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MOLD IN BUILDINGS
FORINTEK RESEARCH AND TECHNOLOGY TRANSFER

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Summary

Indoor pollution is perceived as a serious health risk and mold has been indicated as one of the major culprits. It has received a high profile with considerable media, public and legal attention, especially after several key events in the USA that were picked up by mass media and sensationalized. Scientific literature supports the notion that there is a direct link between a damp living environment and adverse health in occupants. However the contribution of mold alone, among other associated culprits of damp environment including bacteria, mites, insects, volatile organic compounds, etc. is far from clear. Most people seem to agree that any level of visible fungal contamination in the living space could potentially represent some degree of risk for certain populations. Despite the progress of knowledge in the last 10 years there are still huge knowledge gaps, confusion and contradictions and lack of definitive medical evidence connecting molds to symptoms. The public is still in panic mode and mold will remain a challenge in 2004/2005 and probably beyond.

Forintek Canada Corp. and the wood industry in general have experienced increases in inquiries regarding mold and the suitability of wood as a substrate for its growth. Because wood is a widely used building material, it may be encountered more often in situations where building materials came into contact with water and grew mold. Wet wood (like many other wet materials) supports growth of fungi and the public might perceive wood used in the building envelope as a major source of mold. This could affect wood's image in markets and could be exploited by competitor industries. Forintek has continuously monitored development of mold as an issue and reviewed the existing and relevant information about mold, substrates that support its growth and the health issues associated with mold and water-damaged buildings. Several projects and collaborative efforts with other groups have been initiated to deal with recognized knowledge gaps. These include: development of a lab test method for mold resistance; developing a database of literature on mold, building materials and health; limiting conditions for mold growth; survey of mold and staining fungi on KD lumber; and hidden mold and its movement into living spaces.

This paper covers current knowledge and trends on mold and summarizes some of Forintek's recent work. Science will continue to reason that the current level of concern is excessive and unjustified and will fight perception that mold is the asbestos of this decade. Wood and wood products have not been officially singled out as a substrate or source for

mold. Moisture management is widely recognized as a key to addressing indoor air quality health issues and also to minimize mold growth. That message has already reached certain segments of the public and should continue to reach an even wider audience. Forintek will continue to monitor developments on the mold issue and will adjust its research program accordingly.

1. Background

Indoor pollution has been perceived as one of the most serious health risks in the last decade and molds have been implicated as one of the important contributors to ill-health. Mold has had extensive media coverage world wide, in particular in the USA where public hysteria was created following several key events. These included a paper published by the US Center for Disease Control (CDC, 1994, 1997) in which several infant deaths were blamed on a particular mold named *Stachybotrys*. Media-agitated images of a black mold killing babies remain despite findings that refuted the original paper (CDC 2001). In June 2001 a Texan jury awarded the family of Melinda Ballard US$ 32.1 million in a toxic mold law suit against her home insurance, which was slow in responding to a leak in her home, allowing mold to spread, and allegedly causing her and her family serious health problems. This highly-publicized case alone set in the public eye a bad reputation for mold, created the perception that mold property damage can generate a fortune, sent shock waves through the home insurance industry and spurred a flurry of litigation. Other similar cases and sensationalized media reports followed and to a lesser extent still continue. The public has pushed for both regulation and standardization.

Thus 2003 has been a year of much legislative activity. Currently in the USA 28 states have among them 87 pieces of legislation which deal with IAQ issues in schools and public buildings and with regulation of mold remediation and assessment. House Bill 329 (HB 329), passed by the Texas Legislature during the summer of 2003, requires the Texas Department of Health to license mold assessors and remediators, and to establish and enforce minimum performance standards and work practices for conducting mold assessment or mold remediation in Texas (http://www.tdh.state.tx.us/beh/iaq/HB329.pdf). This law will probably be followed as a model by other countries. A new mold standard is also to be published in late November 2003 and this standard draws on existing mold guidelines like the New York protocol (http://www.iicrc.org/). This three year old work has been orchestrated by the Institute of Inspection, Cleaning and Restoration Certification (IICRC) and involved over 20 different associations. It was reviewed by up to 350 reviewers until consensus was reached on its final draft. The mold standard S520 will be available to download from the IICRC site by the end of 2003.

In Canada there were not many lawsuits (over 50 compared to 10 000 suits in the US in the last 3 years). They were primarily property damage claims, and no claims of health effects have been successful. However toxic mold litigation is still a threat in Canada. In today's insurance market, mold exclusion clauses that limit or disclaim liability are the rule rather

than the exception. Further legal developments will depend on current science and if a cause-and-effect relationship is clearly established.

Until recently in Canada there was no clear structure for legislation and regulation or a national strategy for addressing the issue and very few coordinated efforts to deal with different aspects of the problem. Some recent initiatives in Canada (Pollution Probe, 1999-2001, followed by Healthy Indoors Partnership launched in September 2003) worked on development of a national strategy to achieve healthier indoor environments. Numerous stakeholders (including the wood industry) have participated in the extensive consensus, science-based consultation process. Who will be the lead organization on this and how will it affect further research planning and policymaking is yet to be seen.

2. Current Scientific Knowledge on Molds.

Scientific literature confirms that molds can grow on many different building materials and a variety of molds and bacteria are found on wet building materials. Moisture plays an important role in establishment and maintenance of mold growth. The concept that surface moisture availability is the most critical factor has come to be recognized more recently. Thus a measure called water activity (a_w) is employed to describe the availability of moisture to molds and it is a measure of equilibrium RH at the point the mold is growing. It is equal to $1/100^{th}$ of the RH of the air in equilibrium with the material. This is not necessarily the same as the RH in the room. Relative humidity, moisture content and temperature of the material are some of the most critical factors for mold growth. Material characteristics like water-holding capacity and chemical constituents also play a role (Flannigan and Miller, 2001).

Molds may produce a variety of metabolites (mycotoxins) and the production may vary drastically under different conditions. (Nielsen, 2003, Nielsen et al., 1998.). Some molds produce different metabolites under different conditions or do not produce them at all. As materials gradually get wetter this is often followed by a succession of organisms, starting with primary colonizers through secondary colonizers and ending up with wet-loving tertiary colonizers (water damage molds) which also comprise a number of toxin-producing molds. Significant mycotoxin production is reported above 0.95 a_w.

According to health experts, molds and other fungi can cause harm through allergy, infection and toxicity. The American College of Occupational and Environmental Medicine issued a position statement on Oct 27, 2002 recognizing that although molds are common allergens they are not the dominant cause of allergies. They specified that only 5% of individuals are predicted to develop some airways symptoms of allergy to molds in their lifetime. They also acknowledge that fungi are rarely significant pathogens to humans. Sometimes opportunistic infections are reported on severely immunocompromised individuals. Toxicity in molds is mostly due to mycotoxins which are produced by some molds under certain conditions. Serious health effects have been

reported following ingestion of moldy foods that contained mycotoxins. In some industrial and agricultural settings mold products carried in the air, together with other inhalable particles (bacteria, organic debris etc), present an occupational risk. However, despite a huge body of scientific work, there is no evidence that human health is adversely affected by inhaled mycotoxins or volatile organic compounds produced by molds. Dose-response data in animals suggests that delivery by the inhalation route of a toxic dose of mycotoxins in the indoor environment is highly unlikely.

However there is strong opposition among some physicians and scientists who argue that biological effect of many toxins is poorly documented and few were evaluated in vitro and vivo studies. Personal exposure values are also not known, nor the possibility of synergistic activity and accumulation.

There is substantial evidence in the literature which clearly link dampness and ill-health. The causal microbial agents found in the damp environments are still poorly understood and are linked through complex interactions with the growth substrate and other microbes in the environment that could also contain other air pollutants (e.g. mite and other animal products, material VOCs tobacco smoke, diesel particles etc). Thus the contribution of mold to ill-health is not known let alone mold taken out of the damp building context. In addition to this complexity, exposure patterns and human individual responses vary.

In the literature wood has not been singled out or exempted as a source and substrate for mold growth. Many high-profile mold claims have arisen because a water-damage problem wasn't given adequate attention until it was too late. Wood and wood products are widely used in residential and industrial construction and thus are more often found as material in water-damaged situations and are more likely to be examined for mold growth. Mold certainly grows on logs, green lumber and rewetted dry wood products. Molds, to the untrained eye, may appear similar to dirt or other stains in wood. Bluestain fungi may often be found on wet wood and these fungi have not been implicated in any health problems. Whether a real or perceived problem, mold is an issue the wood industry has to deal with.

3. Forintek's Mold Related Research

In the midst of mold hysteria, the wood industry has been receiving questions in regards to mold on wood and wood products. Some forces argue that wood (being organic) is a good food source for mold and use this in a campaign to promote their non-wood products e.g. marketers from concrete and masonry association. The primary fault however is often associated with water and building 'system' failures (envelope, ventilation) and occupant contributions (lifestyle, maintenance) regardless of materials. Forintek anticipated the development of mold as an issue and the potential impact on the wood industry and began several projects and collaborative efforts in the mid nineties to address existing knowledge gaps and identify unexpected ones. Current work includes: development of a lab test method for mold resistance; developing a database of literature on mold, building materials

and health; limiting conditions for mold growth; survey of mold and staining fungi on KD lumber; and determining movement of mold from stud spaces into living spaces. A description of these projects follows:

3.1 Laboratory test method for mold resistance of different wood products and different treatments

This test was initially developed when Forintek started work with the Alberta Research Council developing OSB with improved mold resistance in 1996 (Morris 1997, Morris et al 1999). The method is an adaptation of existing ASTM standard for testing paints. The test chamber is a polypropylene tank covered with a pitched roof to allow condensation to run back to the bottom of the chamber. Three inches of water on the bottom of the chamber and a tray with a moistened soil provide humidity and natural spore inoculum for the system. Constant spore distribution is assisted by an air-circulation fan. The temperature and humidity are controlled electronically to be constantly favorable to mold growth. Test samples hang over the unsterilized soil and are additionally challenged by spraying them with a mixture of mold spores. Samples are removed, weighed and rated for the extent of mold growth every two weeks for the 8 week duration of the test. We have now done 24 tests for 13 clients using this test method and six other organizations have adopted it for their own use. The method has undergone considerable evolution and currently is being evaluated by the American Wood-Preservers' Association for standardization

Figure 1. Samples in the test chamber being tested for mold resistance (left); and assessment and rating of mold growth (right)

3.2 Database of literature on mold, building materials and health

Following a flood of inquiries, Forintek resolved to put mold on wood into context by reviewing published information on all building materials that support mold growth and health issues associated with water-damaged buildings. A one-time literature review was judged to be of limited use due to the complexity and volume of literature and the fact it would rapidly become obsolete as new information is published. The decision was made to develop a relational database where all the relevant interconnected information will be stored and periodically updated. The database will allow searches of the information from different angles, responses to queries and regular updates. Database design, programming, data gathering and entering was completed in December 2002. Partly funded by the American Forest and Paper Association (AF&PA), the database contains information on 2430 cases extracted from close reading of 750 peer-reviewed articles from several disciplines. Over 2000 other articles were discarded as unusable. Unlike other literature search tools the database only yields a hit when two or more parameters are directly linked, not just mentioned independently in the same article. An expert team from Forintek and the University of British Columbia's (UBC) School of Environmental and Occupational Hygiene can now use the database to answer tough questions on molds from Forintek and AF&PA members. The team will also use the database to produce reports and fact sheets to assist the industry.

3.3 Limiting conditions for mold growth

Data on the limiting conditions for mold growth on Canadian wood products are needed for a mathematical model developed by the National Research Council designed to estimate mold growth under predicted conditions of temperature and relative humidity (RH) in wall systems. The 4-year project started in 2001. Test samples from several wood species, wood composites, gypsum board and fiberglass insulation were cut, conditioned to 10% moisture content and placed in test chambers with target RH ranging from 65-100 %. The samples were inspected for mold growth weekly for 8 weeks. In the first year's work no mold grew at 65% RH and 75% RH on any materials. At 85% RH, mold was detected at the third week on some of the materials with the exception of eastern white cedar, white spruce heartwood and fiberglass insulation, which did not support mold growth throughout the test. This work will continue under different conditions and with different materials.

3.4 Survey of mold on re-wetted KD lumber

In the early stages of the mold hysteria a few molds (such as *Stachybotrys chartarum*) were labeled as "toxic". Although it is now recognized that these are only a few of the molds found indoors that are capable of producing mycotoxins, the notoriety of these "toxic molds" remains. This project aims to:

- Identify the types of molds growing on re-wetted KD lumber in transit

- To compare fungi found on re-wetted KD wood with those on green lumber
- To compare them with list of fungi found in building interiors

In the initial experiment green pine lumber studs were obtained and sawn in half with one half dried and planed and the other left green. The end-matched samples were packaged (in duplicate) and left in the weather with the green lumber wrapped and the KD lumber exposed to rain. Since there was little rain we wetted the KD packages with collected rainwater. The weight of the packages was monitored and wetting stopped when the total retained amount of water was the same as the green lumber. In each pile, lumber was closely piled in the first five bottom layers while the top five layers were stickered. Every two weeks one replicate pack of each treatment was dismantled and closely examined for mold and stain growth while the other replicate was not opened until the final week (10 weeks). In the first year we found only a few different genera of molds present both on green and kiln-dried lumber. All were common, ubiquitous molds. In each case, there were more molds in the routinely assessed packages than in those that remained undisturbed until the end, indicating that disturbance was a factor in their spread. Staining fungi constituted the majority of fungal growth on the test material. In the second and third years the project will examine other wood species. The preliminary conclusion is that re-wetted kiln-dried pine lumber supports less mold growth, and probably even fewer genera, than green lumber. Furthermore, "problem" molds (such as *Aspergillus versicolor* or *Stachybotrys chartarum*) were absent suggesting that moldy (stained) lumber is not the means by which these molds are introduced into buildings. This work will be expanded and further work will study fungi on KD products that are soaked and enclosed for extended periods.

3.5 Movement of mold from stud spaces into living spaces

Forintek has long recognized the importance of improved moisture management in wood frame construction and has been assisting Canada's building science community more intensively since 1993 (Morris 1997; Hazleden and Morris 1999, 2001). This project is a partnership between Forintek's wood mycologists, Concordia University's building scientists and UBC's environmental health experts. Concordia has test facilities that allow full scale testing of different types of wood sheathing with real wall construction, realistic weather loading and extensive monitoring. UBC has the ability to measure mold spore concentrations in air and volatile organic compounds. The ultimate goal is to improve the performance of sheathing in moisture management within the building envelope. This project is in the early stages and has support from AF&PA, the Canadian Wood Council and several major forest product companies.

3.6 Forintek's technology transfer

Forintek is working closely with the Canadian Wood Council (CWC), the American Forest and Paper Association (AF&PA) and other organizations to make sure wood users have access to accurate and updated information on mold and the use of wood. To document what is already known, a fact sheet was produced in collaboration with the University of British Columbia's (UBC) School of Occupational and Environmental Hygiene (Forintek and UBC 2002). This is available as pdf file on the website jointly operated with CWC: www.durable-wood.com. Forintek continues to monitor developments on the mold issue and will adjust its research program accordingly. Although reports on Forintek research are only available to members, new information is being converted into suitable knowledge products to be accessible by wider audience. Moisture management is a key to addressing IAQ health issues and also to minimize mold growth. That message has already reached certain segments of the public and should continue to reach an even wider audience.

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Information Sources

A Building Microbiology Database. Forintek Canada Corp., 2665 East Mall, Vancouver, Canada V6T 1W5.

American College of Occupational and Environmental Medicine (ACOEM): www.acoem.org/guidelines/article.asp?ID=52

American Industrial Hygiene Association (AIHA): www.aiha.org

Centers for Disease Control and Prevention (CDC): www.cdc.gov.nceh.airpollution/mold/default.htm

Environmental Protection Agency (EPA), www.epa.gov/iaq/molds/index.html

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Healthy Indoors Partnership http://healthyindoors.com/

Institute of inspection, cleaning and restoration certification *www.iicrc.org/

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