MOLD GROWTH ON GREEN LUMBER AND IN OTHER BUILDING MATERIALS–AN OVERVIEW

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Introduction

In traditional construction defect cases, design and installation, product performance, and maintenance issues were the focus of complaints and/or litigation. Design and installation issues could involve leaks at penetrations in the building envelope, such as at a window. Infiltration of moisture at these locations would eventually result in decay in the adjoining wood and wood-based products (e.g., wood-based cladding, building paper, sheathing and framing). In recent years product performance issues have focused on the in-service performance of some wood-based composite materials, such as hardboard siding and oriented strandboard (OSB) siding and sheathing. In these cases, the wood-based composite materials were alleged to be less durable than other wood products or alternative materials. Until recently, mold issues had generally played a minor roll in these cases. Construction defect cases have now begun to include a "personal injury" component, which has increased the requested settlement amounts in these cases. The health related effects of mold growth that has been routinely observed on green Douglas-fir framing lumber has also called into question. The purpose of this paper is to review the requirements necessary for the establishment and growth of mold fungi, discuss moisture movement in homes, and to summarize indoor air quality and related health issues surrounding mold growth on wood and wood-based products, with particular focus on the emphasis on the mold that routinely occurs green lumber.

Requirements for Mold Growth

Four basic requirements are essential for the establishment and growth of fungi on wood and wood-based materials. These include an adequate temperature (usually between 60 and 105°F), sufficient oxygen, sufficient moisture (free, or liquid, water where the fungus is active), and a food source (Zabel and Morrell 1992). For brown-rot decay fungi, the food source consists of the hemicellulose and cellulose (the carbohydrate fraction), and for white-rot fungi, the food source consists of the carbohydrate fraction and lignin. The food source for mold fungi consists of sugars and other low molecular weight carbohydrates, plus organic debris that may settle on horizontal or vertical surfaces.

It is important to note that even though the food utilized by mold and decay fungi are different, the moisture requirements are the same. For green lumber the moisture source is from the lumber itself – once the surface of the lumber drops below 28% or so (the nominal fiber saturation point), there is insufficient moisture to support mold growth. Fungi produce enzymes that must diffuse through a liquid medium (i.e., water) to reach the food source, and the break down products must diffuse back to the hyphae of the fungus. Once the lumber is unbundled at the job site, and installed in the building, the surface begins to dry immediately, and any mold growth on the lumber would become dormant.

Health Issues

Individual health problems can develop from exposure to fungal spores and other products produced by fungi. In particular, fungi produce microbial volatile organic compounds (mVOC's) that cause the musty odor commonly noted with fungi, and under ceratin conditions some mold fungi can produce mycotoxins, organic compounds that can "initiate a toxic response in vertebrates" (McNeel and Kreutzer 1996). Exposure can result from inhalation, physical contact, or ingestion. Common symptoms resulting from exposure include runny nose, eye irritation, cough and congestion, headache, fatigue, aggravation of asthma, etc. (New York City Department of Health 2000). The susceptibility of individuals varies, and because of this variability, it is not currently possible to set a minimum exposure level for general population. Individual susceptibility varies with age, general health, and exposure levels (e.g., high or low level, short- or long-term exposure).

Molds typically mentioned in indoor air quality (IAQ) cases include *Aspergillus*, *Penicillium*, *Alternaria*, *Auereobasidium*, *Cladosporium*, *Fusarium*, *Trichoderma* and *Stachybotrys*.

Moisture Sources/ Moisture Movement in a Building

Given the importance of moisture for the growth of fungi, some of the common sources of water will be described. For green lumber, the wood itself is wet enough to support fungal growth. The presence of liquid (free) water implies that the wood is above the fiber saturation point, which is typically taken to be about 28% (ovendry basis) for Douglas-fir. Mold growth on green lumber is most commonly observed on the sapwood, where the initial moisture content can easily be in excess of 100% (Wood Handbook 1999). Given that green lumber is normally solid piled during shipment and storage between the mill and construction site, the surfaces of the lumber contained within the unit would stay wet.

Moisture movement into and through a wall cavity can occur by diffusion or convection. Moisture movement in a material can also occur via capillarity or gravity (Lstiburek and Carmody 1993). Moisture movement by diffusion and convection can occur with both exterior and interior sources. Capillarity and gravity are most significant where groundwater and rain are the major moisture sources.

Moisture sources are either external (leading to infiltration, or moisture movement into the building envelope) or internal (leading to exfiltration, or moisture movement out of the building envelope). Common external moisture sources include leaks in the building envelope and the crawlspace (assuming that the crawlspace is outside the conditioned (heated/cooled) space of the building). Water entry at leak locations results from rainfall (or landscape irrigation water) falling on the building exterior (roof or wall). Leaks in the building envelope typically occur at penetration points (such as windows), and other intersections where two or more different materials intersect. Unless specifically designed for, water entering the building envelope does not readily dry out, resulting in an accumulation of moisture that can result in the growth of mold fungi, and eventually decay fungi. Since the growth rate of mold fungi is much quicker than that of decay fungi, it is common to see the growth of mold and not decay fungi.

Internal moisture sources include items such as plumbing leaks and "habitation" activities such as cooking, bathing, and breathing. Since most of the "habitation" activities produce water vapor (and not liquid water), these moisture sources become important, from a fungal growth perspective, when they lead to, or are combined with factors that result in condensation. As seen in the psychrometric chart given in Figure 1, at elevated

relative humidities, small changes in air temperature can result in condensation on a cooler surface.

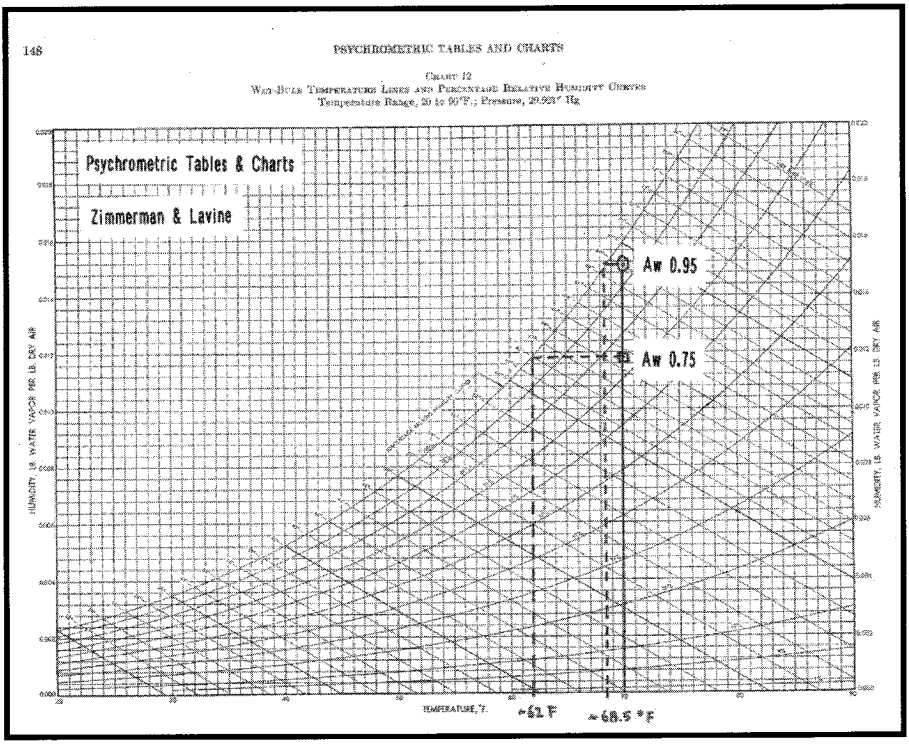

FIGURE 1. Psychrometric chart showing the ease with which condensation can occur at initially high relative humidity conditions. Relative humidities initially at 95 and 75% are shown here. (Zimmerman and Lavine 1964)

Molds Identified on Wood and Wood-based Products In-service

Samples of mold growing on green lumber have been taken both in selected lumberyards located in the San Francisco Bay Area, and also at some construction sites prior to buildings being enclosed. All samples were found to contain fungi from the *Ceratocystis/Ophiostoma* (C-O) group and/or *Gonatobotryum*. C-O is a sapstain fungus, an example of which is the common blue stain commonly seen in pine lumber. *Gonatobotryum* is a mold fungus that is sometimes found in conjunction with C-O, and grows parasitically on it.

The spores of fungi are typically disseminated either by air currents (most common) or insects. The spores of C-O have evolved to be disseminated by insects, and as a result the spores are in a sticky mass on the lumber. Because of the preference for insect dispersal, the spores of C-O are not readily disseminated by air, which should minimize the potential health consequences of this particular fungus.

The food source for the C-O group is sugars and other short-chained carbohydrates contained in storage (parenchyma) cells located in the sapwood portion of

the lumber. "Sapwood" is a term that refers to the portion of the tree near the bark. "Heartwood" is a term that refers to the portion of the tree away from the bark. A chemical change takes place in the storage cells when sapwood is converted into heartwood. These chemical changes alter the "food source" and makes it unavailable for sapstain fungi. It is not uncommon to find both sapwood and heartwood in the same member, and that is why you will sometimes see C-O growing only on a portion of framing member. (Figure 2).

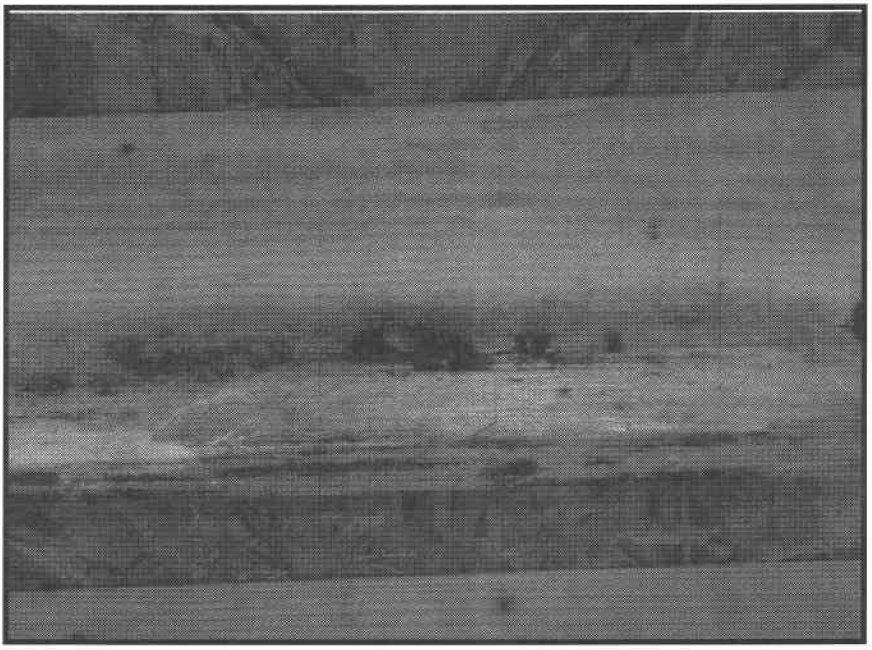

FIGURE 2. Sapstain fungus on Douglas-fir lumber. Note the abrupt transition in growth between the sapwood and heartwood zone.

I have taken samples of mold growing on wood-based materials in framed-cavities in buildings where leaks had occurred. These framed cavities contained lumber that was originally "green" and where C-O was identified. The other wood-based materials (including solid wood used in the flanges of I-joists) were installed in a dry condition. All materials were wetted (or re-wetted) as a result of the leaks (Figure 3). The pertinent finding with regard to C-O was that whereas mold growth occurred on all wood-based material, C-O was not found anywhere except on the sapwood portions of the originally green framing. A number of other mold fungi, which are disseminated by air borne spores and are commonly in the air, were found on the wood and wood-based materials, including the framing materials. This reinforces the inability of even dry C-O spores to move about in an enclosed cavity.

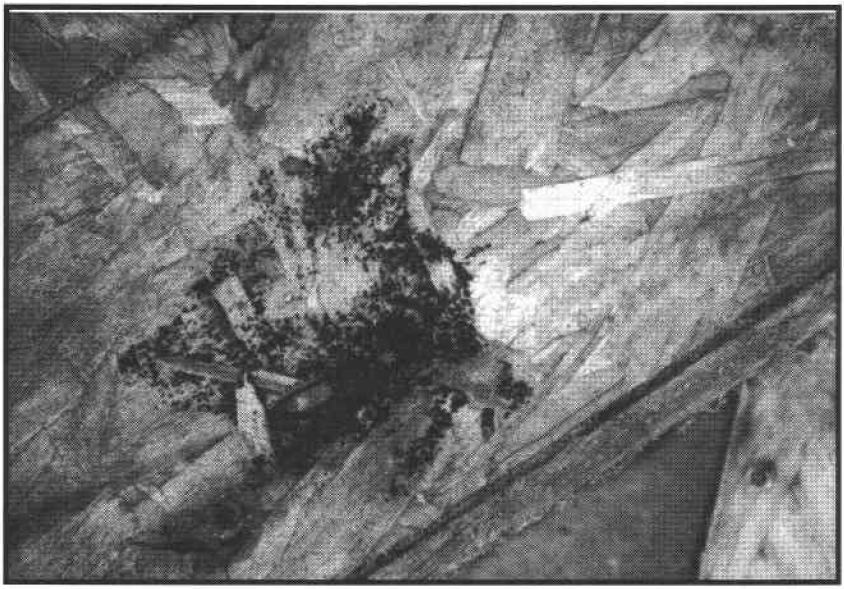

FIGURE 3. Mold growth on OSB. The OSB was wetted after installation as a result of a leak at a window penetration.

Summary

To summarize, sapstain fungi from the C-O group is commonly found on the sapwood of green Douglas-fir framing lumber. Spores from C-O have evolved to be disseminated by insects, and as such, are not readily disseminated in the air. To my knowledge, the C-O group has not been mentioned in CIH reports as being a concern from a human health perspective. Mold fungi that have been mentioned in CIH reports as being of concern are those that are disseminated by air currents, and have consistently been found on building materials that are installed in the dry condition, and are wetted after installation. Wetting after installation typically occurs as a result of a leak in the building envelope, or as a result of condensation on the surface of a material.

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