DISCOLORATIONS ON WOOD PRODUCTS:

Causes and Implications

A Wood Protection Fact Sheet

Sometimes those black smudges are just dirt.

Why is construction lumber sometimes discolored and what does this mean? Many things can color or stain wood. For example, dirt and iron may leave indelible marks on wood. The heartwood portion of a tree is often darker than the sapwood and may appear to be discolored. Weathering will usually change the color of wood. In other cases, wood stains are due to the growth of microscopic organisms, the most common of which are harmless staining fungi. However, other fungi can potentially colonize wood products. Mold in building materials is a popular news topic due to possible health concerns. What are the implications of mold growing on wood? Because Forintek has often been asked to investigate such questions we have prepared this fact sheet to assist buyers and users of wood in understanding the nature of wood discolorations and deciding whether or not action is required.

Forintek Canada Corp.

THE UNIVERSITY OF BRITISH COLUMBIA
The School of Occupational and Environmental Hygiene

Wood: Inedible for Most Fungi

Like any other organic material, wood can support growth of certain fungal species. However, wood is often not a preferred material by most fungi as it is low in nitrogen, sugars and starches. Wood primarily consists of cellulose (the strong fibers) and lignin (the glue that holds them in place). Some fungi can digest cellulose, but cellulose is protected in wood by a natural coating of lignin, and only a few fungal species (the wood-rotting fungi) can break this coating. Additionally, heartwood (the center of the tree, making up the bulk of the wood in many species) contains naturally occurring compounds that can inhibit fungal growth and is especially poor in nutrients.

Products that include paper or fibers, such as acoustic tiles, wallpaper and drywall surfaces, are often more favorable for mold growth than wood. This is because the pulping process removes lignin, thus making cellulose available to the fungi. In addition, starch may be added as a glue or binder in pulp-based materials.

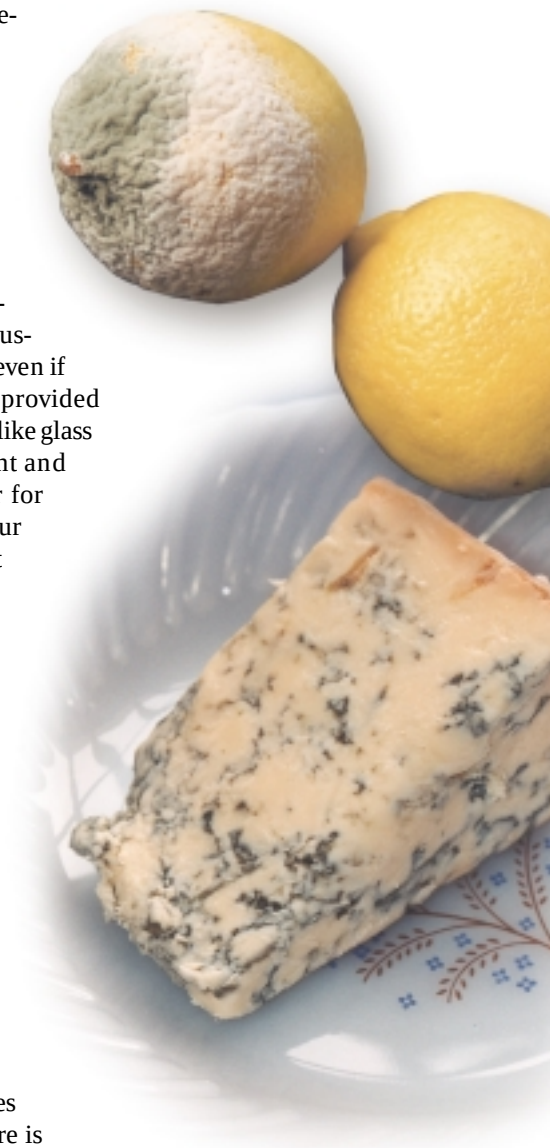
Lumber sold in the green (wet) condition may be pre-treated with fungicide to control stain, mold and decay fungi. Lumber pressure-treated with wood preservatives to control decay is much more resistant to but not completely immune from mold. Lumber production often involves kiln drying, where the heat from the kiln destroys any fungi in the wood. Following drying, there is insufficient water present in the wood to enable re-infection by molds or other fungi. However, kiln-dried wood must be protected from re-wetting to prevent re-infection.

The Fungal Kingdom

Fungi are part of our daily lives, usually without our being aware of them. The Fungal Kingdom, with over 100,000 known species, includes molds, yeasts, lichens and mushrooms. Some fungi produce useful products, like cheese, antibiotics, enzymes, and fermented products such as soy sauce, beer and wine. Other fungi can lead to problems when they grow where they are not wanted and cause undesirable effects on foods, materials, or air quality. In addition, some fungi are important because they cause plant or human diseases. However, the vast majority of fungal species have no direct impact on us at all.

Fungi can grow on just about anything. Fungal life support needs are simple: air, nutrients and water. Air is readily available. Unlike plants, fungi cannot make their own food but rely on breaking down complex organic substrates into simple nutrients that sustain life. Organic material is readily available even if it is not always visible – for example, it can be provided by microscopic particles on inorganic surfaces like glass or tiles. Fungi do require a moist environment and water is most likely to be the limiting factor for fungal growth. Water sources can be in vapour or liquid form, including the liquid water that is created when vapour in moist air condenses on a cold surface.

Most fungi reproduce via microscopic spores, which are carried on wind currents until they land on a suitable surface where they can germinate and produce new colonies. An individual fungal colony can produce large numbers of spores with the result that spores are almost always present in air and are generally harmless to most of us. However, some people have allergies to mold. This explains why mold spores are often counted, along with plant pollen, to alert people with sensitivities on days when these levels are high. Concentrations of fungal spores are particularly elevated in the fall, when there is plentiful moisture from dew, fruit is beginning to ferment, leaves are falling and vegetation is dying.



Most molds are harmless or, indeed, beneficial. *Penicillium glaucum* is the mold responsible for the blue veining and fine flavour of this Stilton cheese. Other *Penicillium* species cause spoilage of fruit or produce the drug Penicillin. *Botrytis cinerea* is a widespread mold which causes "Noble Rot" of grapes, resulting in valuable wines like Sauternes or this speciality wine.

Fungi of Interest in Construction

Fungi are common in all buildings as their growth requirements for food and moisture are relatively easy to meet. Molds and yeasts are the most common fungi found both indoors and out.

Mold

Molds are a specific group of fairly simple fungi that are often colorful and can appear as spots or fuzzy masses. The downy fuzz that makes up the visible mold growth, when seen under a microscope, is a mat of thread-like structures called mycelia which bear many microscopic spores that easily become airborne. Molds are widely harnessed in the food industry, as well as in medicine and science. The most common fungi found in outside air are generally *Cladosporium*, Basidiomycetes, yeasts, and *Penicillium*. Of these fungi *Penicillium,* and *Cladosporium* are molds. Molds are everywhere, and spore counts are typically much higher outdoors than indoors– this is why sensitive individuals are directed to stay indoors when spore or pollen counts are high.

Molds grow best on sources of freely available nutrients, such as sugar, starch and protein, and in the presence of plenty of moisture. Besides the far corner of the refrigerator, they are most likely encountered indoors on tile grout in the bathroom and window sills as a result of condensation. Basements, garages, and the back walls of cupboards on a cold wall are other likely locations. Molds can also be found in the ducts of the heating and ventilation system. Molds can grow on drywall, paint, wallpaper, insulation, acoustic tiles, wood products and a variety of other building materials, particularly if they get wet during transport, storage, construction or in service. They can grow on carpets, curtains, clothes, footwear and furniture if these get damp. They are common in house plant soil. Different mold species are associated with different substrates.

Mold can only grow within wall cavities if there is enough moisture – for example, due to a leak, or if water vapour condenses inside the wall due to faulty construction. Even if molds grow in the wall cavity, this is of much less concern than mold visible in the living space for the following reasons: (1) the mold is physically separated from human contact by solid elements of the wall, (2) if there is a vapour-retarding layer on or immediately behind the interior drywall (typical in much North American construction) this reduces the diffusion of volatiles from the stud space into the living space, and (3) if there is an air barrier between the cavity and the interior space, this limits air-borne transportation of mold spores or volatiles into the living space. In older construction, unsealed openings into the wall cavity (electrical outlets, etc.) can allow fungal products into the living space but in newer construction, seals are normally used.

In general, molds stop growing if the moisture content of the substrate drops below 19%, or the relative humidity of the surrounding air is below 80%. Substantial growth of mold, which requires higher moisture content or relative humidity, is a strong indicator that the building has a moisture problem, such as a rain ingress or plumbing leak, or excessive condensation due to inadequate ventilation, poor insulation or other causes.

What is Mildew?

Although many people use the word, mildew is a non-specific term with little agreed-upon meaning. Scientifically speaking, a few species of fungi, associated with causing plant diseases and typically white or grey in color, are correctly called mildews. However, the popular usage of the term mildew is as a general equivalent word for mold. Or, more specifically, the term is often used to describe the visible result of mold growth – for example, the dark stains often seen on damp bathroom walls.

Other Fungi of Interest in Construction

Yeasts

Yeasts are occasionally found on construction materials, particularly black yeasts**.** Black yeasts have slimy spores that do not become airborne as readily as molds and are mainly spread in films of water. Like molds, they are common outdoors where they grow in soil and on plants, fruits, and woody debris. On exterior wood that is regularly wetted, they can produce black stain on, and rupture through, paint and varnish. Black yeasts are also found indoors where moisture accumulates, especially bathrooms and kitchens, on shower curtains, tile grout, cold window sills and textiles.

Staining Fungi

These fungi are especially adapted to grow on wet woody substrates, to which they often give a streaky blue or black color. They live mostly in freshly felled logs or green (non-dried) lumber. Unlike molds, most of the biomass of the fungus is not visible on the surface but beneath it. There are two different types of stain caused by staining fungi.

Deep bluestain is associated with logs, and these fungi are often only revealed as a deep blue discoloration when the log is cut into wood products. At this stage the staining fungus has most often stopped growing and it usually dies after the lumber is air or kiln dried. These fungi cannot tolerate dry conditions.

Surface stain is associated with green lumber, grows on the surface of the wood, and may still be alive upon purchase of the product. These fungi are usually not as downy as molds but are more likely to appear as black whisker-like hairs. The hairs produce slimy spores designed to be dispersed by sticking to passing insects. Spores from stain fungi are not easily dislodged from wood; they only become airborne via rain splash and are rarely picked up in the spore traps used to sample air. **While common on wet construction lumber, these fungi are rarely encountered in the indoor living space**. Nevertheless, when a building is made from green framing lumber, stain fungi may initially be present in the wall cavity if they have not died off by the time of purchase. Growth stops as the framing dries.

Wood-decaying Fungi

Decay fungi, which are in the group known as Basidiomycetes, have more complex enzyme systems, such that they are able to break down wood and can therefore cause structural damage – unlike any of the other fungi mentioned above. A sure sign that these fungi are there is the presence of mushrooms or conks (the spore bearing structures) found in the latter stages of wood decomposition. More commonly, decay fungi show up as a white or pale cottony growth, often fan-shaped (see photo, page 7).

Decay fungi can grow on unprotected wood in the presence of moisture and mild temperatures. Outdoors, wood is safe if protected by natural preservatives found in certain species like western redcedar or by pressure treatment with preservatives. Indoors, wood is protected by keeping it dry.

Identifying the Discoloration on Wood

Non-fungal Discolorations

If a wood product appears discolored, the first step is to determine the cause. This will enable one to decide if any action is required. Begin by ruling out non-biological stains such as dirt, ironstain or weathering. Dirt or dust can easily be confused with dark molds. Dirt that has been rubbed into the surface usually has a smeared appearance, but is not fluffy like a mold, nor will it produce airborne puffs of spores when rubbed. If the dirt is not oily, it may wash off with water. Sometimes microscopic examination is required to be sure.

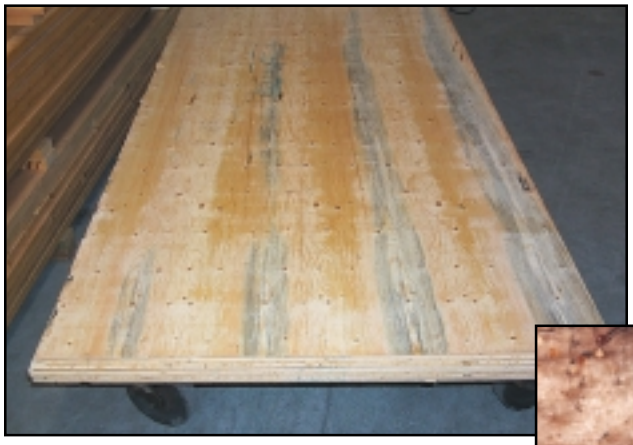
Lumber is sometimes discolored with ironstain – this happens when iron particles react with phenolic chemicals in the wood, leaving behind black iron tannates (a common ink pigment). Iron can come from steel wool, filings, lubricants containing metal fines, from invisible iron particles where the wood has rubbed on steel rollers or chains, or even from airborne particles, for example from the brakes or from the wheel-on-rail friction of railway cars (called travel stain). Diagnosing iron stain can usually be done by spotting a dilute (~3%) phosphoric or oxalic acid on the stained part; the acid breaks down the iron tannate into colorless iron salts, and the ironstain is decolorised.

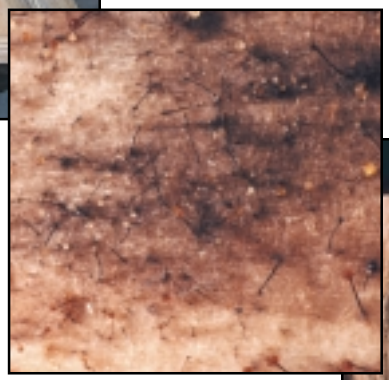
Simple exposure to sun and rain will also cause wood to change color, usually first darkening or yellowing due to sunlight, then eventually weathering to a silvery grey if left outdoors long enough. In all these cases of non-biological staining, the wood has not been harmed and no action is required.

This may look like mold or stain, but it is not biological in origin. It is ironstain caused by iron particles reacting with natural phenolic chemicals in the wood. While it is unsightly, it does no harm to the wood.

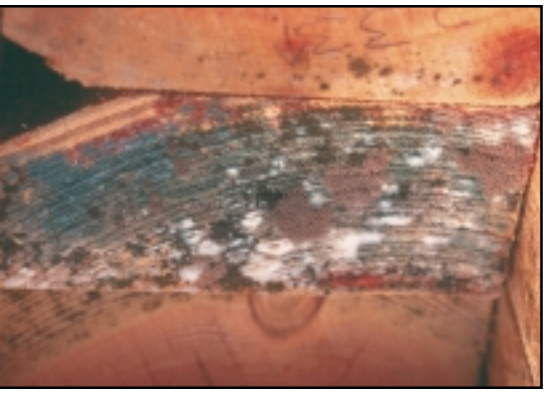
Staining Fungi: They're Innocuous

If the stain is biological, then the discoloration is quite likely due to bluestain or surface sapstain. This will almost certainly be the case for newly-purchased wood products, in a lumberyard or on a construction site. Sometimes there is more bluestained wood on the market, such as that salvaged from trees killed by mountain pine beetles in northern BC. The stain, caused by a bluestain fungus carried by the beetle appears blue or black, and is often streaky, with the streaks following the wood grain. The stain is not harmful to the wood, and the wood will not be damaged by the fungus. The fungus will be dead by the time the dried lumber is purchased and no action is required.





The sapwood in the log cross section (left) is stained because the tree has been killed by mountain pine beetle and the beetle carries a bluestain fungus. The wood is still useful but results in bluestained lumber or plywood (above). The fungus harms neither the wood nor humans and is quite dead in plywood and kiln dried lumber. The green lumber on the far right shows a surface sapstain fungus, which can develop if wood is kept wet for a prolonged period. The wood is not harmed and the wet sticky spores, which grew on top of the "whiskers" (middle right), are not airborne.



Mold is not common on wood, but if it develops it typically has a spotty appearance and smudges when rubbed. The molds seen here growing on the end of a green board include *Penicillium* sp. *Cladosporium* sp. and *Botrytis cinerea*. The latter is the same mold in the specialty wine shown earlier.

Is it Mold?

To an untrained eye, a surface sapstain fungus may look like mold, whether actively growing or not. Several molds can grow on sapwood, usually the same ones found on outdoor woody debris and fallen leaves. Small amounts of mold will be detectable on virtually all re-wetted wood products. Mold does no harm to the wood. It is most commonly found in situations where wood has been kiln-dried and wrapped, but the wrapping has permitted some water to enter and remain. The water makes the air inside the package humid, which enables the localized growth of mold on the otherwise "clean" lumber.

Molds and staining fungi can sometimes be differentiated on the basis of color. Mold growths appear in a variety of colors, including white, black, grey, green, brown, red and yellow. By contrast, sapstain fungi are nearly always black and whiskery, although if growth is active some of the freshest growth may however be still white prior to darkening.

Another way of distinguishing molds from other fungi is if clouds of spores are produced when disturbing an affected area for the first time. If this happens, the discoloration is due to mold and it is advisable not to breathe in the spores, as a precaution. The safest action is to walk away, ventilate the area, and let the spores settle to the ground before clean-up. Identifying exact species of mold cannot be done with the naked eye, nor can it be accomplished by amateurs – molds are identified by experts using a microscope. It is usually a lengthy, expensive and specialized process.

Building Renovation

In a building repair project, opening up a wall may reveal discolored wood products inside, due to any of the causes mentioned earlier. If the wall cavity is dry, it is almost certain that any organisms which may have lived there at one time are now moribund or dead, but spores may still be present. If the cavity is wet, there could be active wood-decaying fungi or molds.

Wood-decay fungi differ from the molds and stains discussed above. They are not often confused with other organisms as they are frequently characterized by fan shaped, cottony mycelia, usually white. In addition, there may be clear evidence of wood decay. If the wood is below about 25% moisture content or if it feels quite dry, the mycelium will probably also be dry and not active. If the wood is damp to the touch or measures greater than 25% moisture content, the mycelium could be active. If the wood itself appears altered, for example, broken into a cubical pattern or a stringy mass, if the wood feels spongy, or if pieces of wood can be easily broken off, then the wood has been structurally damaged. All damaged wood should be replaced.

It is not the intent of this fact sheet to address the remedial actions which may be required if decay or mold is discovered on wood in an occupied building. See the section "for more information" at the end of this document.

Fungi and Health

Of all the fungi species associated with wood, only molds are considered to have potential health effects. This is because some mold colonies produce spores and sometimes metabolic by-products. Among these by-products are alcohols, ketones, esters and hydrocarbons that are volatile under normal atmospheric conditions, and are thus called "volatile organic compounds" or "VOCs." These VOCs contribute to the musty smell associated with active mold growth. Other compounds produced by molds may have no odour and be less volatile. Some of these compounds can be toxic to other organisms (including humans) and are called mycotoxins. Mold spores may also have allergens on their surfaces.

When a mold colony stops actively growing, particularly if it begins to dry out, the VOCs will no longer be produced, but spores may still be dislodged if disturbed, and mycotoxins will still be associated with the mold colony, the spores, and to a certain extent, the substrate upon which the colony grew. For example, moldy food will be contaminated beyond the visible growth of the mold colony.

Molds that have been found in buildings with moisture problems and which have also been suggested as causing health problems include species from the genera *Stachybotrys*, *Aspergillus* (especially *A. fumigatus*, *A. versicolor*), *Fusarium*, *Trichoderma*, *Ulocladium*, *Wallemia*, *Phialophora*, *Acremonium*, *Exophiala*, *Chaetomium*, *Eurotium*, and a bacterial group, the Actinomycetes. Of these, *Stachybotrys chartarum* (*atra*) has drawn particular attention. This mold has an affinity for delignified cellulose materials such as wet wallpaper and the paper layers of drywall (*charta* is Latin for paper).

Wood-rotting fungi show typical fan-like growth of white mycelium. This fungus was spreading under exterior sheathing in a building which had faulty construction.

The relationship between molds and human health is not yet well-understood. Some epidemiological studies indicate correlation with, but not causation of, a variety of symptoms of ill health. The association of mold with damp buildings is well established, as is the association of damp buildings with some types of health problems. However, the contribution of molds to various conditions, such as sick building syndrome, is still being researched. In addition, individuals are highly variable in their response to molds.

Whether or not molds affect people depends on the species of mold, the size of its colony, the spore load in the living space, the sensitivity of the individuals, and the duration of exposure. The VOCs produced by certain molds and actinomycetes under specific conditions may be toxic to people when they reach a threshold level in the air. The toxicity of the VOCs is very dependent on the growth substrate and source of nutrition for the organisms. The most publicized mold that generates mycotoxins in the laboratory is *Stachybotrys chartarum*, but *Aspergillus versicolor* and *Streptomyces* species (actinomycetes) have also been identified as culprits under some conditions. *Stachybotrys* is uncommon but when present, it is always associated with a severe moisture problem and normally shows up as black slimy colonies on damp drywall. The clinical significance of VOCs from mold has not been established.

The health of building occupants, and especially that of hypersensitive individuals, is associated with the quality of indoor air. In addition to the possible contribution made by fungal growth, other factors contribute to indoor air quality, including air brought into the building, interior finishes and furnishings, indoor activities of the occupants, cleaning products, and the condition of the heating and ventilating system. In addition, environments conducive to mold growth also favor development of other organisms, such as dust mites, that are more strongly associated with negative health impacts than mold. For example, Finnish tests of children attending schools with moisture problems indicated more children were allergic to house mites, pollen and animal dander than were allergic to mold.

Sapstain fungi, so common on green wood, have not been identified as potential health hazards. In addition, their spores are not likely to be airborne since they are dispersed by insects or rain splash. The black yeasts have occasionally been associated with health problems, but their spores are also not easily airborne. Wood-decay fungi are not normally identified as health hazards, although two species (*Serpula lacrymans* and *Leucogyrophana pinastri*) have been reported in the literature as associated with rare cases of allergic alveolitis. These species are very rare in wood-frame buildings in North America. In fact, wood-frame buildings are not considered to pose any greater health risk to occupants versus other building types, despite the organic nature of wood and its ability to support certain fungal organisms. Researchers in Finland, where research in this area has been most active, recently found more health problems in newer concrete buildings than older wood buildings.

Does Green Lumber Come with Stachybotrys?

In 1990 and 1999, Forintek conducted studies of fungi associated with green (not dried) lumber in sawmills across Canada. Out of a total of 1646 isolates from 250 wood samples, there was not one single record of *Stachybotrys chartarum*.

What To Do About Mold Indoors

As mentioned, irritations and allergies can be caused by several agents, including dust mites, construction dust, and VOCs from furnishings and some building materials. Sampling for airborne fungal spores requires specialized equipment, laboratory analysis, and expert interpretation if it is to have any value. Sampling done without the advice of someone with training in mycology is unlikely to be useful at best, and is not recommended.

In general, visible mould growth is undesirable in occupied spaces. Heavily colonized (contaminated) materials or furnishings should be removed and replaced with new materials. If mold is nonetheless suspected as the cause of a health complaint, one must realize that there is uncertainty involved with sampling, and sampling is expensive. Simply sampling the air for mold spores will be inconclusive and may unduly alarm building occupants. Fungal spores are found everywhere, indoors and outdoors. There is no simple relationship between fungal spore concentration and health effects, and there are no threshold limit values established for fungal spore concentrations in air in buildings. The issue is not whether spores will be found (they will), but are there more spores, or spores of molds of concern, than expected?

If there is visible mold or any other type of fungal growth indoors, then there is a moisture concern that may cause other, more serious problems, such as deterioration of the building. It's important to find and fix the moisture problem in order to prevent any further complications, including recurrence of mold growth. Please refer to the sources listed for expert information on detecting, remediating and preventing mold indoors.

Forintek Canada Corp.

Forintek is Canada's wood products research institute. Established as a private not-for-profit corporation in 1979, Forintek is an amalgamation of two former public laboratories whose history dates back to 1913. To this day, Forintek continues to provide leading-edge technical support to the solid wood products industry. As part of its broad program, Forintek is a major North American supplier of information on treatment technologies and durability performance of wood and wood products. Visit www.forintek.ca.

THE UNIVERSITY OF BRITISH COLUMBIA

The School of Occupational and Environmental Hygiene

In the Faculty of Graduate Studies, UBC, this school provides graduate education and conducts research on exposures, health effects and control strategies in work and community environments. The aim is to prevent disease and injury, and to promote human health and well-being. Given the nature of the discipline, the School emphasizes applied research and has been interdisciplinary in character since its inception. Formal academic links exist with the Faculties of Medicine, Applied Science, Science, and Commerce. Visit www.soeh.ubc.ca.

For More Information (particularly on mold)

The Condominium Home Owners Guide to Mold

A small booklet published by Canada Mortgage and Housing Corporation providing useful and simple tips on prevention and cleanup. Phone 800-668-2642 in Canada, 613-748-2003 outside Canada.

Clean-Up Procedures for Mold in Houses

A booklet published in 1993 by Canada Mortgage and Housing Corporation.

www.cmhc-schl.gc.ca

Available from the "order desk" at the web site, or phone 800-668-2642 in Canada, 613-748-2003 outside Canada.

Mold in Housing. An Information Kit for First Nations Communities

This is authored by CMHC, Health Canada and Indian and Northern Affairs Canada. Although written recently with the intent of guiding first nations housing providers and managers, this document addresses mold issues in housing, and what to do about it, in layperson's language. Available from CMHC by phoning 800-668-2642 in Canada, 613-748-2003 outside Canada.

Fungal Contamination in Public Buildings: A Guide to Recognition and Management

www.hc-sc.gc.ca/main/hc/web/ehp/ehd/catalogue/bch_pubs/fungal.pdf

Published by Health Canada in 1995, this large, thorough and scientific report provides a protocol for investigating buildings with suspected fungal problems affecting human health.

Guidelines on Assessment and Remediation of Fungi in Indoor Environments

www.ci.nyc.ny.us/html/doh/html/epi/moldrpt1.html

Published in April 2000 by the New York City Department of Health, Bureau of Environmental and Occupational Disease Epidemiology. Covers health issues and provides a protocol for assessment and remediation. Similar in scientific approach to the Health Canada document, however much shorter.

Moulds: Isolation, Cultivation, Identification

www.botany.utoronto.ca/ResearchLabs/MallochLab/Malloch/Moulds/Moulds.html

An on-line book by a University of Toronto professor.

Building Envelope Rehabilitation: Consultant Guide and Owner/Property Manager Guide

A two-volume set published by Canada Mortgage and Housing Corporation in 2001, providing guidance of assessment and remediation of moisture damage in occupied buildings. Phone 800-668-2642 in Canada, 613-748-2003 outside Canada or visit www.cmhc-schl.gc.ca.

Mold Resources

www.epa.gov/iaq/pubs moldresources.html

This United States Environmental Protection Agency website gives comprehensive information on molds including what they are, cleanup procedures and health issues.

Report of the Microbial Growth Task Force.

www.aiha.org/Committees/documents/webmicrobial.pdf

This report, by The American Industrial Hygene Association dated May 2001, covers issues about procedures and methods of remediation of molds in structures.

Forintek Canada Corp. would like to thank its industry members, Natural Resources Canada, and the Provinces of British Columbia, Alberta, Saskatchewan, Quebec, Nova Scotia, New Brunswick, and Newfoundland & Labrador for their guidance and financial support for this research.

This document is also available in French.
Document revised — September 2002