Robbins, Ph.D., CIH and Jeff Morrell, Ph.D.

Western Wood Products Association

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TABLE OF CONTENTS

Introduction

Fungi, including molds, evolved over 400 million years ago (Sherwood-Pike, 1985) and references to mold in buildings suggest that molds have always been present in human environments. At present, there is continued public concern about the potential health effects of mold in homes and structures that has been heightened by past media reports and litigation.

There are a host of materials in and around the home that, under the right conditions, can sustain mold growth. Molds can grow on organic materials, material that contains carbon in a form that fungi can use as food, (ie: drywall paper, wood and carpet backing) and equally well on inorganic materials (ie: concrete, glass and plastic) as long as there are organic nutrients on the surface (such as dust, dirt, grease, etc.). In all cases, the presence of moisture is a requirement for mold growth to occur.

Of particular interest in homes and buildings is the ability of mold to grow on lumber in situations with adequate moisture. However, in most cases involving mold growth indoors, underlying problems such as flooding or water leaks can affect many materials in the structure, and are not likely to be limited to lumber.

The purpose of this document is to provide information to lumber users regarding the origins of mold growth on wood, types of damage caused by mold and steps that may be taken to prevent, remove and control mold growth. Additionally, this document will also discuss possible health concerns associated with mold exposure.

Why is there concern about mold in homes?

Mold growth in homes has not necessarily increased in recent years, but lawsuits involving mold, media coverage and publication of articles with unsupported claims of adverse health effects due to mold exposure have increased public awareness of the issue.

Much of the concern about mold arose after articles on the subject appeared in scientific journals. One of the most widely publicized articles was written by researchers from the U.S. Centers for Disease Control and Prevention (CDC) (CDC, 1994, 1997). They reported that in 1993, there were 10 cases of acute idiopathic pulmonary hemorrhage/hemosiderosis (AIPH) in infants, one of them fatal, that were thought to be linked to the mold *Stachybotrys chartarum* (also known as *Stachybotrys atra*).

This article caused great concern and spurred reactions across the country. However, both a CDC expert panel and an outside expert panel refuted the initial findings upon closer examination of the data, the study and its conclusions. Both panels determined there was no reliable scientific evidence that *Stachybotrys* caused the health problems in these infants (CDC, 2000a).

While the initial report of the CDC research was widely publicized, the revised findings received little coverage. As a result, there continues to be the misconception that there is scientific proof and CDC support for the idea that *Stachybotrys chartarum* causes serious health problems. In fact, the CDC noted: “At present there is no test that proves an association between *Stachybotrys chartarum* (*Stachybotrys atra*) and particular health symptoms” (CDC, 2000b). Since this time, no additional clusters or studies that show a relationship between AIPH and *Stachybotrys* or mold of any type have been reported.

In the years since the CDC revised the findings of this study, there has been further research and investigation to determine what adverse human health effects may result from mold exposure in indoor environments. Comprehensive reviews of scientific literature by the Texas Medical Association (TMA, 2002), the American College of Occupational and Environmental Medicine (Hardin, 2003), the Institute of Medicine (IOM, 2004) and the World Health Organization (WHO, 2009) have similarly concluded that an association has not been shown to exist between the presence of mold or other agents in damp indoor spaces and AIPH.

In extensive analyses, neither the Institute of Medicine (IOM) or the World Health Organization (WHO) were able to conclude that any adverse health outcomes were generally caused by the presence of mold in damp indoor environments (IOM, 2004; WHO, 2009). They did find sufficient evidence to conclude that there is an association between the health effects of upper respiratory (nasal and throat) tract symptoms, cough, hypersensitivity pneumonitis in susceptible persons, wheeze, and asthma symptoms in sensitized persons and mold or damp indoor environments. However, they reported no evidence that mold or damp environments are causing these health effects. This means that these health effects are more commonly found in moldy or damp environments compared to non-problem environments, but it’s not known what specific agents are causing the health effects. Other factors associated with environments with mold and damp can produce these health effects, for example dust mites are a well known cause of asthma and thrive in damp conditions. So, a person living in a moldy or damp environment with these adverse health effects has to be evaluated individually to determine the cause of their problems and whether or not they are related to their environment (IOM, 2004; WHO, 2009).

The IOM and WHO also found that the evidence is not sufficient to show even an association between the presence of mold or other agents in damp indoor environments and any other symptoms such as shortness of breath, airflow obstruction, mucous membrane irritation syndrome, chronic obstructive pulmonary disease, inhalation fevers, cancer, skin symptoms, asthma development, gastrointestinal tract problems, fatigue, neuropsychiatric symptoms, lower respiratory illness in otherwise healthy adults, and rheumatologic and other immune diseases.

Other studies have claimed to show a causal link between working in buildings with mold and symptoms such as headache, fatigue and cough, as reported in questionnaires (Johanning, 1996; Hodgson, 1998). The authors of these studies concluded that mycotoxins (toxins produced by some molds) were the root of the health symptoms. However, when these reports were examined closely, they were found to have many limitations and the data did not support these conclusions (Fung, 1998; Page, 1998; Robbins, 2000). Other reviews have concluded that there was no evidence to support the relationship between inhaled mycotoxins and adverse health outcomes (Page, 2001; Kuhn, 2003; Hardin, 2003). In addition, there are some widely cited anecdotal reports of acute, or sudden, health effects attributed to mycotoxins after exposure to extremely moldy conditions (Brinton, 1987; Croft, 1986; Di Paolo, 1994; Emanuel, 1975; Malmberg, 1993). There is little information in these reports to relate the health effects to mycotoxins and no measurement of exposure to mold or mycotoxins. In all of them, the individuals were likely exposed to high concentrations of mold spores and other airborne particles but recovered after they were removed from exposure.

What is mold?

Molds are part of the kingdom Fungi. Fungi are a diverse group of species that produce a wide range of structures that include mushrooms, bracket fungi, molds and mildew. Distinguishing features of fungi are the need to extract their food from the organic materials they grow on and the ability to reproduce by way of minute spores. Fungi, including molds, cannot make their own food since they do not photosynthesize like plants and generally lack the capability to capture their own food. Fungi are a part of nature's recycling system and play an important role in breaking down materials such as plants, leaves, wood and other organic matter.

Mold is the common name for many types of micro fungi (i.e. they are generally identified using a microscope). The most important requirement for mold growth is moisture. Otherwise, molds are pretty flexible with what conditions they can survive and reproduce in. In addition to moisture, molds require food, oxygen and suitable temperature (ideally between 70 and 85 degrees Fahrenheit, but ranging from just above freezing and just below the temperature where proteins unfold at about 140 degrees Fahrenheit or 62°C) (Zabel, 1992; Maheshwari, 2000; CDC, 2006). When these minimum conditions are met, mold spores that are present on virtually all surfaces, will grow and eventually can produce more spores that can be released into the air if disturbed. Spores are deposited on other surfaces, and if the conditions are right, the cycle begins again. The powdery or fuzzy spot appearing on an old loaf of bread is an example of a mold colony growing from a mold spore that landed on a suitable food source with adequate moisture. Molds are very adaptable and can grow even on damp inorganic materials such as glass, metal, concrete or painted surfaces if a microscopic layer of organic nutrients is present. Such nutrients can be found in household dust and soil particles that accumulate on surfaces.

Conservatively, more than 100,000 species of mold exist in the world. At least 1,000 mold species are common in the US. (Hawksworth, 1991). It is estimated that molds and other fungi make up some 25 percent of the earth's biomass. Most mold spores land on places unsuitable for growth (dry and with no food source), lose the ability to grow a new mold colony and eventually die. A select few land on surfaces containing nutrients and where the moisture, oxygen and temperature conditions are right for growth.

Mold and mold spores are everywhere around us and have always been a part of our environment. Therefore, exposure to mold spores is impossible to avoid in homes and commercial buildings. Extreme sanitation, filtration and isolation are required to remove the spores from the air completely, which is only done in extreme clinical settings. The air we breathe is a virtual jungle of fungal spores. We routinely encounter mold spores as part of everyday life both indoors and outdoors. Spore levels may vary seasonally, but some spores are always present.

Why does mold grow on wood?

Wood is a biological material consisting primarily of cellulose, lignin and hemicellulose. These three structural polymers make up 90 to 99 percent of the wood mass and give wood its unique properties that make it an excellent structural material (Panshin, 1980).

Wood also contains a variety of other materials, including sugars, starches, proteins, lipids and fatty acids. These materials are present in the storage tissues of the living tree and are essential for a variety of functions. Even after a tree is harvested, these materials remain in the wood and can provide the initial food source for mold fungi.

Mold fungi are rarely active inside a living tree because the bark provides an excellent barrier against fungal and insect attack. Once the tree is harvested, these protective effects decline and the many spores present in the air can settle on the surface and colonize the wood. Also, the food sources for mold—the stored sugars, starches and other compounds—are exposed when logs are processed into lumber.

What types of molds are found on wood?

Under the proper conditions, wood may be colonized by a variety of fungi (Davidson, 1935; Dowding, 1970; Kaarik, 1980). A study at Oregon State University revealed that Douglas fir sapwood was colonized by over 45 species of fungi within six weeks after sawing (Kang, 2000). Most of these fungi are common to many other materials, while a few were specialized and only grow on wood.

Molds and stain fungi are the most rapid colonizers of freshly exposed wood. Both fungi discolor the wood and are almost indistinguishable from each other to the naked eye.

Molds are typically characterized as fungi that discolor the wood surface through production of pigmented spores that can be yellow, green, orange, black and an array of other colors. The discoloration seen with molds is usually confined to the wood surface.

Stain fungi discolor the wood more deeply and are not as easily removed. These fungi may produce some discoloration as they grow on the wood surface, but the primary changes occur as they grow deeper into the wood. Stain fungi darken as they age. This darkening creates what is called "blue stain" in the wood (Zink, 1988). Stained wood can experience minor losses in physical properties, but the primary changes are in color and the increased ability to absorb liquids (Lindgren, 1952).

Decay fungi may also grow when wood products are exposed to chronic moisture. Decay fungi attack beyond the surface of the wood into the structural polymers of the fiber, reducing its strength. Decayed wood may be discolored, but spores of the decay fungus are not typically found on the surface. Spores of most species are produced on more complex fruiting structures that can produce billions of spores. Generally, decay fungi invade wood in structures after prolonged exposure to moisture which is often associated with plumbing leaks or seepage from outdoor water sources.

Many molds and other fungi that grow on wood are found on almost any material containing sugars or starches, including plant leaves, bread and other foods. They can grow on a microscopically thin layer of organic material, even forming on common household dust.

Molds have evolved to rapidly colonize a substrate and utilize the stored sugars as quickly as possible, but they lack the ability to cause significant effects on the wood structure. The most common effect of mold attack on wood is an increase in permeability, which can lead to an increase in moisture or paint uptake (Lindgren, 1952).

How are molds identified?

Typically the most effective and economical method for identifying mold growth indoors is by visual inspection. As a practical matter, areas with mold or other fungal growth versus areas that are clean are often obvious. However, in certain situations, collecting samples and testing areas for mold growth presence and type is useful. There can be questions about whether an area has mold growth or is simply discolored or soiled, or information about the type of mold or fungi present may be useful, for example, in distinguishing between sapstain fungi and mold.

Mycology is the scientific study of fungi. Proper identification of molds can be accomplished using classical methods that require the person examining the fungi to have extensive professional training in mycology. Although some species produce distinctive structures or colors, it is nearly impossible to identify the specific fungal species present on wood with the naked eye. Depending on the species, the identification of fungi from a sample using a microscope can take a few days to several weeks.

Most mold and stain fungi are identified by the spores they produce and the structures on which they are produced. Samples can be taken by smoothing a piece of clear tape on the wood surface, then mounting the tape on a microscope slide. Another approach is to cut small pieces from the wood surface, then place these on a nutrient media. Fungi growing from the wood onto the media are then examined under a microscope for spores and other key identifying features.

An alternative to culturing and microscopic examination is to use the genetic material (deoxyribonucleic acid or DNA) to identify the genus and species of fungi present in an environment. Samples are collected from the air or wipe surfaces. The sample is processed to harvest the DNA which is then copied many times and then the individual elements of the DNA are sequenced and identified. The results are compared with data bases to identify the fungi present in a sample. DNA sequencing has become almost routine in research and allows for rapid identification of organisms present on a surface. More sophisticated methods for analyzing all DNA on a wood sample are emerging. However, these tools must be used with caution since finding DNA on the wood does not always mean a fungus was actively growing there. These techniques are far more than would be needed in the vast majority of mold identification cases.

Many homeowners ask to have molds identified to the species level. In most cases, this is unnecessary and costly. Molds are a moisture indicator and should be dealt with as such. Eliminating the moisture source and cleaning the affected surfaces generally negates the need for identification. So-called “mold test kits” should be used with caution and the results interpreted carefully since sampling accuracy and interpretation of results are important aspects in using these kits.

In the absence of visible mold growth, sometimes the air is sampled to estimate the number of airborne mold spores if hidden sources are suspected. However, air sampling is largely a research activity and numerous samples are required to determine if mold spore levels are abnormal. Air sampling can be expensive and results are difficult to interpret in terms of what is a “normal” environment and what has the potential to cause adverse health effects. Air sample results only indicate what the airborne mold spore levels are at the sampling time, providing only a “snapshot in time” of airborne spores. Results are highly variable, due to the natural variability of the environment and the sampling and analysis methods (Baxter et al., 2005; CDC, 2006). Finally, air samples cannot be used to determine if indoor surfaces are free of abnormal amounts of mold spores or mold growth.

In general, normal indoor environments are expected to have mold spore levels similar to or less than outdoors. This is because the outdoor air is normally the dominant source of spores in the indoor air. The most important limitation of air sampling is that there are no health-based standards for mold exposure levels in indoor air, so there is nothing with which to compare the air sample results; and therefore, no way to determine the potential risk of effects from the amount of airborne mold spores found (Terr, 2004).

It is important to note that finding mold growth on surfaces does not provide information about the possible inhalation exposure to mold, nor do airborne mold spore concentrations inform you about the types and quantity of molds found on surfaces. Additionally, the potential for adverse health effects due to mold on surfaces or in the air cannot be determined by either of these parameters.

Individuals who inspect and test homes for mold should have the appropriate education and experience. A certified industrial hygienist (CIH) with experience in sampling for molds is generally qualified to inspect a home for the presence of visible mold, to collect samples for mold if necessary and to help with interpretation of the results. Industrial hygienists have training in exposure assessment and methods of controlling exposures to molds and other dusts. They can also provide advice on how to control exposure and contamination from dusts and particles including during repairs and cleanup of mold.

The American Board of Industrial Hygiene sets standards for certifying hygienists. These standards require at least a bachelor's degree with a minimum of 30 semester hours of science and specific industrial hygiene coursework, a minimum of four years of professional level-1 industrial hygiene experience and successful completion of a comprehensive one-day examination.

Where is mold found in buildings?

The presence of molds in our everyday environment means they can grow anywhere under the proper conditions. In all cases, moisture is the essential element for mold growth in buildings.

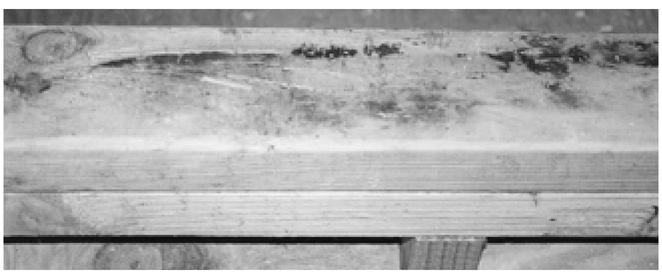

Fig. 1: **Mold on lumber**

There are many potential sources for excess and unwanted moisture in buildings. For example, improperly maintained air conditioning systems that create excessive condensation can be a breeding ground and distribution mechanism for mold spores and particles.

Mold growth may be found in walls, ceilings and floor cavities when there is standing water in a building or if the material stays wet for more than a few days (≥48 hours). Sources of water to support molds and other fungi in homes include plumbing leaks, gaps in roofs, siding or masonry, poorly sealed windows, porous slabs and foundations, inadequate drainage and faulty roof drains and downspouts. In such instances, where wood is chronically exposed to water, wood decay fungi can invade. Decay fungi can penetrate more deeply and attack the structural polymers in the fiber, reducing the strength of the wood.

Poor ventilation and/or air circulation combined with high indoor humidity—from showers, cooking or other activities—can result in condensation that promotes mold growth on cooler surfaces. Poorly insulated walls may also provide a surface for a cool surface condensation, leading to mold growth in buildings that have no general humidity problems.

Other conditions that can increase the amount of mold spores in the indoor air of buildings include homes with exposed dirt crawl spaces and basements tend to have more airborne mold spores (Lumpkins, 1973; Su, 1992). Some molds can even grow on house dust under the proper humidity conditions. It is not surprising, then, that poor housekeeping and high indoor humidity are both associated with increased levels of airborne mold spores (Solomon, 1975; Kozak, 1979).

The biggest source of indoor mold spores is often the outdoor air (Solomon, 1975). Higher levels of indoor mold spores tend to be found in homes with yards having dense and overgrown landscaping (Kozak, 1979).

Indoor mold levels are generally lower in buildings with forced-air heating systems (as opposed to window ventilation) and lower still when these systems include a well maintained and properly functioning air conditioning system with efficient filters.

Outdoor mold spore levels vary with the season and weather. They may be very high in the warmer season or approach zero when snow covers the ground (Solomon, 1975). Except for the snow cover situation, mold spores in normal indoor environments are usually between 20-50 percent of the outdoor levels. However, indoor levels will approach those of outdoor levels when windows and doors are left open or when non-filtered air is drawn into a building through the HVAC system.

Surface moisture on unseasoned framing lumber, appearing as the wood dries, may create conditions for mold growth. However, once the moisture content of the wood falls below 20 percent, mold growth can no longer be supported. Depending on the climate, framing lumber will dry to below 20 percent moisture content during the construction and before the building is enclosed. Depending on the project, some builders now use forced-air heaters to rapidly dry framing before installing drywall. Even if the framing lumber has mold it is typically encased by panels or siding on the outside and drywall or panels on the inside.

Do mold spores move from inside walls or floors into living spaces?

Mold spores may be present in a home but out of sight inside a wall or floor cavity. If this environment remains dry, the spores will become dormant or die. However, if moisture is introduced, such as if a leak occurs, the mold spores may germinate and resume growth.

There is limited research about whether such "hidden" mold can move into the structure and increase the amount of mold spores in the living space. The authors of a study which included analysis of data from 200 homes, concluded that the presence of *Stachybotrys* inside intact walls was not correlated with *Stachybotrys* found in the air of living spaces (Kuhn, 2005).

The Wisconsin Department of Health and Family Services investigated the relationship between mold on surfaces of oriented strand board siding and mold levels inside the home. The results of the study indicated that mold levels in the affected homes were not significantly higher than those measured in homes without mold on the siding (Daggette, 1999).

Exposure to mycotoxins, if any are present, in mold on framing lumber in a finished home is improbable. Mycotoxins are not volatile, so they cannot "off-gas" into the environment or migrate through walls or floors independent of a particle. Since particles cannot move through solid objects, mycotoxins in molds contained inside a wall or floor cavity will stay there unless physically disturbed.

As such, there is virtually no chance for occupants in a home to be exposed to any mold on the framing wood through skin contact, inhalation or ingestion.

In Veritox's experience sampling many buildings with chronic water leaks and large amounts of enclosed mold (usually more than 10 percent of internal wall area contains mold or wood rot), mold concentrations found indoors are at or below the levels found outdoors. From this it is reasonable to infer that small amounts of mold enclosed in walls, floors or ceilings will not have a large impact on the indoor air quality.

How can mold on lumber be prevented?

All fungi have four basic requirements for growth: suitable temperature, oxygen, food and moisture. Eliminating one of these required elements can prevent fungal growth, but removing moisture appears to be the most effective way to control mold growth (Scheffer, 1940; 1973; CDC, 2006).

One method for preventing stain fungi and mold in lumber during production and storage is to submerge it in fresh water, which fills the wood cells with water and limits the availability of oxygen. Lumber and wood product mills often utilize this method by spraying log decks with water or storing logs in ponds at the plant.

While controlling temperature and/or oxygen is generally not practical for wood products used in active construction projects, it is possible to remove moisture as quickly as possible during manufacturing. Reducing the moisture content of lumber to less than 20 percent will significantly decrease the opportunities for mold to form on the wood.

Drying lumber reduces the likelihood of mold growth, but it does not guarantee the wood will remain free of mold. Lumber that is exposed to moisture after it has been dried can support mold growth. Dry lumber can become wet through direct sources, such as rainfall or condensation. Even dry lumber contains some moisture. So, wet pieces inside wrapped bundles of lumber could create conditions for mold growth. Exposing the bundle to direct sunlight, for example, could heat the lumber and the wrapping may trap the evaporating moisture. This trapped condensate can result in moisture levels that are sufficient to support mold growth.

Each year, billions of board feet of lumber are sold as unseasoned, or green products and are allowed to dry naturally, usually during the framing stages of building a house. Many mills reduce the risk of mold and stain on green lumber by applying anti-stain, or sap stain treatments, which are thin coatings of fungicides on the wood surface. These fungicides are applied by dipping entire bundles of lumber into a treatment solution or by spraying all four surfaces of individual boards (Scheffer, 1940; Zabel, 1992, Morrell 2002).

These chemicals are designed to provide a microscopic barrier against fungal attack that lasts for three to six months, depending on a number of factors such as the chemical and concentration used, the wood species and weather conditions. The chemicals used for preventing mold and stain are usually very mild and include many used on food crops as well as in shampoos and paints. They are not designed for long-term protection of the wood.

When should mold be removed?

Visible mold growing on surfaces where people may come in contact with it should be cleaned and removed, as described below. The decision to remove mold from enclosed cavities must be made after considering how much mold is likely to be present and how likely it is to be opened or disturbed.

Where mold is present in existing structures, there are often reasons for opening walls and removing building parts that are unrelated to mold growth (such as for repairing warped and water-damaged floors or walls). In buildings where mold removal from enclosed cavities is not desirable or feasible, air sampling can be conducted to monitor the level of mold spores in the occupied spaces.

The process of removing mold from enclosed spaces could increase exposure to spores in the short term. High indoor mold spore levels are sometimes found when walls and floors containing mold are opened or disturbed, and when visible mold growth is present on exposed surfaces.

Can I clean the mold from the wood?

The decision to clean mold from lumber depends on the amount of mold present and how likely it is to be disturbed. In nearly all cases, mold cleaning should be undertaken only after moisture problems are resolved. The molds seen on lumber are largely a collection of fungal spores on the surface of the wood. As such, wet wiping or scrubbing the lumber will remove the mold. Simply wiping the wood, however, can release those spores into the surrounding air. A better approach is to gently spray or wet down the mold prior to removal. Once the mold has been wetted, it can be removed by wet-wiping the surfaces with a water and detergent solution, scrubbing if necessary as discussed below.

There are a number of products on the market, from commercial mildewcides to household bleach, which are promoted for removing mold from wood. The CDC recommends using a bleach solution of 1 cup bleach in 1 gallon of water when the water damage is due to contaminated water, such as flood waters (CDC, 2006). For large mold clean ups, the U.S. Environmental Protection Agency (EPA) suggests using mild detergent and water. Specifically, for cleaning wood surfaces, the EPA recommends wet vacuuming the area, wiping or scrubbing the mold with detergent and water and, after drying, vacuuming with a high-efficiency particulate air (HEPA) vacuum (EPA, 2001). If commercial products are used for cleaning mold, be sure to follow the manufacturer's instructions for use. When using bleach and other cleaning chemicals indoors, make sure there is adequate ventilation and never mix bleach with ammonia.

Cleanup of small spots or areas of mold generally does not require any special protective equipment. For any mold clean up that may generate large amounts of dust, basic personal protection equipment such as rubber gloves, eye protection and a high-quality pollen or dust mask should be used. Follow specific instructions for use of recommended protective equipment, such as gloves or goggles, when using mold removing products including detergents and bleach.

Removing small amounts of mold from wood is relatively straightforward. Mold removal becomes more complex when there are heavy amounts of growth on a majority of the lumber or if the building has been in service for some time and the mold originated from leaks into the building cavity. In these instances, the mold clean up should be done by a professional cleaning and restoration company.

Once I clean the mold, can it come back?

Mold spores are present on surfaces in all homes, so cleaning alone will not prevent regrowth of mold (Taylor, 2004). Even if a building is stripped of all components and every spore is killed or removed, normal background mold spores from outdoors or on replacement parts will be present and have the potential to grow.

The most important objective in any mold removal is to eliminate any sources of moisture. Should the wood framing in a house become wet, through leaks or flooding, it is imperative that the area be dried as soon as possible to prevent mold growth.

In many climates, this drying will occur naturally once any standing water is removed. In other climates where the relative humidity is higher, it may be necessary to bring in portable fans to increase airflow or to use the existing heating system or portable electric heaters to encourage faster drying.

Are there mold regulations?

In the U.S., there are currently no federal regulations or exposure limits for molds or mycotoxins. This is true for homes, occupational settings, schools, stores and other public buildings.

In the occupational setting, the general duty clause may apply to mold exposures. This is the rule that requires employers to provide workers with a safe and healthy work environment. The Occupational Safety and Health Administration (OSHA) should be consulted for specific information on work-related mold questions.

Because there are no exposure limits for molds, there are no "benchmarks" with which to compare exposure measurements. Typically, measured indoor airborne mold levels are compared to outdoor concentrations. Differences between the types and numbers of molds indoors vs. outdoors can provide clues as to whether the exposures indoors are above the background level and whether there is a source of mold inside the building. However, these data usually cannot be used to determine if exposure levels are safe. In most cases, air sampling for mold is not needed to assess or remediate a mold problem.

What are "toxic molds"?

"Toxic mold" is a misnomer. The toxins that this nonsense term alludes to are called mycotoxins. Mycotoxins are compounds produced by fungi that are toxic to humans, animals and bacteria (Ciegler, 1980; Borchers, 2017). When mycotoxins are used on bacteria, we call them antibiotics. Many common molds can produce mycotoxins, but only under certain conditions, only in small amounts and these compounds do not produce a vapor or gas. Some mold species that arbitrarily have been cited as "toxic molds" include *Stachybotrys chartarum* (or *atra*), and various species of Aspergillus, Fusarium and Penicillium.

Mycotoxins are relatively large and heavy molecules (Schiefer, 1990; WHO, 1990). This means they are not volatile and do not evaporate from the mold spore or substrate particle. The musty odor associated with mold comes from compounds generated as the mold reproduces, which are called microbial volatile organic compounds (MVOCs) (Pasanen, 1996). These compounds may be annoying, but are not mycotoxins and are not highly toxic. The levels that these compounds can be smelled at, even in damp and moldy buildings, are well below the concentrations that might result in sensory irritation symptoms such as burning eyes and upper airway irritation (Pasanen, 1996; 1998; Korpi, 1999).

Mycotoxins are secondary metabolites. This means that the mold does not need to produce mycotoxins to grow or survive. Mycotoxins are produced only when certain environmental conditions are in place. Even when such conditions allow for mycotoxin production, the concentrations are extremely small. Mycotoxins are contained in the spore itself and also may be found in the substrate or material in which the mold is growing (Jarvis, 1986).

Presence of a mold type that has shown to produce toxins ("toxigenic" species) does not substantiate the presence of mycotoxins (Ren, 1999). For example, known mycotoxin producing strains of *Aspergillus flavus* and *A. fumigatus* were grown on various building and construction materials. No mycotoxins were found in extracts of densely colonized ceiling tiles, wallboard, wallpaper and air filters. Even when supplemented with carbon and nitrogen, to enhance fungal growth, no mycotoxins were found (Tuomi, 2000). This is another reason why there is usually no reason to identify the species of mold present when visible growth is found. The type of mold present does not affect the need for or the way clean up is done.

What is *Stachybotrys*?

Stachybotrys is a genus of mold that grows well on chronically wet cellulose material. It is deeply pigmented, and is often referred to as "black mold". It should be noted that just because a mold is black does not mean it is Stachybotrys. Additionally, there are other dark-colored molds and mold colonies of different colors that may turn dark or black when they die off. Outdoors, Stachybotrys typically grows on and decomposes dead plant material. In research conducted by Oregon State University, none of the 45 different species of fungi growing on samples of Douglas fir sapwood were *Stachybotrys chartarum* (Kang, 2000). *Stachybotrys chartarum* and *Stachybotrys atra* are two different scientific names for the same mold.

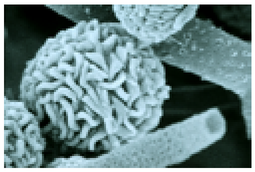

Fig. 2:* A conidium of *S. chartarum* showing the ridged surface of a mature spore. Scanning electron micrograph. *Courtesy of Berlin D. Nelson, Ph.D. and APSnet

Indoors, Stachybotrys can grow on cellulose building materials such as lumber, wood panels, drywall backing, insulation and ceiling tiles that are wet for extended periods (weeks to months). Moisture contributing to indoor growth of Stachybotrys is usually provided by flooding or leaks. Left wet, the spores of Stachybotrys are not easily released to the air. However, if allowed to dry, the spores can become airborne if disturbed.

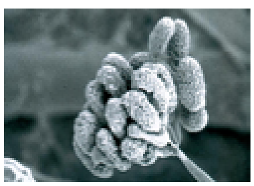

Fig. 3:* The mass of conidia of *S. chartarum* at the tip of the conidiophore. Scanning electron micrograph. *Courtesy of Berlin D. Nelson, Ph.D. and APSnet

The refuted CDC article, discussed earlier, and other questionable scientific papers directed much attention to Stachybotrys. However, these studies provided no credible scientific evidence of an association between chronic, low-level Stachybotrys exposure and health effects (Page, 2001). The few reports that associated direct contact and exposures to high concentrations of Stachybotrys with symptoms of skin rash, coughing, chest tightness, bloody nose, fatigue, nausea and — in rare cases — lower white blood cell counts are anecdotal, and were not supported or confirmed by objective scientific data. In these anecdotal stories, symptoms were also reported to cease after the exposure stopped.

What are the possible health effects of mold?

Humans are constantly exposed to molds in the environment, whether indoors or outdoors. Our immune systems and respiratory clearance systems provide defense mechanisms that protect us from health effects of airborne molds. Problems arise when the immune system is suppressed (HIV infection, cancer treatment), over-responsive (allergy) or when exposures are exceedingly high (irritation and mycotoxin effects).

Routes of exposures to mold include dermal (skin contact), inhalation and ingestion. The route of exposure has a profound effect on the dose, or amount of material that can be absorbed by the body.

Dermal exposure to mold occurs when the skin is in contact with mold colonies or mold spores. The spores do not pass through the skin, but may cause irritation if there is contact with large amounts of spores or moldy material (Dobrotko, 1945). The irritation may be from reaction to allergenic compounds or chemicals, including mycotoxins, and possibly from rubbing against the spores themselves. Skin is generally a good barrier against particles. Since mycotoxins stay with the particles, the skin is not a significant route of exposure. Inhalation exposure to mold spores and particles can occur when they become airborne. Bigger particles are stopped in the upper airways of the nose or mouth, and in the trachea and bronchi. Generally, only the smallest particles—those smaller than 5 micrometers (μm)—are able to reach the lungs. Ingestion exposure to molds can occur from eating moldy foods.

Infections

Fungal infections are simply a nuisance for healthy adults (ie: athletes foot, toenail fungus, thrush), however, these are not due to molds that grow on wet indoor surfaces. The severely immunocompromised, such as those undergoing chemotherapy, organ transplant recipients or people with HIV/AIDS, may be at increased risk for opportunistic infections from common molds both indoors and outdoors. Infections among the immunocompromised have not been reported to occur due to mold in residential settings.

Allergies

Some people are allergic to molds. Allergic responses include hay fever and asthma. Only about 5 percent of the American population experiences allergic symptoms due to molds and other fungal antigens (fungi other than molds produce spores that may also provoke allergic responses) (Hardin, 2003). Allergies to other antigens, such as those found in food, on cats and in house dust are much more common.

Toxicity

Although mycotoxins can be inhaled, the amount needed to get to a toxic dose is in the range of many hundreds of millions of spores per cubic meter of air because the mold spores are small and the amount of toxin in each is tiny (Kelman, 2004). These airborne concentrations are not found in indoor environments, even when visible mold contamination is present.

Ingestion is a more direct exposure route for mold. Eating moldy foods has led to historical incidents of mass human and animal poisonings (Hudler, 1998). Much larger masses of mold—and any mycotoxins present—can be taken into the body through ingestion as compared to the inhalation route. For a more in depth analysis of the health effects of mold, please refer to “Mold and human health: a reality check” (Borchers, 2017). Mycotoxins are present in very small amounts in foods such as milk, coffee and nuts. Levels of mycotoxins in food in the US are regulated by the Food and Drug Administration (FDA).

Summary

Molds play an important role in nature by breaking down organic materials. We routinely encounter mold spores as part of everyday life, in both outdoor and indoor environments. In most cases, the body’s immune and respiratory systems normally provide defense mechanisms that protect it from health effects of regular exposure to molds.

Inhalation of molds can result in a range of health effects in some circumstances. Infections are possible in immunocompromised people, although there are no reports of this occurring from mold growth in a residence. Allergic responses to molds include hay fever and asthma, and many people with allergies are also allergic to mold. The amount of mold that must be inhaled to cause an allergic response is unknown. Toxic effects from inhalation of mold may occur in situations where there are prolonged exposures to exceedingly high airborne mold concentrations, such as in an agricultural setting. These high concentrations have not been reported to occur in residences in general or specifically with mold enclosed in finished walls.

Lumber is just one of thousands of materials that can be a potential growth substrate for mold under the proper conditions. In a vast majority of cases, mold problems in homes are related to flooding or water leaks that affect many materials in the structure, including lumber.

Moisture is essential for mold growth and controlling moisture offers the best protection against mold. While all wood contains moisture, mold growth is not supported on wood dried to below a 20 percent moisture content. Lumber used in construction will typically dry to below 20 percent moisture content before the structure is enclosed.

Drying lumber does not guarantee the wood will remain free of mold. If lumber is exposed to moisture after it has dried, it can provide a surface for mold to grow. If visible mold is present, the cause should be determined, remediated and then the area should be cleaned. Sampling for mold on surfaces or in air is costly and usually uninformative and unnecessary.

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