Technical Bulletin 26

Canadian Conservation Institute

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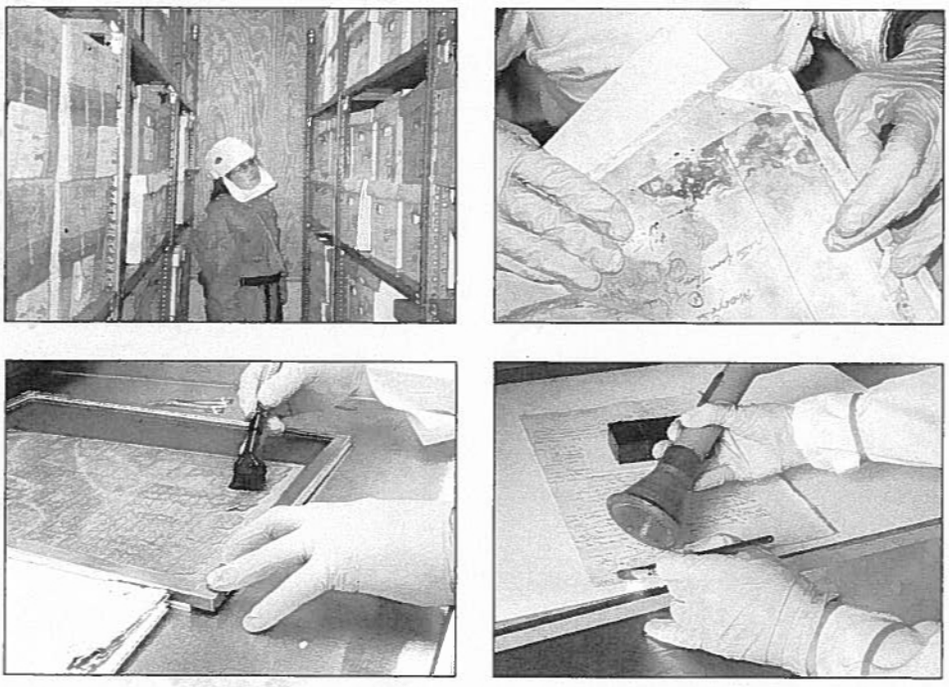
Mould Prevention and Collection Recovery: Guidelines for Heritage Collections



Canadian Heritage Patrimoine canadien

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Technical Bulletin No. 26

Mould Prevention and Collection Recovery: Guidelines for Heritage Collections

by Sherry Guild and Maureen MacDonald

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The authors welcome comments.

Abstract

Mould infestation in heritage collections can damage artifacts and may pose a health risk to individuals who work with these collections. This Technical Bulletin presents information on mould morphology, prevention of mould growth, actions to take should mould occur and health effects relating to mould exposure. It informs the reader how to remove mould growth from artifacts and it describes the appropriate personal protective equipment to wear when working in a mould-contaminated environment or when working with mould-infested artifacts.

Authors

Sherry Guild studied fine art at the University of Guelph and graduated from the Art Conservation Techniques program at Sir Sandford Fleming College in Peterborough, Ontario. Since 1984, she has been a conservator at the Canadian Conservation Institute (CCI) in the Works on Paper Laboratory, Treatment and Development Division, specializing in the conservation of works of art on paper. Sherry has been assisting and advising clients on the recovery of mould-contaminated artifacts since 1999.

Maureen MacDonald has worked in the Preventive Conservation Services Division of CCI since 1981. Her interests include environmental monitoring equipment, ultraviolet filtering materials and biological materials. Over the years, her projects have included the microscopical characterization of frozen archaeological skins and studying preparation techniques for natural history specimens. She has been a member of the Canadian Association for Conservation of Cultural Property (CAC) since 1981 and was named an Honourary Life Member in 1998. Maureen served on the Board of Directors as secretary from 1987 to 1990 and treasurer from 1990 to 1992. Other positions she has held include the Chair of the membership committee from 1992 to 1996 and Chair of the conference committee for the CAC Ottawa 2000 conference. Her current work focusses on the study of mould and mouldy materials.

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Preface

This Technical Bulletin provides general information for the archive, library, museum and gallery community regarding fungal[1] (or mould) infestation in heritage collections. It presents information on fungi morphology, prevention of fungal growth, actions to take should fungal growth occur and health effects connected to mould exposure. It informs the reader how to remove mould growth from artifacts and describes the appropriate personal protective equipment to wear when working in a mould-contaminated environment or when working with mould-infested artifacts.

Treating infested objects with chemicals (i.e., thymol, ethanol, ortho-phenyl phenol) or by non-chemical methods (i.e., gamma radiation, ultraviolet light, microwaves) is not addressed in this Technical Bulletin. For information on these topics, consult the conservation literature[2]. In general, using chemicals to treat mould is no longer recommended for heritage collections. Although chemical methods have been used, their efficacy, possible deleterious effects on the artifact and considerations about the effects of these substances on humans have not, in some cases, been fully investigated. Also it is important to note that killing fungal organisms usually does not destroy their antigenic or toxic properties. This means that dead fungal growth on the artifact remains a health concern and that no chemical treatment confers lasting or residual mould control. These factors have contributed to the shift away from using chemicals to treat mould infestation in heritage collections[3].

Any treatment to combat mould infestation should focus mainly on measures that keep the level of moisture in the air and the moisture content of the artifact below the level conducive for mould growth. The conscientious removal of mould growth and the reduction of spores from infested artifacts are also necessary.

This Technical Bulletin adopts information regarding levels of mould contamination and appropriate personal protective equipment from industry guidelines for remediation of mould in buildings. Sources include:

- Health Canada. *Fungal Contamination in Public Buildings: A Guide to Recognition and Management. Federal-Provincial Committee on Environmental & Occupational Health*. Ottawa: Environmental Health Directorate, Health Canada, June 1995.

- Manitoba Department of Labour. *Guidelines for the Investigation, Assessment & Remediation of Mould in Workplaces*. Winnipeg: Workplace Safety & Health Division, Manitoba Department of Labour, November 2000.

- New York City Department of Health. *Guidelines on Assessment and Remediation of Fungi in Indoor Environments*. New York: April 2000.

However, this Technical Bulletin does not address mould remediation in buildings, building envelopes or heating, ventilation and air conditioning systems. For information on these subjects, consult the appropriate professionals.

PLEASE NOTE: It is strongly recommended to read the entire Technical Bulletin and to consider the information carefully before proceeding to treat mould-infested collections. If in doubt, consult professionals. Mould can be a serious health concern and medical research into its effect on humans is a rapidly developing area. Regard the presence of mould growth as a potential health hazard. Keep abreast of research while undertaking work in this area.

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1. Mould Prevention

1.1 Mould

The nature of fungi, how they grow, under what conditions, the viability of mould spores and triggers of activation are discussed in this section. Although mould remediation in buildings is not addressed in this Technical Bulletin, mould, or conditions conducive to its growth in buildings, presents a risk to the collection. For this reason, detection of mould spores, the level of mould spores likely to be found in indoor environments and a chart identifying potential sources of mould in buildings and factors contributing to its growth are presented.

What is Mould?

Moulds are members of the Kingdom Fungi. There are thousands of fungi species, ranging from yeasts, which are single-celled organisms, to the more complex multi-cellular mushrooms and toadstools. The majority of fungi lie somewhere in between. Fungi play an important role in the cycle of nature. Unlike green plants, fungi lack chlorophyll and cannot photosynthesize their own nutrients from carbon dioxide and water. Most fungi are saprophytic; that is, they are organisms that live on and derive their energy from dead or decayed organic matter, such as plants, food, leaves, etc. They feed solely by digesting the substrate (i.e., the surface) on which they grow. A few are parasitic and some live symbiotically with a host. Their growth is often called mould. Mildew, a term often used to describe mould in the home, is actually a parasitic fungi that grows only on living plants.

Under a microscope, mould looks like a network of thread-like filaments, referred to as hyphae, woven into a network, called the mycelium. Moulds grow from microscopic spores, some of which are referred to as conidia[4]. The conidia are produced during the sexual reproductive phase from a specialized structure or fruiting body, called a conidiophore. The shape of a spore is determined by the species. A spore can be round, elongated, oblong, cylindrical, sickle-shaped, single-celled, multi-cellular, etc. In general, spores and fruiting structures must be present before most moulds can be positively identified. Depending on the species, spores range in size from 1 to 200 μm in length (a micron (μ) is one-millionth of a metre or 1/25,000 of an inch). Even the largest spores are buoyant enough to be carried long distances by air currents.

In the temperate regions of Canada, the most common species of moulds are *Cladosporium, Alternaria, Aspergillus* and *Penicillium*. The latter two species are mostly found indoors. These species are known as filamentous or conidial types. The spores (conidia) form at the ends of branched (tree-like) structures called conidiophores (Figure 1). In general, the species of mould found inside a building are the same as found outdoors, but they are found in much lesser concentrations.

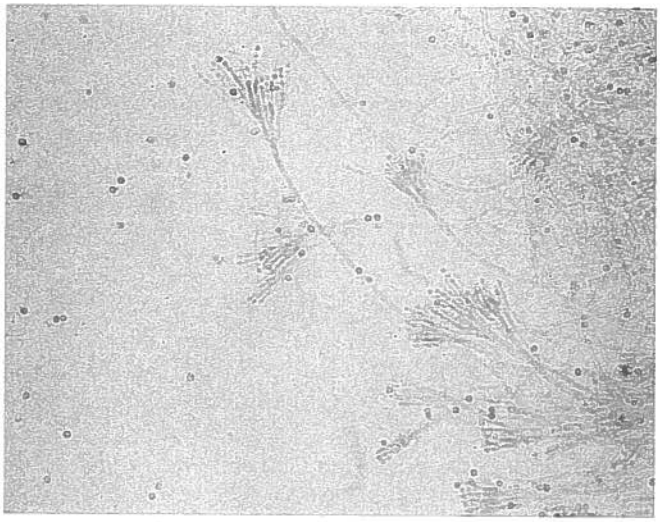

Figure 1. Conidia and conidiophores of a Penicillium *species.*

Mould Growth

Mould can grow under a very wide range of conditions. When the environment is suitable for germination, the spore swells and a germ tube extends outward. For most mould, this action is triggered by a significant change in temperature or in the elevation of moisture. A germ tube is a vegetative cell that elongates as it assesses the amount of moisture and nutrients in the substrate. If adequate moisture exists, the germ tube begins to branch as it continues to elongate. These branches multiply and become the hyphae. The hyphae grow forming an interwoven colony of fibres called the mycelium. Depending on the texture or porosity of the material on which the mould is growing, the hyphae will penetrate, to some degree, into the substrate (Figure 2). Sporulation, the production of fruiting bodies and spores, can result from a change in the growing conditions of the mycelium (Griffin 1981). Specialized hypha form into conidiophores that mature and release spores into the air, which starts the cycle again. Conditions that have the potential to trigger sporulation include:

- exhaustion of nutrients
- production of chemical by-products
- changes in light and temperature

Mould grows outwards from a central point in a circular pattern (Figure 3). The centre of the mycelium is the first to die out. It does so for two reasons:

- the nutrients become exhausted
- different chemicals appear during metabolism that inhibit mould from growing back on previously infested areas

These mechanisms ensure that the hyphae are always spreading outwards and seeking new nutrients. The newest growth, usually white, is on the leading edge. The centre of the mycelium can develop a colour, which results when spores are formed. Colour change can also indicate a pH change in the substrate. As the spores mature, the colour of the area can also change.

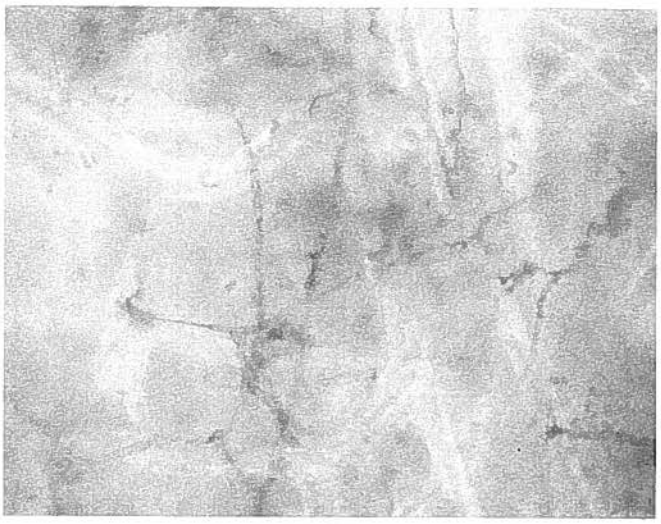

Figure 2. Mould hyphae and spores embedded into paper fibres.

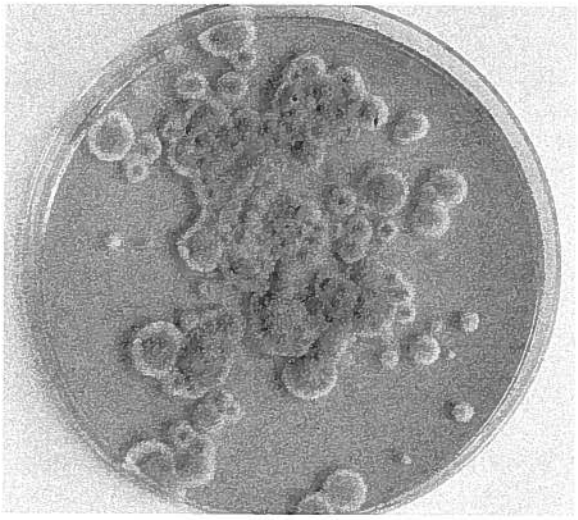

Figure 3. Agar plate of mould.

Requirements for Growth

Nutrients

The nutrients required for mould growth are very basic and are supplied by organic materials. Enzymes break down the organic substrate into the necessary nutrients that are absorbed through the hyphae walls. Nutrients are derived from simple sugars, starches, small peptides and complex carbon-containing substances such as amino acids. In fact, fungi are able to secrete a tremendous number of enzymes capable of digesting any organic material, either plant or animal. However, non-organic materials, such as glass or metals, can also support growth if there are residues of organic materials on their surfaces.

Moisture

In order for a mould spore to grow, several conditions must be present. The first and most important is an adequate amount and supply of moisture. Each mould species requires a minimum amount of water in order for the spore to swell and begin germination. This water

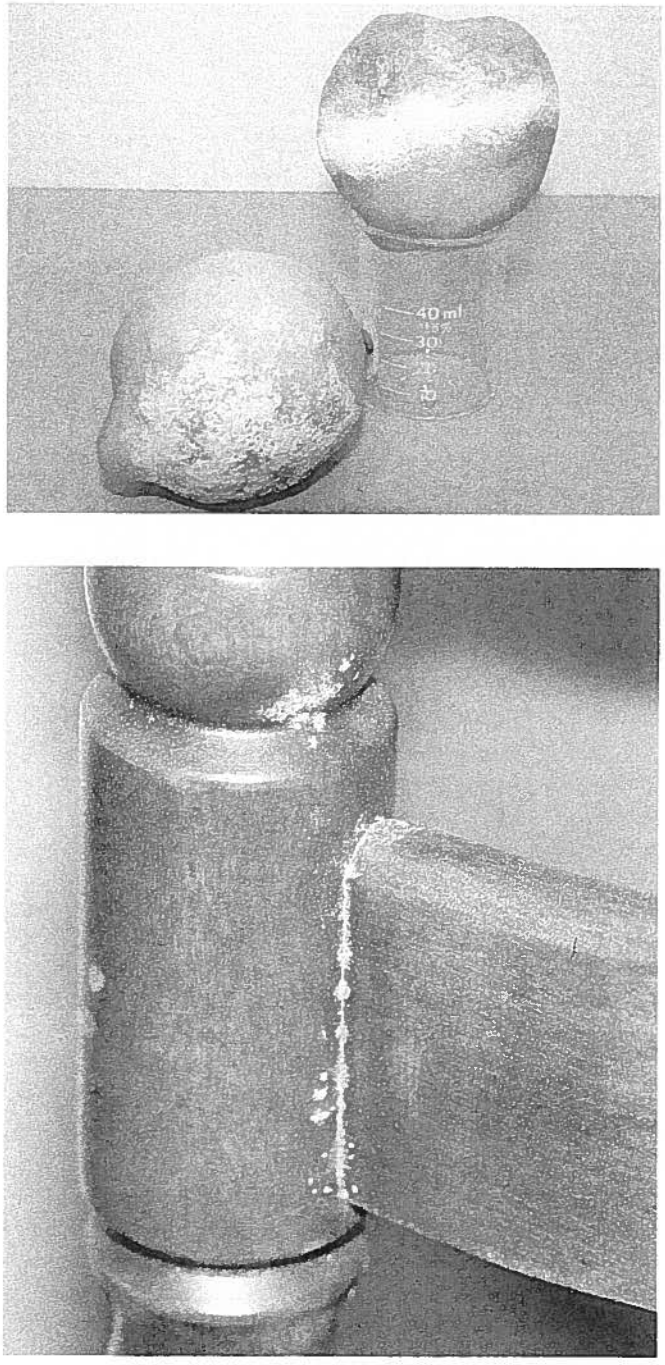

Figure 4. Examples of mould on food stuffs and artifacts.

comes from the substrate material. Water vapour in the air, measured as the relative humidity (RH), influences the moisture in the substrate material. This source in the substrate is the only moisture available to the mould.

Biologists describe the moisture available in a substrate by the term water activity (a_w), expressed as a fraction of 1 (Ayerst 1969). Water activity is equivalent to the equilibrium relative humidity (ERH) of air adjacent to the material or within its pores. ERH is measured by placing the material in a sealed container and then measuring the RH of the trapped air, after enough time for equilibration has elapsed. Thus, a measurement of 90% RH indicates an ERH of 90% and, in turn, an a_w of 0.9. The majority of moulds will not grow until the a_w of the substrate material is 0.75 or higher (Onions et al. 1981). (This value is discussed in more detail in a later section.)

Temperature
Moulds are able to grow under a very wide range of temperatures, as exemplified by mouldy food in the refrigerator. Most mould spores will grow in temperatures from 4°C to 30°C (39°F to 86°F). The rate of mould growth can be regulated by temperature. Growth decreases with lower or higher than optimal temperatures. The majority of heritage collections are maintained between 15°C and 25°C (59°F and 77°F). These temperatures are ideal for mould growth. (It bears noting that Canadian collections kept in unheated winter conditions below 0°C [32°F] are, therefore, not at risk of mould growth until spring.) Short-term exposure to temperatures slightly beyond those for optimal growth will bring about dormancy. A return to optimal conditions will activate growth. Freezing temperatures kill growth. However, some spores can also tolerate extended periods of extremely low or high temperatures. Spore viability is diminished by the alternating action of freezing and thawing.

pH
The pH (acidic, neutral or alkaline) of the substrate will affect the germination, colour and growth of mould. The pH range of the substrate for spore germination may extend from 2 to 9. The optimum is between pH 4 and 7. Many artifacts in heritage collections fall within this range. Actions, such as washing or deacidification, to adjust pH do not deter mould. As with moisture, certain species of mould have different pH triggers. The pH of the substrate material is likely to be altered due to the chemicals released during metabolism, such as metabolites, enzymes and exudates.

Air circulation
Air circulation is important to maintain an even level of RH. Good air circulation eliminates areas where a micro-climate of high or low RH might develop. If water damage occurs, a good flow of dryer air facilitates rapid evaporation and drying, thus preventing the retention of moisture in the substrate material that would make it conducive to fungal growth. In some circumstances, for example air drying damp artifacts, air circulation may be a factor in determining whether or not mould grows. An adequate airflow, one that feels "drafty", will help prevent fungal growth.

Light
The role that light plays in mould growth is not well defined. Some studies of certain moulds have shown that light affects moulds in the following ways: it may inhibit growth, affect the direction and rate of growth and affect the production of certain compounds (toxins and volatile organic compounds). Light can also affect the reproductive processes of mould. For some species it is essential, for others it is not required.

Artifacts stored in the dark to reduce the rate of deterioration are not more susceptible to mould growth than those stored under light. Light is not a critical factor for controlling indoor fungal growth: nutrients, moisture and temperature are the critical factors (Shaughnessy et al. 1999). However, mould growth may go undetected for long periods of time if routine inspections of storage areas or areas where human occupation is minimal are not regularly carried out. Also, there is less natural air circulation in dark storage areas, which may contribute to mould growth.

Viability

Dormant (inactive) spores wait for the right amount of water and nutrients before beginning to grow. As spores age waiting for optimal growth conditions, their viability decreases. Some species of mould spores are capable of remaining viable for many years, while others are able to survive for only a few hours. Within the particular range of a certain species, environmental conditions play an important role in the viability of spores. Fluctuations in temperature, RH and radiation are all factors of viability, as is the presence of many chemical agents, such as fungicides. Spores of the species *Aspergillus* and *Penicillium* are known to be viable for up to 10 years (Sussman and Halvorson 1996).

It is also believed that certain species of mould spores are activated by chemicals, such as detergents or organic solvents (e.g., acetone and ethanol/water mixtures). This action is not well understood. Perhaps some of the chemicals acting as wetting agents cause the activation (Griffin 1981).

Levels of Mould Spores

All mould spores originate from the outdoor air. Spores in the air fall on artifacts, regardless of where the artifacts originate, travel, are stored or displayed. Thus, it is important to remember that artifacts are never completely spore free. The species of mould differs depending where in the world it is located and what season it is. The level or concentration of spores in the air also varies with the season, temperature, RH and geographical location.

Every mould has a favourite environment and favourite nutrients upon which it prefers to grow. In the temperate regions of North America and similar climates, the most active period for mould spores is spring to fall, when there is the highest concentrations of mould spores outdoors. In other climate regions, such as the tropics, high concentrations may be found throughout the year or mould concentrations may have higher and lower periods depending if it is the rainy or wet season. In tropical regions, *Aspergillus* and *Penicillium* species are more dominant than in the temperate regions of the world (Mullins 2001).

The species of mould found indoors should be similar to those found outdoors. In a normal healthy indoor environment, concentrations of mould spores are much less than those found outdoors. It has been reported that at peak times during the year, outdoor fungal particles can reach $10^4/m^3$ (Miller 2001). An indoor air-handling system filters out a portion of the spore material based on the filter's efficiency.

The following levels measured in CFU/m^3 (colony forming units per cubic metre) are considered acceptable for human occupation in an office-type building or institution (Health Canada 1995):

- 50 CFU/m^3 of a single species other than *Cladosporium* or *Alternaria* spp.
- 150 CFU/m^3 of a mixture of outdoor species (higher counts suggest dirty or inefficient air filters or other problems)
- 500 CFU/m^3 of *Cladosporium* in summer only (higher counts suggest dirty or inefficient air filters or other problems)

If indoor air quality tests identify a fungi that is not found outdoors at that time of the year, it may indicate an indoor source, referred to as an fungal amplifier, growing inside a building or collection. These higher levels may indicate a moisture problem or other conditions favourable to mould growth that may already have reached or may eventually reach a collection. Action should be taken immediately to deal with the problem.

High concentrations of certain mould species pose a health risk for humans. Breathing air containing a normal array of mould spores does not usually affect healthy humans. However, if a mould problem exists in a collection (or a building), the concentration of spores can be many times the concentration normally found indoors. This could lead to adverse health issues in hypersensitive people. (Health issues are addressed in **Section 1.5 Health Effects** [p. 13].) Further investigation will be required to determine the source of the mould.

Detection

Moulds commonly found on bread or other food stuffs are recognized by their fuzzy, coloured appearance or smell. Mould growth on artifacts has essentially the same appearance and smell. The smell is the odour of the microbial volatile organic compound (MVOC). The fuzzy growth is often black or white, but can appear in other colours depending on the substrate it is growing on. The growth consists of thread-like filaments – the hyphae. When actively growing, the mould patch will be damp and smear if brushed.

Fungal growth on artifacts may also be encountered in a dormant state. When dry, it may appear as a coloured stain, smudge or dirt. It may smear when brushed. Artifacts that exhibit signs of previous contact with water may contain fungal growth. If this growth has had a recent contact with water and crucial growth factors are present, it may become active again. Given enough time without critical growth factors, the mould hyphae may die. Dormant fungal growth may not emit the characteristic mouldy smell. Although dormant mould does not pose an immediate risk to an artifact, it may be a health risk to humans. **Mould does not lose its allergenic or toxigenic properties when it is dormant or non-viable.**

As noted above, one indication of a fungal problem is its familiar musty, earthy odours. These odours include:

- musty paper-like, mildew-like mustiness
- fresh mushroom-like mustiness
- heavy cat-like mustiness
- sack-like mustiness
- snow pea pod-like mustiness

Certain odours can be attributed to specific moulds of the *Aspergillus* and *Penicillium* variety (Burge 1995). Some of the MVOCs making up these odours include alcohols, esters, terpenes and ketones.

One of the most obvious places to encounter mould is in a basement or in a below-ground-level storage area. Basements are usually damp, dusty and dark locations with stagnant air. These four conditions can make a basement or any area a likely habitat for mould to grow. Most often these locations are below ground level, have earthen floors, crawl spaces, cement or masonry-type walls that transfer water vapour. Basements are also prone to lower temperatures, higher RH and poor air circulation. Crawl spaces are usually poorly ventilated, which creates areas with chronic high humidity. It is important that properly screened, adequate venting be installed and maintained throughout the year. Venting should be open in the warmer months and closed in the colder months. Calculations to determine venting requirements can be found in ASHRAE 1985.

Fungal growth can also be found where there has been a saturation of water. Accidents such as a leak from a broken pipe or roof, backed-up sewers, the failure of a heating, ventilation or air conditioning (HVAC) system and fire and floods can all elevate the RH and may initiate mould

growth. A significant temperature drop can also increase the RH. Corners on the outside of buildings at roof or floor lines are susceptible to cooler temperatures and higher humidity. If these conditions are not dealt with quickly (within 48 hours), mould growth can begin.

Dirt and dust are hygroscopic (water loving) and a source of nutrients for mould. Their presence in the collection may increase the potential for mould to grow. Mould spores and mould fragments, such as hyphae and mycelium, settle out of the air at a rate determined by the size of particles. Spores can fall at the rate of 0.5 cm/s to 2.8 cm/s onto surfaces and become part of the dust and dirt (Mullins 2001, Tétreault 2003). Figure 6 shows the comparative sizes of various airborne pollutants.

Some storage conditions may contribute to mould growth on artifacts. Cardboard, wood, adhesives and sizes provide a suitable nutritional base for mould. Boxes, especially cardboard or wood sitting on cold floors or against exterior cement walls, absorb moisture and may support mould growth. Mould growth on the container may contaminate the contents of the container as well as the surrounding environment, including any artifacts in the area. Other examples of susceptible artifacts may include wooden furniture or paintings stacked against an exterior cement wall. It is not recommended to store artifacts directly on floors or leaning against exterior masonry walls.

Artifacts stored in archival-quality matboard boxes and paper and plastic enclosures are somewhat more protected against fungal growth than those stored in the open. For short periods of time, a box or other container made from a hygroscopic material, such as paper, cardboard or wood, buffer the artifact from increased ambient RH. However, a prolonged period of elevated RH is enough to raise the water activity of the artifact inside the container to a point where it can support mould growth. Contact of the container (or artifact inside) with water is a significant risk. If an artifact is in a well-sealed impermeable container (i.e., polyethylene bag or container), it is protected from sudden increases in ambient RH and from direct contact with water. It is crucial that the artifact is dry when placed inside the container and does not have an equilibrium moisture content (EMC) capable of elevating the ERH in the container beyond 65%. If periods of elevated RH are prolonged, staff should regularly examine the artifacts stored in enclosures (paper or plastic) for mould growth.

It is important to note that eventually those artifacts within polyethylene containers will reach equilibrium with the outside ambient RH (Strang 2001).

The first two columns of Table 1 (p. 6) follow Macher (1999) and illustrate potential sources of bioaerosols (mould, bacteria, viruses, etc.) contamination in buildings and the factors contributing to mould growth. The building engineer or maintenance person in charge of the building and its air-handling system should be aware of these potential trouble spots. The third column suggests programs or measures to prevent the problems from happening.

1.2 How to Prevent Mould Growth in the Collection

Because mould spores are everywhere in the air, it is impossible to completely eliminate them from a building, a collection and storage or exhibition areas. They circulate in the air moving with the air currents, some falling on the surface of artifacts, floors, walls, ceilings and furnishings. They drift indoors through the air-handling system, open doors, windows and drop off people and materials coming into the building.

The most effective strategy to prevent damage to artifacts and to prevent adverse health effects for humans is to ensure that the environment and other conditions inhibit mould growth. This section focusses on ways to prevent fungal growth in a collection and a building.

Figure 5. Water-damaged building materials.

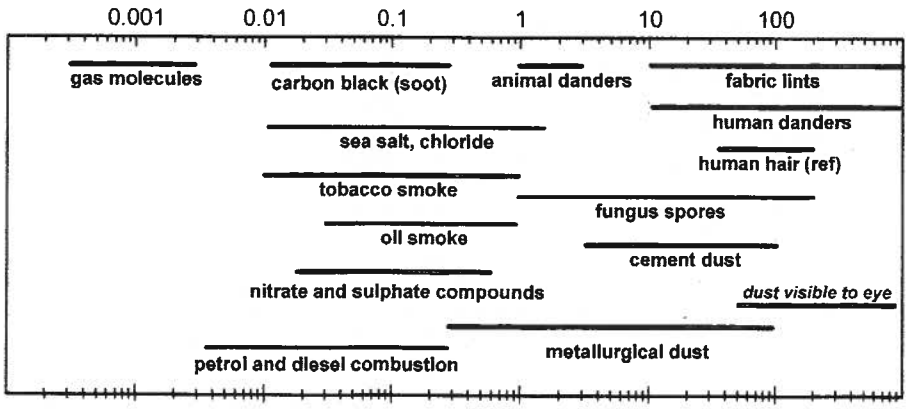

Figure 6. Graph showing the particle size in microns (μm) of various materials.

Table 1. Maintenance of Building and Engineering Systems

Source	Contributing Factors	Preventive Measures
Building exterior	• intrusion of water through cracks, etc., improper grade near a building, rain gutters (blocked or drained too close to building), damage to exterior envelope (wall) • pest intrusion (the majority of moulds are located in dirt and organic material on the ground – pests living in these areas carry mould spores on their bodies)	• immediately repair all sources of water leaks from the outside • maintenance and inspection programs for exterior building surfaces, etc. (rain gutters, door seals, etc.)
Outside air	• nearby agricultural area, construction sites, composting operations, water treatment facilities	• face air intakes away from source of contamination • close windows and doors in direction of source of contamination
HVAC systems, air intakes	• sources of bioaerosol composed of dead plant material, pest infestations, pest excrement, moisture from standing water evaporating condensers and cooling towers adjacent to a building intake supply	• regular inspections of air intake area and regular cleaning program
Filters	• damp, improper fitting, low efficiency	• regular maintenance and replacement program
Heat exchanger	• poorly maintained (dirty, excessive water in pans, improper drainage, damp acoustical linings, stagnant water in humidifiers)	• regular maintenance and regular cleaning program
Plenums and duct work	• dampness, humidifiers inaccessible, dirty surface deposits	• regular maintenance and regular cleaning program
Air diffusers	• surface deposits, rusty (indicates a moisture problem), microbial growth, poor air mixing	• regular inspection and regular cleaning program
Occupied space - water damage	• history of roof leaks, spills, plumbing problems, musty odours • carpets always requiring cleaning, excessive humidity (>65%)	• repair and fix any leaks, spills and plumbing problems immediately
Constant condensation	• poor insulation, poor vapour barrier and hot humid air from the outside condensing on air conditioned (cooler) surfaces causing moisture on windows – outside walls and cool surfaces – and the opposite – warm, moist, interior air condensing on cooler envelope (exterior wall) material	• use dehumidifier in conjunction with air conditioner in summer, • lower humidity levels during winter
Window air conditioners	• poor maintenance, dirty grills, standing water	• properly sized for space, regular inspection and cleaning program (drip pans)
Potted plants	• over watering, mould growth on leaves, soil and plant containers	• eliminate potted plants where possible, do not over water plants
Carpets	• previously water-damaged, dirty, poor maintenance, frequently washed without sufficient ventilation to dry quickly, traps spores (electrostatic effect)	• maintain regular cleaning program, replace or professionally clean previously damaged carpets, provide adequate ventilation for faster drying
Fabric partitions, drapes and furniture	• previous water-damaged items, poor maintenance, dirty, traps spores (electrostatic effect)	• maintain regular cleaning program, replace or professionally clean damage items
Portable humidifiers and dehumidifiers	• poor maintenance, drip pans	• properly sized for space, regular cleaning and maintenance program

Critical Factors to Control

Reducing indoor spores

Mould spores can only be reduced, not eliminated. The following actions can be taken to limit spores entering the indoor environment (Flannigan 2001):

- closing windows and doors reduces outdoor spores by 2%
- using central air-conditioning reduces outdoor spores by 5%
- using electrostatic filtration reduces outdoor spores by 3%

Nutrient sources

When they are broken down into simple sugars, amino acids and small peptides, many artifacts provide suitable food for mould growth. Artifacts made from organic material or that have organic components, such as paper (cellulose, sizes and coatings), some media, book cloth, leather, basketry, wood, upholstery, cotton, linen, wool and photographic materials, are definitely food sources. Some inorganic artifacts may also be susceptible to mould because of their age and surface accretions of dust, dirt, insect debris and oils from handling. Where possible, remove nutrient sources that encourage fungal growth by cleaning and maintaining the collection as well as storage and display areas. Dust is a major source of fungal spores and nutrients.

Moisture

Moisture, as has already been stated, is essential for mould to germinate and grow. Because it is practically impossible to eliminate all nutrients, moisture becomes the easiest factor to control. It is essential to avoid two conditions condusive to mould growth: all peaks of very high RH that initiate spore germination and prolonged periods of elevated RH that support mould growth.

Figure 8 illustrates the relationship between RH/a_w and mould growth (Michalski 2000):

- at 65% RH, 0.65 a_w, experiments lasting three years show no noticeable mould growth
- at 75% RH, 0.75 a_w, growth is noticeable between two and three months
- at 80% – 90% RH, 0.80 – 0.90 a_w, growth is noticeable between three and five days

Based on this information, one can ignore short periods "high" RH in each range given, as long as the duration is substantially less than the period stated above for noticeable growth.

The risk of mould damage to artifacts obviously increases from extended exposure to RH and depends on the ability of the artifact to absorb water vapour. The risk of mould beginning to grow can be greatly reduced by storing objects in containers. The important issue is how long will the particular container protect the enclosed object from high humidity exposure. In uncontrolled environments, containers such as closed cardboard boxes protect artifacts for only a very short period of time. For long-term protection, sealed plastic containers are more effective. Once the objects inside reach levels of greater than 0.75 a_w, containers or boxes work against maintaining mould-free objects. Objects that have already absorbed water vapour

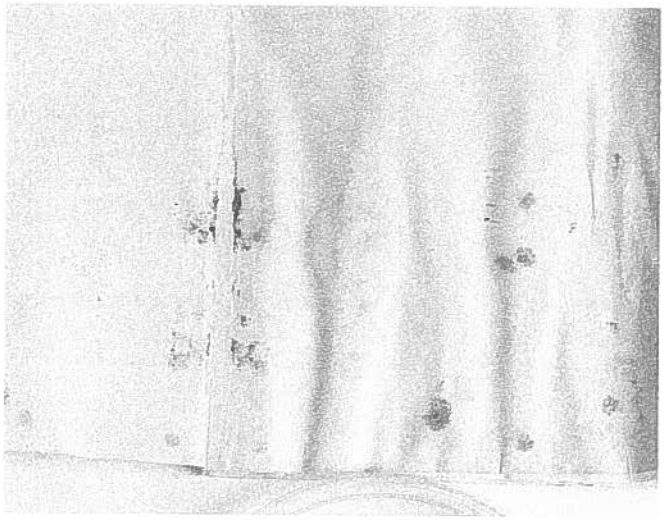

Figure 7. Water-damaged book showing mould growth.

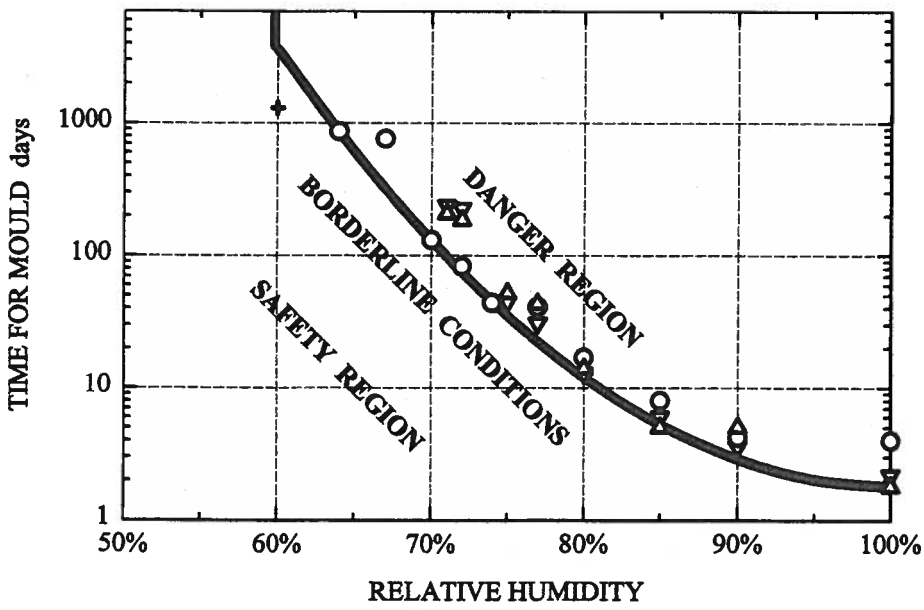

Figure 8. Graph showing time required for visible mould growth, assuming highly susceptible material at 25°C and an RH that has climbed (not fallen) to these values.

are slow to dry. Although the environment inside the container will eventually reach an equilibrium with the normal outside environment, the artifact will react more slowly. Therefore, for a period of time, the artifact may retain a level of water activity sufficient to support mould growth. Two properties govern the environment within containers: the rate at which water vapour can permeate the container and the ability of the artifact to buffer the internal humidity/water activity.

Figure 9a shows the time it takes for moisture to permeate or leak through various barriers. It is assumed the conditions are at equilibrium. Note that by bagging an object, the response rate to moisture changes can be decreased from minutes and hours to up to a year.

Once the artifacts have been stored in polyethylene bags it is still important to maintain the ambient temperature so as not to promote the growth of mould within the bags. Following are some suggestions for bagging artifacts (Strang 2001):

- bag artifacts with an ERH less than 65% and avoid elevating temperatures that would raise the ERH above 65%
- do not bag artifacts at an ERH above 65%
- do not store the bags on a cold shelf or counter top (this creates a temperature drop, which increases the RH in the part of the bag closest to the shelf)
- do not store the bag in a high RH environment because eventually water permeates the bag (note that this permeation significantly slows down if the object is well wrapped in RH-buffering material and if the entrapped air volume is small when compared to the wrapped object)

Figure 9b graphically illustrates the above situations that may arise with bagged artifacts. A change in the ambient temperature will cause a change in the ERH. If the artifact was initially bagged at 55% RH (I) and there is a 15°C drop from the ambient temperature, the RH within the bag will climb to 80% (C). An increase of 15°C will lower the RH within the bag to 35% (W).

There is no single way or one instrument that can be used to measure the moisture content of all substrates. To determine the ERH, the following steps can be taken. Place the artifact into a clear, airtight container that allows one to read the hygrometer inside the container. Allow time for equilibrium to be reached. The reading on the hygrometer shows the RH value equivalent to the object's moisture content/water activity.

Ambient RH is often used to indicate mould growth potential. By keeping RH values below 60%, it is logical to assume that corresponding a_w values in substrate materials would be limited to 0.6, which is the lowest a_w level at which certain moulds can begin to grow.

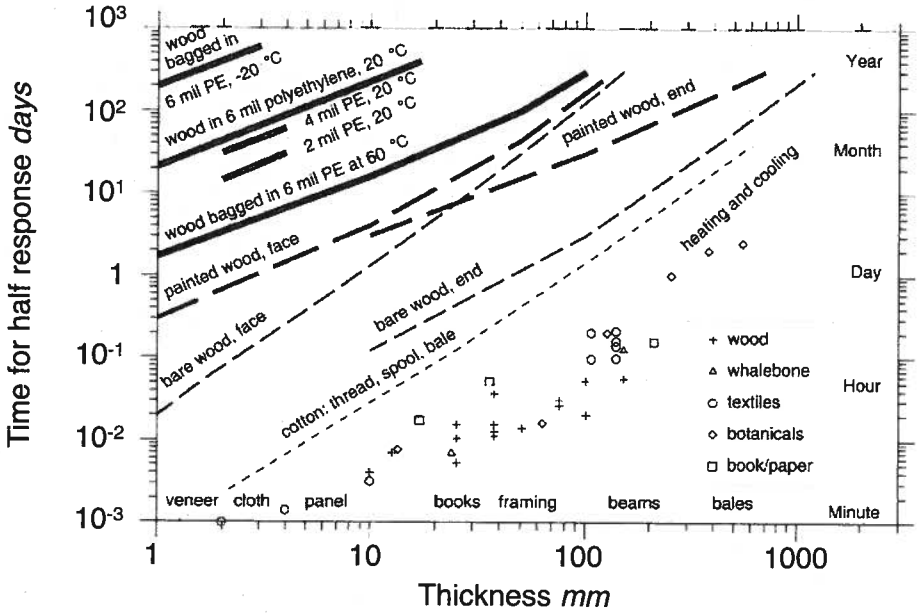

Figure 9a. Half-time response curve.

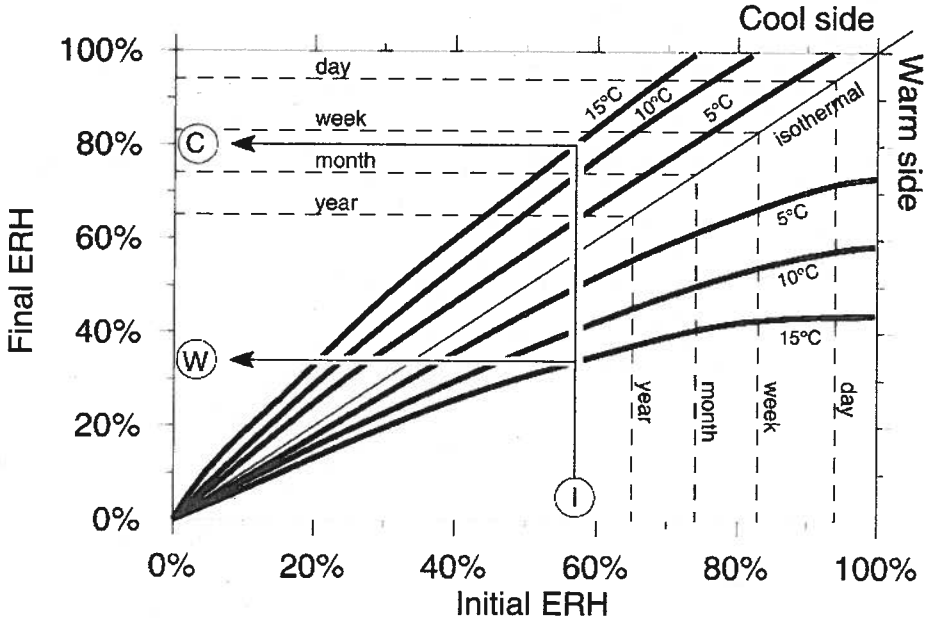

Figure 9b. Changes to initial ERH caused by temperature shifts.

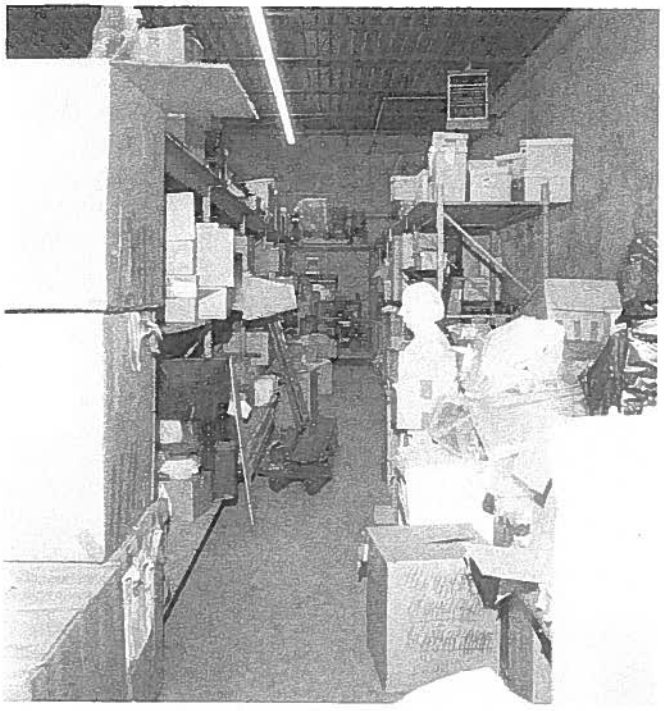

Figure 10. Improper storage limits air circulation.

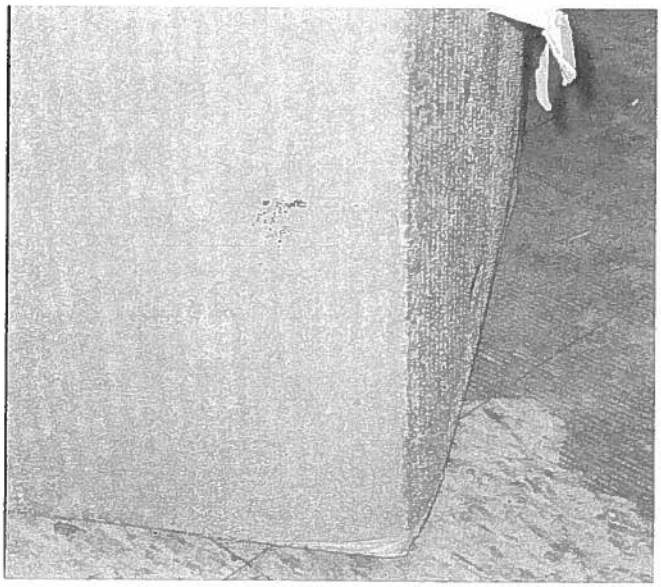

Figure 11. Example of a mouldy box.

Limiting the a_w of materials in heritage collections to less than 0.75 (as described by Michalski 1993) will prevent mould problems from rapidly building up. However, maintaining a level less than 0.6 should be the primary goal.

In the event of water intrusion or elevated RH, remedial action must be taken as quickly and as efficiently as possible. Staff must be ready to respond to eliminate the moisture problem in order to avoid, or at least limit, a mould outbreak.

Air conditioning

It is crucial to control the moisture content of the air so that it does not exceed 60% RH when using air conditioning systems. This can be achieved if dehumidifiers are used in conjunction with large heating, ventilation and air conditioning (HVAC) systems. Small, portable window air conditioners must be properly sized for the space. Window air conditioners tend to be cyclic. Warm, moist air passes over a refrigeration unit and is cooled. At the same time, moisture condenses and runs into a drip pan. As the refrigeration unit cycles, it shuts down and the frost/ice buildup melts into the drip pan. Because warm air is still being passed over this unit and the drip pan, it, therefore, picks up some of the moisture in the drip pan and carries it into the room. An effective way to ensure good humidity control is to also operate a dehumidifier. Domestic dehumidifiers with a capacity of 200 cubic feet per minute will handle a 12,000 cubic foot room (this equipment is capable of exchanging the room air once per hour). Be aware that the dehumidifier will not operate efficiently below 18°C (65°F) or 35% RH. Some dehumidifiers using desiccant wheels will work efficiently below 18°C (65°F). The dehumidifier must be properly sized for the space and the drip pans on both humidifiers and air conditioners must be cleaned regularly.

Air circulation

Maintaining room RH below 60% may keep materials dry, but it does not eliminate the possibility of mould growing in local cold spots (i.e., exterior walls and corners) or of water leakage that may raise the RH near the substrate material over 70% (Flannigan and Miller 1993). For example, in a room with a temperature of 20°C (68°F) and 60% RH, the surface temperature of an exterior wall may be 15°C (60°F) and the resulting RH 80%. The wall will absorb moisture increasing the a_w from 0.60 to 0.80 and enabling certain moulds to grow. If the surface temperature of the wall reaches dew point temperature[5], the resulting condensation may allow mould to grow despite the ambient RH being in the right range. Proper air circulation would help eliminate these concerns. It is very important not to store cardboard boxes next to a cold exterior wall because they will absorb moisture and be vulnerable to mould growth (Figure 11). In order to prevent this from happening, storage enclosures, artifacts or other materials should be located 35 cm to 45 cm (15 in. to 18 in.) away from outside walls. Maintaining this space will allow good housekeeping to be practised, some circulation and access to the wall if water seeps through it.

Temperature

In many buildings, the temperature is determined by human comfort level, which ranges from 18°C to 24°C (65°F to 75°F). This temperature range is also within the optimal range for mould growth. In areas not normally occupied by humans (e.g., seasonal museums, long-term storage), a lower temperature will benefit the collection, provided the RH is also kept lower than 60%.

Preventive Measures Checklist

In summary, the following checklist of preventive measures can be used to maintain a stable environment and prevent mould growth in a collection:

- maintain RH below 60% (this includes preventing any temperature drops)
- maintain good air circulation
- conduct regular inspections of artifacts on display and in storage
- remove dust by instituting a program for regularly cleaning floors, shelves, cabinets, surfaces of materials, such as boxes, plastic coverings, etc.
- isolate in-coming artifacts, examine and, if necessary, clean off dirt and debris before housing them with a collection
- guard against water leaking into a building and a collection
- use ongoing programs to maintain environmental control systems, portable humidifiers and dehumidifiers
- always separate plants and food areas from artifact storage and display areas

After a water leak, immediate action is required to prevent the onset of mould growth:

- at the first sign of mould in a collection, isolate the contaminated artifact(s) and locate and correct the causative agent
- immediately begin – within 48 hours – cleaning up water spillage or leakage
- if RH is above 60%, circulate air and dehumidify to below 40% until materials are dry; once materials are dry, resume a rise to normal humidity
- the movement of dryer air into the problem area from another space or from the outdoors can quickly lower the RH and dry things out
- develop a disaster plan and, where appropriate, be prepared to either air dry or freeze water-damaged artifacts within 48 hours

1.3 Mould Outbreak — The First Steps

The following section outlines a general course of action to respond to an outbreak of mould in a heritage collection. Intended as a guide, it is appropriate for small to medium-sized outbreaks of mould. If mould growth is extensive, or if toxic mould is suspected or known to be present, additional measures and outside expertise is required.

Protect staff
Take preventive measures to protect staff working in the facility. People with allergies or those with asthma should not be in contact with affected material or where the mould infestation is located. For more information, refer to **Section 1.5 Health Effects** (p. 13) and **Section 2.1 Personal Protective Equipment** (p. 15).

Isolate artifacts
Isolate mould-contaminated artifacts. If only one or a few artifacts are contaminated, isolate them. If many artifacts are involved, isolate the collection area. This will prevent mould spores from dispersing into clean areas of a collection and the rest of the building. Artifacts can be isolated and the contamination contained by placing them in a sealed box or bag. If large, they can be wrapped in plastic sheeting. If the artifacts are wet or damp, this is a temporary measure until they can be dried. If the artifacts are dry, they can stay in containers or wrapped in plastic until they are cleaned of visible mould growth. If the collection area must be isolated, seal the entrance and return air intake vents with 5 cm (2 in.) tape and heavy gauge plastic/polyethylene sheeting. This will prevent mould spores entering clean areas of a building.

Figure 12. Covering books and shelves to prevent the spread of spores.

Isolate and control access to affected artifacts or contaminated areas to reduce exposing people to mould. People entering the isolated area or opening sealed objects should always wear the appropriate personal protection equipment (PPE). (See **Section 2.1 Personal Protective Equipment**.) Determine the extent of the mould infestation, consider the available resources and determine whether the infestation can be handled in-house or whether outside help is required. When looking for outside help, contact a conservator who has experience in dealing with mould and contaminated artifacts.

Identify and eliminate the causative agent
Determine the cause of the mould outbreak and take immediate action to correct it. This may include measures to lower the RH, to increase air circulation, to lower room temperature and to remove any standing water. If necessary, employ a company that specializes in desiccant drying to dry the affected facilities and furnishings, such as carpets and drapes.

Deactivate the mould
The mould is actively growing if it feels damp and smears when brushed or if a musty or sweet mouldy smell is present. Steps to deactivate the mould will stop growth and prevent further damage to the artifacts. Lower the humidity and moisture content of the material as quickly as possible. In the case of artifacts, this can be done either by air drying or freezing, as discussed below.

Once the artifact is dry, mould can be removed. Detailed information on cleaning procedures, techniques and equipment is presented in **Section 2. Collection Recovery** (p. 15). If cleaning is delayed, keep the dry artifact isolated and in a sealed container to prevent any inactive, but still viable, spores from dispersing.

Air drying
Air dry artifacts by lowering the RH and increasing air circulation. The mould spores of most species are easily airborne. If damp or wet artifacts have mould, air dry them in a way that does not disperse mould spores. If only a few objects are contaminated, bag, box or wrap them and move them to another area to prevent spores dispersing. Take measures to prevent the spores from dispersing throughout the building. Seal the return air vent and, if possible, open windows to vent air outdoors. Select an isolated room, with a minimum of furniture, that is easy to clean afterwards. Allow artifacts to air dry or use fans. Place fans so the airflow is directed away from the artifacts to limit spore dispersal. This is also necessary to slow the drying process in order to reduce physical distortions, such as fine checks or cracks that can result from an abrupt decrease in the object's moisture content. Objects made of a thick layer of organic material, or objects that are composed of different elements (such as inlays or veneers) joined together, are the most likely to undergo high physical stresses leading to damage during air drying. Once the artifact is dry, consult **Section 2. Collection Recovery** for detailed information on cleaning procedures for objects, furnishings and storage areas.

If air drying indoors cannot be accomplished without dispersing fungal spores, it is preferable to freeze the material, air dry a few at a time in a fume hood or dry the material outdoors. Air dry objects outdoors on a clear day away from people and building air-intake systems.

Freezing
Freezing is a quick method of killing actively growing mould. Although a mould's vegetative growth will freeze and break down, spores are able to withstand the cold temperatures and remain viable.

Freezing artifacts is a suitable treatment for numerous water-damaged or mouldy objects. This method eliminates the urgency to safely dry all wet artifacts within a short time frame. But freezing is not appropriate for all artifacts. In general, it is safe for textiles, furs, feathers, leather, paper and wood. However, it is not recommended for glass plate negatives, oil paintings or acrylic paintings. If in doubt, check with a conservator first. Before freezing, seal the object in a clear polyethylene bag or wrap with polyethylene film and seal with tape.

Household horizontal chest freezers, which generally operate between -18°C and -28°C , can be used for a small number of objects. Freezing on a large scale requires a larger freezer. Large walk-in freezers can be rented. Freezer trucks can also be rented and brought to a site. The labour-intensive drying process can then be postponed until the staff is fully organized and has secured the space, time, resources and people to deal with the artifacts.

1.4 Indoor Fungal Investigations

Begin an indoor fungal investigation if there are health concerns or symptoms from individuals, evidence of mould growth, a mouldy smell or if water has leaked into a collection or a building. Indoor fungal investigation may include visual observation, collection of surface and bulk samples and/or air sampling. The method used is determined by established indoor air-quality (IAQ) protocols for investigating indoor fungal contamination. Guidelines and procedures are published in the following documents:

- Health Canada. *Fungal Contamination in Public Buildings: A Guide to Recognition and Management. Federal-Provincial Committee on Environmental & Occupational Health*. Ottawa: Environmental Health Directorate, Health Canada, June 1995.
- Macher, J., ed. *Bioaerosols Assessment and Control*. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists, 1999.

The investigation may also include reviewing the history of the building for clues that might explain or locate previous water damage that has supported mould growth that has not yet been seen. If people are experiencing negative health effects, a health evaluation or interview may be conducted. Adverse health effects may be related to a specific activity or place where mould is growing. By using this information, air-quality experts may be able to narrow down the source of the contamination more easily.

In general, identifying mould is not required in order to respond to an outbreak in a heritage collection, to remove visible mould from heritage material or to treat artifacts damaged by mould. Identifying mould is done for specific reasons; for example, if there is a health hazard concern or if some staff have health problems.

The following sections provide basic information on techniques and equipment that can be used in an indoor air investigation. For more detailed information, consult the literature.

Visual observation
Visual observation consists of walking through a building or collection and using sight and smell to evaluate the

indoor air. Observations may include noting the presence of humidifiers, standing water, water-damaged materials, poor housekeeping, poor ventilation and high RH. Often the first step in indoor air investigations, such observations may provide sufficient evidence to develop a remediation action plan for a building or collection.

Surface and bulk sampling
Surface samples may be taken with sterile swabs, or bulk samples (small pieces of contaminated material, such as wallboard or carpet) may be removed for testing. Both types of samples are analyzed by either direct contact with growth media or by diluting the sample and distributing a specific amount over a growth medium. After an incubation period, usually seven days, the mould colonies are identified and counted. The mould is either identified to a genus level[6], for example *Aspergillus*, or to a species level, such as *Aspergillus flavus, Aspergillus fumigatus, Aspergillus versicolor*. If certain types of mould are found, it may be appropriate to identify the mould to the species level to determine if it is toxigenic. This level of identification may be necessary when health risks or concerns are an issue.

The results are reported as total colony forming units (CFU). Each species is identified as a percentage of the total. Generally, most laboratories report surface samples as colony forming units per square centimetre of area sampled (CFU/cm^2). Bulk samples are reported as colony forming units per gram of material sampled (CFU/g).

Bulk and surface samples may be useful to detect certain mould species. For example, the species *Stachybotrys chartarum* (previously known as *Stachybotrys atra*) is not easily measured using air samples because the spores, when growing, are wet and sticky and not easily airborne. Once they are dry and then disturbed, they can become airborne for short periods of time, but soon fall because of their heaviness. The spores are normally found in the dust on the horizontal surfaces of furniture or floors. In many cases, *Stachybotrys chartarum* can be found only by bulk, surface or aggressive[7] air sampling.

Air sampling
Air sampling can be used to determine if higher-than-normal concentrations of mould spores are present in the environment. The technique may be used when mould is not clearly evident; for example, if mould growth is not visible, but individuals are experiencing unexplained health symptoms that might be related to exposure to bioaerosols.

When indoor air sampling is performed, a sample of outdoor air must be taken at the same time to use as a comparison. In general, when results indicate a higher level of fungal contamination in the indoor air and/or the type of mould species differ from those found outdoors, there is cause for further investigation. Guidelines are available from various sources to help interpret airborne sampling results:

- Health Canada. *Fungal Contamination in Public Buildings: A Guide to Recognition and Management*, 1995.
- Dillon, H.K., P.A. Heinsohn, and J.D. Miller, eds. *Field Guide for the Determination of Biological Contaminants in Environmental Samples*. American Industrial Hygiene Association, 1996.
- Macher, J., ed. *Bioaerosols Assessment and Control*. Cincinnati, Ohio: American Conference of Government Industrial Hygienists, 1999.

Not all fungi or moulds can be found in air samples. It should be noted that an air sample indicates only the bioaerosol material present at that moment. Air sampling is effective when used before and after remediation. It can also be used during remediation, if part of the building is still occupied, to ensure that the air quality is fit for human habitation.

Sampling the air for mould involves using special sampling equipment. These instruments are used by industrial hygienists or by indoor air-quality experts, who follow a protocol determined by the manufacturer of the equipment.

Viable spore collection method
Collecting and culturing viable mould spores has been used extensively. The data from this method have been compiled into an accumulated database that is used to compare results. The method also helps distinguish one organism from another, although it also has disadvantages. The use of the growth media may create a culture bias. For example, some organisms may not grow well on certain growth media and others will have different competitive abilities against other mould species collected. These factors may influence the end result. The technique takes time – usually seven days to culture the initial sample, although 15 to 20 days is not uncommon. If fast-growing cultures overpower slower ones, subsequent culturing may be necessary. Finally, the method does not detect non-viable or sterile spores in the indoor environment. Non-viable and sterile spores can still cause negative health effects.

This sampling technique uses an instrument that pumps a certain volume of air during a given time period through a specific pore-sized filter onto special plates or strips containing a nutrient medium that supports biological growth. The Anderson multi-hole impactor sampler and the Reuter centrifugal sampler are two examples of indoor air-quality sampling equipment.

Once the samples have been collected, the plate or strip is removed and incubated at temperatures optimal for mould growth for a set period of time, usually seven days. The plate or strip is examined and the biological growth counted and identified. The results will be reported as colony forming units per cubic metre of air sampled (CFU/m^3).

Non-viable spore collection methods
Non-viable methods such as spore trap or tape methods are used to collect particulate matter from the air, but the sample is not cultivated. As a result, one of the advantages of these collection methods is evaluation of the sample usually within 48 hours. It is a useful sampling method because organisms that will not grow on growth media and/or do not compete well with other organisms may be detected. These methods, therefore, may yield a more complete representation of the fungal composition of total (viable and non-viable) spore levels. The disadvantage of these methods is the inability to distinguish between species that produce morphologically similar spores.

Spore traps, such as the "Air-O-Cell" from Zefon International and the MK3, use specialized equipment that collects the material from the air onto a sticky surface or a slide coated with a collection media. The slide can be immediately examined under a microscope and the spores counted. Because the physical attributes (size, shape, texture) of most spores are fairly specific, a general level of identification is possible. As well, certain moulds, such as *Stachybotrys chartarum,* are limited in species and easily identifiable by this sampling technique.

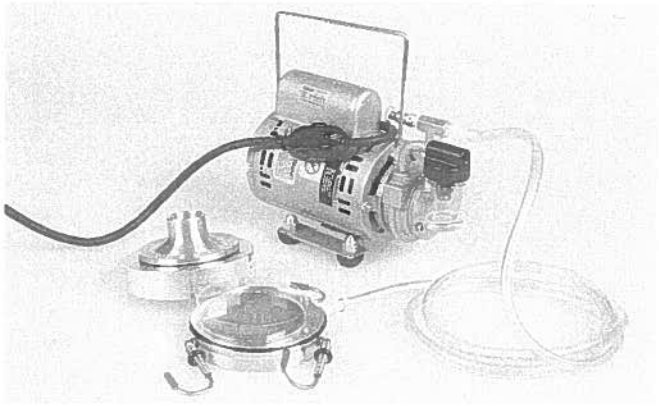

Figure 13. Anderson single-stage air sampler with petri dish.

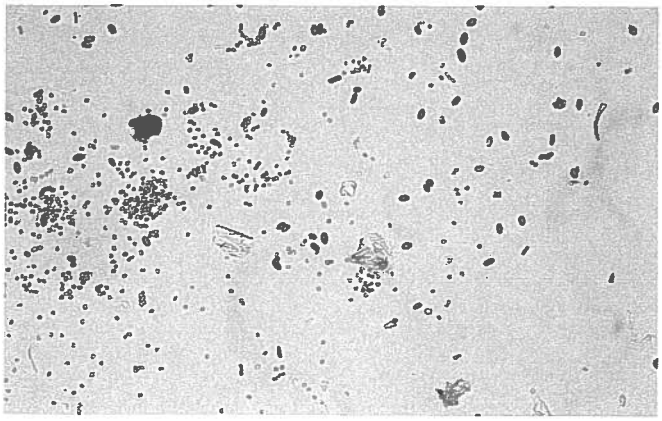

Figure 14. Spore trap slide showing spores, etc. collected from the air.

In some instances, further sampling by culturing may be recommended to identify the mould species and to determine if it is toxigenic.

Interpreting results
All sampling techniques require specific knowledge and expertise. This work is performed by a technically qualified professional who uses an accredited[8] laboratory for analysis. Identifying the fungi should be done by someone trained in mycology. Health Canada has published the following guidelines that help interpret airborne sampling results and determine if a potential microbial contamination exists indoors:

- *Indoor Air Quality in Office Building: A Technical Guide*, 1993.
- *Fungal Contamination in Public Buildings: A Guide to Recognition and Management*, 1995.

The indoor air-quality expert and the laboratory prepare and forward a report to the client. The following points are typical of a good indoor air-quality report:

- description of the sampling methodology
- time and date samples were taken and date samples were processed
- location of each sample taken (room number, location in room)
- total number of particles
- number of particles per mould genus and species

The report should indicate if there are toxigenic mould species present. If so, a cautionary note should be included that underlines their potential as a possible health hazard. Recommendations about remediation or the appropriate level of personal protective equipment will be given. A list of references used in the identification process should also be included.

1.5 Health Effects

Mould is ubiquitous. Normal background concentrations of mould do not usually affect healthy individuals. In contaminated environments, however, the risk of health effects from exposure to mould increases. Reactions are varied and depend on the nature of the species involved, the metabolic products being produced by these species, the amount and duration of exposure to mould and mould products, and the susceptibility of the individual. Roughly 8% of the population is predisposed to be affected by exposure to mould. As well, people with asthma or respiratory problems, those suffering from allergies or an allergy to mould, those with compromised immune systems and anyone taking steroids may be affected. Several studies have shown that the presence of fungi in the home can be equated to health effects on the occupants (Brunekreef et al. 1999, Health Canada 1995, Dales et al. 1991a, b). Large areas contaminated with

visible mould resulted in more symptoms. One study showed that those who had skin sensitivities to mould spores were at higher risk for severe asthma attacks (O'Hallaren et al. 1991).

Generally, health effects fall into the following categories: irritation, allergy, toxicity and infection (Ammann 2003).

Irritation
Microbial volatile organic compounds (MVOCs), such as short-chained alcohols, aldehydes, esters and ketones, are produced by some fungi. They are responsible for the characteristic mouldy, musty, earthy smell associated with damp buildings. Although the health effects from exposure to MVOCs have not been well studied, they may be responsible for symptoms of headache, dizziness and eye and mucous membrane irritation among people living or working in fungal-contaminated buildings (Levetin 1995).

Allergy
Mould is a well-known source of allergens (any substance that causes an allergic reaction). Many, possibly all, fungal spores contain allergens. Mould spores do not have to be viable to retain allergenic properties. Exposure to dormant mould can trigger an allergenic response in individuals. People who are allergic may develop symptoms when their respiratory system or skin is exposed to mould or mould products.

People who suffer from asthma or allergies or who have become sensitized through prolonged association with mouldy materials or a mouldy environment, may respond after inhaling spores with hay fever-like symptoms, such as runny nose, sneezing, red, itchy eyes and dermatitis (skin rash). A first-time exposure for a healthy person may result in a mild form of any of the above symptoms. Repeated exposure to mould may result in increased sensitization and a more intense response. Once the allergy develops, it may be a permanent, lifetime condition.

Although it is recognized that there is a cause and effect relationship between exposure to mould spores and allergic reaction, threshold levels either for sensitization or symptom development have not been clearly defined for any fungal allergen. People handling contaminated material should be advised of the risks that increase with the frequency and duration of exposure to mould. Exposure to mould may aggravate existing health conditions, such as asthma.

Allergy tests performed by physicians are for specific mould allergens. There are few mould allergens available to use for testing; therefore, while a positive result may indicate sensitization to a specific mould antigen, a negative test result does not rule out mould allergy for susceptible individuals (Ammann 2001).

Toxicity
The naturally occurring substances, produced by some moulds, which cause a toxic response are called mycotoxins. Not all moulds produce mycotoxins, but many species do. The genera *Aspergillus, Penicillium* and *Stachybotrys* are usually found indoors and are known producers of mycotoxins. Sampling and species identification of mould by a mycologist can determine whether a mould is toxic. Viability of spores is not essential to toxicity. Non-viable spores can still be a source of toxins.

Mycotoxins produce a variety of health effects through ingestion, skin contact and inhalation. Depending on the kind of mycotoxins and the nature of exposure, effects may include mucous membrane irritation, skin rashes, dizziness, nausea, immunosuppression, birth defects and cancer. Nearly all of the mycotoxin literature focusses on ingestion exposure, although the role of inhaled mycotoxins in human disease is currently under study. In view of the potential severity of resulting disease, a conservative approach to limiting exposure to mycotoxins is recommended (Burge and Otten 1999).

Infection
Infection from exposure to moulds that grow indoors is not common, but it can occur in susceptible individuals, such as those with a compromised immune system due to disease or drug treatment. For example, *Aspergillus fumigatus* is a weak pathogen capable of causing infections, called aspergilloses, in susceptible individuals. Infections can affect the skin, the eyes, the lung or other organs and systems (Summerbell 2001). Other fungi can also cause systemic infections, such as *Coccidioidomycosis, Histoplasmosis* and *Blastomycosis*. These fungi grow in soil or may be carried by bats and birds, but do not generally grow in indoor environments (Dales and Miller 2001). Bird or bat droppings that have accumulated in air intakes, ducts and/or rooms frequently contain virulent pathogenic fungi. These organisms are not all reliably detected by sampling the air or droppings. Accumulated droppings should automatically be regarded as hazardous sources of pathogenic fungi. Appropriate action should be taken to safely remove any accumulations of bird or bat droppings (Health Canada 1995).

Symptoms
Symptoms that result from exposure to abnormal levels of indoor moulds, including toxigenic moulds, may include the following (Johanning and Landsbergis 1999):

- nasal irritation, burning, itchiness, stuffiness and congestion, bloody nasal discharge, throat irritation and soreness
- cough, shortness of breath, wheezing, chest congestion and tightness
- severe headaches, concentration problems, irritability, dizziness or lightheadedness, fatigue
- burning, irritation, blurry vision
- burning, skin rash
- low-grade fever, flu-like symptoms

People experiencing any of the above symptoms that may be related to exposure to abnormal levels of indoor moulds should consult their physician.

2. Collection Recovery

This section informs the reader how to remove mould growth from artifacts. It also describes the appropriate personal protective equipment (PPE) to wear when working in a mould-contaminated environment or when working with mouldy artifacts.

Before beginning a collection recovery, follow the guidelines in **Section 1.3 Mould Outbreak — The First Steps** (p. 10) which outlines a general course of action to follow in response to a mould outbreak in a heritage collection, including identifying the causative agent and taking steps to correct it, how to protect staff, how to isolate affected artifacts and how to deactivate vegetative mould growth on artifacts.

2.1 Personal Protective Equipment

Mould is a serious health concern, so every effort should be made to limit human exposure to it. PPE that should be worn when handling mouldy artifacts or when working in mould-contaminated areas is described below. Under occupational health and safety legislation in Canada (federal, provincial or territorial regulations), an employer must take every reasonable precaution to protect the worker. Employers should provide training on the safe handling and cleaning of mould-contaminated artifacts and on the proper manner of wearing and maintaining PPE. Employees have a responsibility to follow these instructions.

The minimum level of personal protection suggested in this Technical Bulletin (see **Table 2. Recommended Personal Protective Equipment** on p. 19) is based on the total surface area contaminated by visible mould growth: small (<0.3 m^2), medium-size (0.3–3 m^2), large (3–10 m^2) or extensive (>10 m^2). These levels are estimates adopted from the literature for mould remediation in buildings (Health Canada 1995; Manitoba Department of Labour 2000; New York City Department of Health 2000). They are not derived from an examination of health effects. There is no conclusive research that specifies a level of personal protection that is appropriate at a certain number of square metres of contamination (Environmental Protection Agency 2001). If in doubt regarding the appropriate level of PPE, consult health and safety experts.

As well, consult a reputable supplier of safety equipment for information on specific products. Some companies have technical consultants trained to help select appropriate PPE.

The following sections describe the PPE appropriate for working with mould.

Respiratory Protection

American-based NIOSH (National Institute for Occupational Safety and Health) is the only North American organization to test and certify respirators. Accordingly, its standards are used as a benchmark by federal and provincial occupational health and safety bodies. Under a new standard, adopted in July 1998, there are nine classifications of air-purifying respirators based on filter efficiency and use limitations.

Generally, for mould infestations in heritage collections, particulate filters from the N series (N for not resistant to oil) are appropriate. Filters described as N100 offer the greatest protection against particulate matter. These filters are also referred to as HEPA[9] (high-efficiency particulate air) filters. When a mouldy smell is present, a filter that combines HEPA and organic vapour cartridges is recommended. For more information on the latter, refer to the section **Respiratory Protection and Microbial Volatile Organic Compounds** (p. 17).

Respirators, including disposable respirators, should be test fitted by a qualified individual[10] to ensure a proper fit. It is useful to have several different styles and sizes of respirators on hand to find the right fit. Respirators should always be stored in a clean area or in a bag to avoid buildup of particulate matter on the respirator. At the end of each day of use, respirators should be cleaned according to the manufacturer's instructions. Used respirator filters will support mould growth. To prevent this, allow the respirator (and filters) to air out before storing them in a sealed bag.

Some individuals may be unable to wear disposable, half-, or full-face respirators. Facial hair or unusual facial shapes may prevent the apparatus from establishing a proper seal against the face. Others may be unable to wear respirators for health or psychological reasons; for example, claustrophobics may experience extreme discomfort.

Appropriate respiratory protection must be worn when working with wetting or cleaning agents (e.g., organic vapour cartridges for high concentrations of bleach).

Disposable particulate respirators
Disposable respirators are inexpensive and maintenance free, but proper use requires careful reading and closely following the manufacturer's instructions. In order to get a good fit from a disposable respirator, follow the instructions on the package. For example, most models require that users fit the seal of the mask against the contour of their nose by pushing the nose area of the mask down against the bridge of their nose.

Disposable respirators are not appropriate for every individual. If improper facial contact is made with the respirator, it may actually increase the concentration of mould spores being inhaled. These devices, therefore, are not appropriate for people with facial hair. Although many

brands of disposable respirators are available in one size only, some MSA models (Affinity Pro N95 and N100), are available in five different sizes.

It may be difficult to find, and awkward to wear, protective goggles in combination with a disposable respirator. This is even more problematic when prescription eyeglasses are worn. Some combinations of respirator and goggles will work better than others.

If a disposable respirator is used more than once, be sure to air it out after use and store it in a clean environment. Stuff the inside of the respirator with clean tissue to ensure it remains clean. If the respirator becomes damaged, soiled or breathing becomes difficult, discard it.

Half-face respirators
A half-face respirator consists of an assembled face piece worn over the mouth and nose. Cartridges selected to protect against a hazardous environment are attached to the face piece. Particulate and combination cartridges are available. Half-face respirators are more expensive than disposable respirators, but are re-usable because the cartridges can be replaced. Half-face respirators are available in different shapes, styles and sizes.

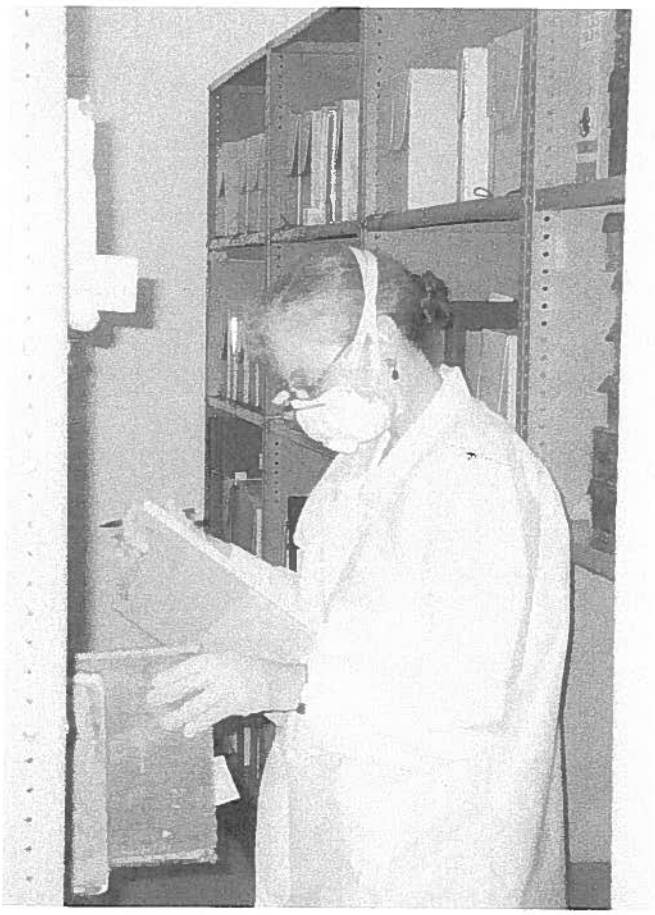

Figure 15. Conservator is wearing a N100 disposable particulate respirator, lab coat and gloves while conducting a survey of a potentially mould-infested collection.

They are not appropriate for people with facial hair. It may be difficult, if not impossible, to accommodate protective goggles while wearing a half-face respirator. This may be even more difficult if a person wears prescription eyeglasses.

Full-face respirators
A full-face respirator consists of an assembled face piece worn over the mouth, nose and eyes. Cartridges selected to protect against a hazardous environment are attached to the face piece. Particulate and combination cartridges are available. Full-face respirators can be re-used by replacing the cartridges as required. Full-face respirators are available in different materials, styles and sizes.

A full-face respirator is not appropriate for people with facial hair. It is not necessary to wear protective goggles with a full-face respirator, but the seal of the respirator may be compromised if the person wears prescription eyeglasses. It may be necessary to consult with a reputable technical consultant of respiratory equipment to select the most appropriate full-face respirator. Full-face respirators or a powered air purification respiratory system are recommended when dealing with extensive mould growth.

Powered air purification respiratory systems
A powered air purification respiratory system (PAPRs) is a positive-pressure airflow respirator that delivers a steady supply of filtered air. The user of a PAPRs wears a battery, fan, motor and cartridge on a belt. Filtered air passes through the breathing tube and into the headpiece. PAPRs provide up to eight hours of continuous use, after which the batteries must be recharged. PAPRs protect individuals with facial hair and do not require test fitting. There are various headpieces, cartridges and combinations of cartridges available. Tyvek hoods and head covers are economical, disposable and offer maximum protection. The PAPRs is more expensive than other respiratory options and is recommended when dealing with extensive mould growth.

Two systems of note are the 3M Breathe-Easy PAPRs and the 3M Air-Mate HEPA 10 and HEPA 12 PAPRs. The latter two are less expensive, but can be used only with a HEPA filter. The difference between the Air-Mate 10 and 12 is one of head covering. The Air-Mate 10 has a shoulder cape attached to the hood. The Air-Mate 12 has a hood. The Breathe-Easy PAPRs is more expensive, but it is also more versatile because a number of different cartridges or combinations of cartridges are available (i.e., combination HEPA filter and organic vapour cartridges). If an adaptor breathing hose is also purchased, the Breathe-Easy PAPRs can be worn with either of the Tyvek hoods.

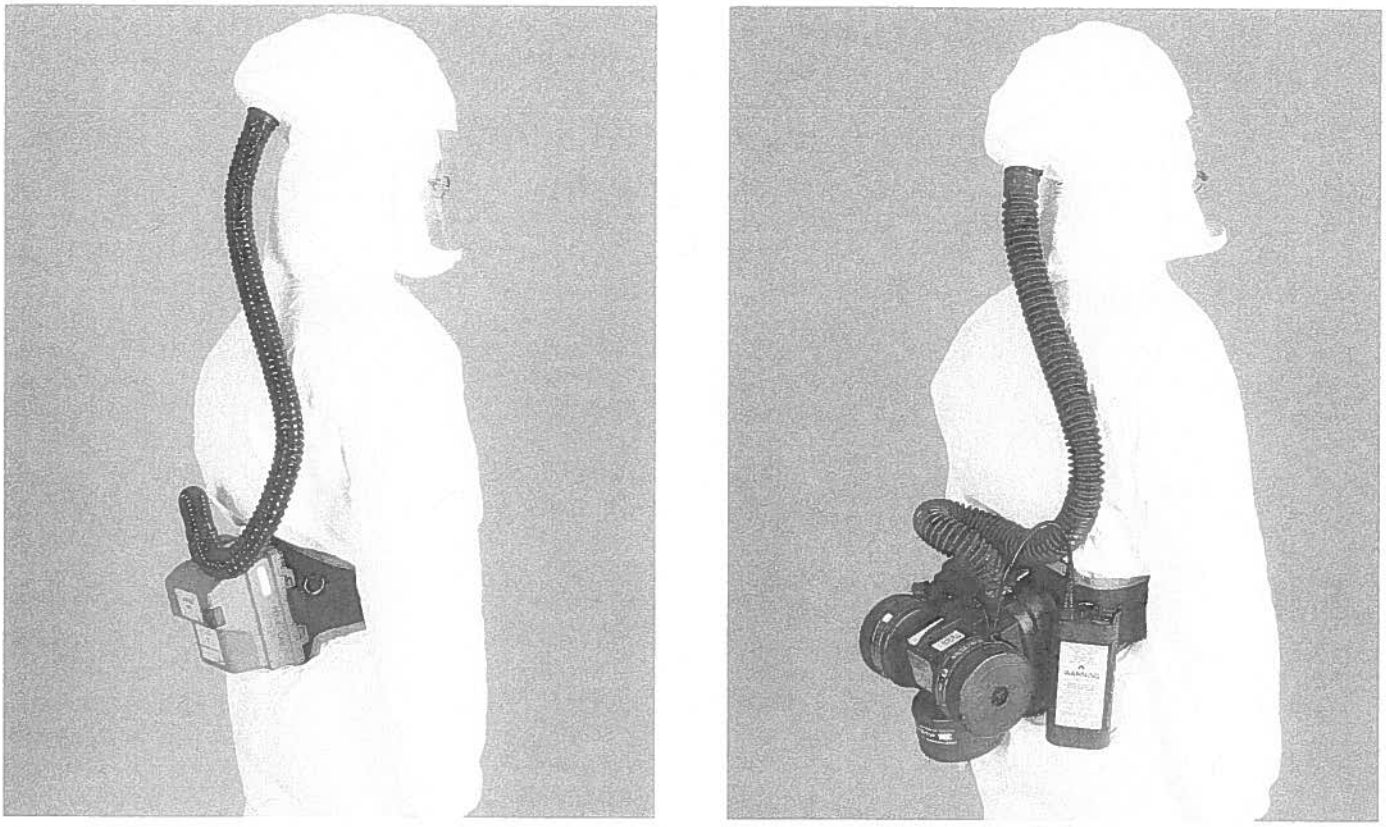

Figure 16. Two examples of powered air purification respiratory systems (PAPRs). The conservator on the left is wearing a 3M Air-Mate HEPA 12, the one on the right a 3M Breathe-Easy PAPRs. An adaptor breathing hose purchased from the manufacturer has been used to connect a disposable hood to the breathing system.

Respiratory Protection and Microbial Volatile Organic Compounds

Some fungi produce volatile metabolites[11] that cause unpleasant odours, including the characteristic mouldy smell associated with damp areas or materials. Although many different types of compounds have been identified, the major volatile organic compounds are short-chained alcohols and aldehydes. The health effects of exposure to microbial volatile organic compounds (MVOCs) have not been well-studied. They may be responsible for headache, dizziness and eye and mucous membrane irritation (Levetin 1995).

If a mouldy smell is present, a combination of HEPA and organic vapour cartridges is recommended. Organic vapour cartridges, not particulate respirators or cartridges, protect against MVOCs. Some particulate disposable respirators incorporate nuisance-level organic vapour relief and may be appropriate for some circumstances. Half-face and full-face respirators and some PAPRs can be fitted with combination HEPA and organic vapour cartridges that protect against MVOCs.

Goggles

Protective goggles must also be worn when dealing with mould. The appropriate, recommended goggles are not ventilated and must accommodate a disposable or half-face respirator. If the user wears prescription eyeglasses, tight-fitting yet comfortable goggles may be difficult to locate. In this case, a full-face respirator or PAPRs may be an option.

Protective splash goggles should be worn when working with wetting or cleaning agents (e.g., high concentrations of bleach).

Gloves

Protective gloves should be worn when handling mouldy material. Due to concerns about latex allergies, vinyl (PVC) or Nitrile gloves are recommended. Disposable gloves are replaced as required. Torn gloves should be replaced immediately. Disposable gloves are removed by grasping the cuff of one glove and peeling it off while at the same time turning it inside out. Once removed, this glove is balled up and placed in the palm of the hand still wearing a glove. As the remaining glove is peeled off and turned inside out, the balled up glove is covered up inside the worn glove. This reduces the dispersion of mould spores by containing one glove within the other and by turning the gloves inside out, so the non-contaminated side of the glove is on the outside. Hands should be washed with soap and water after handling contaminated material, even when gloves have been worn.

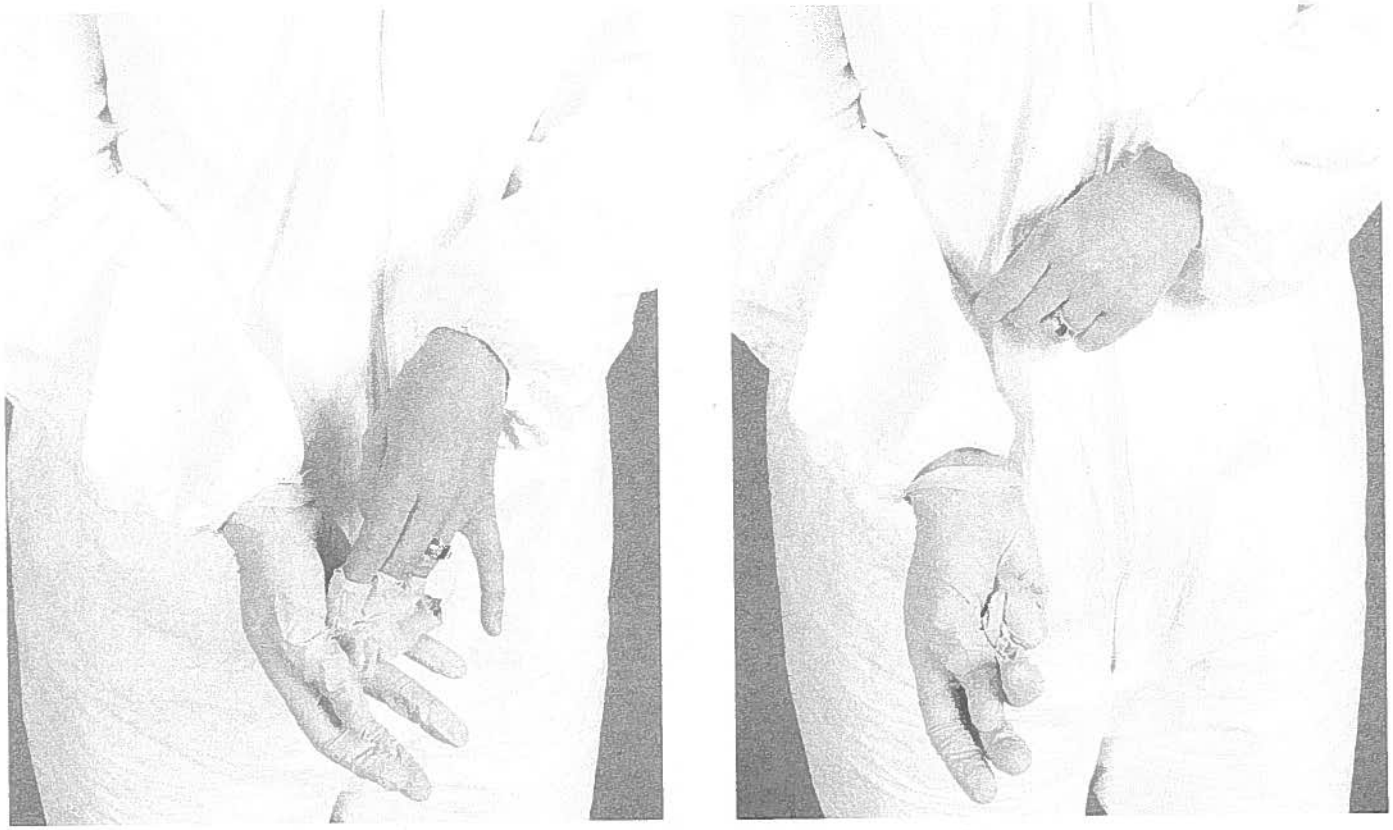

Figure 17. The correct way to remove disposable gloves after handling mouldy material. The glove from one hand is turned inside out as it is removed. This glove is balled up and placed in the palm of the gloved hand. The remaining glove is turned inside out as it is removed. This technique reduces dispersion of mould spores and ensures that the contaminated surfaces of the glove are contained.

Appropriate gloves must be worn when working with wetting or cleaning agents (e.g., heavy duty vinyl (PVC) or Nitrile for high concentrations of bleach). Other suitable glove materials include natural rubber, neoprene and polyethylene.

Protective Clothing

When dealing with mouldy material, protective clothing must be available for all personnel and properly worn and fastened. Coveralls and protective hair and shoe covers should be used when significant amounts of mould spores might be released into the air. Disposable clothing is recommended, but re-useable protective clothing (lab coats or coveralls) may be appropriate for small and medium-sized levels of contamination. Protective clothing must not be worn outside the contaminated area. It should be removed on-site and washed in hot water and bleach.

Discarded Disposable PPE

There are no special requirements for discarding contaminated PPE. Always exercise caution when handling and discarding contaminated PPE. Place disposable clothing, gloves, etc., in thick (6 mil) plastic garbage bags or two layers of thin plastic garbage bags. Seal and discard the bags in an outdoor garbage container.

Ear Protection

When cleaning mould from objects involves using a vacuum cleaner extensively, noise levels may be a health and safety concern. Ear protection may be necessary when using machinery for long periods of time. Sound intensity is measured in decibels -- dB(A). Noise rated at 120–130 dB(A) causes pain, sound above 140 dB(A) can harm ears permanently. The Canadian Centre for Occupational Health and Safety (CCOHS) reports that many regulatory agencies recommend a time-weighted sound level of 85–90 dB(A) as a noise exposure limit for an eight-hour work day.

Manufacturers of vacuum cleaners will provide the noise level rating for specific vacuum cleaners. For example, the Nilfisk vacuum cleaner (model # 8C-1950) is rated as under 70 dB(A) at six feet. If earplugs are worn while working with mouldy material, they should be changed daily to reduce the possibility of microbial contamination of the plugs.

Back Safety

When mould remediation projects involve lifting heavy boxes, the risk of back injury may be a concern. The CCOHS has done research that proves back injury is the cause of one-third of all lost work time and 40%

Table 2. Recommended Personal Protective Equipment (PPE)

Personal Protective Equipment	Level 1: small isolated areas (<0.3 m^2 of visible mould)	Level 2: medium-size isolated areas (0.3–3 m^2 of visible mould)	Level 3: large isolated areas (3–10 m^2 of visible mould)	Level 4: extensive contamination (>10 m^2 of visible mould)
Minimum respiratory protection	• N 95 or N100 disposable respirator	• half-face N100 respirator	• full-face N100 respirator	• full-face N100 respirator or PAPRs with HEPA filter
Other	• disposable gloves and protective goggles	• disposable gloves, protective goggles and protective clothing	• disposable gloves, and protective clothing with head and boots covered	• disposable gloves and protective clothing with head and boots covered
Additional protection	• appropriate respiratory, eye and hand protection for any wetting or cleaning agents (e.g., high concentrations of bleach)			
Additional comments	• disposable respirator with nuisance-level organic vapour relief for MVOCs may be appropriate	• organic vapour cartridge for MVOCs may be appropriate		• organic vapour cartridge for MVOCs may be appropriate • professional help likely required for collection recovery on this scale
	• half-face respirator, gloves, goggles and protective clothing are recommended for collection recovery at any scale where toxigenic fungi is known or suspected			

of workers' compensation costs. The weight limit they recommend for workers is 20 kg. Lifting loads weighing over 20 kg creates too much stress on the back. An additional factor in back injury is working with heavy weight loads in confined spaces, which causes workers to twist and turn as they lift. The CCOHS also reports that employees required to manually lift or carry loads over 10 kg must be trained in safe lifting skills. In some circumstances, back support belts may be required.

2.2 Cleaning Mould-contaminated Artifacts

This section addresses cleaning artifacts that have mould growth. This information can be used to design a collection recovery plan or to assess a plan submitted by outside professionals. Keep in mind that each institution will encounter a unique set of circumstances during a mould infestation; therefore, the information presented here may need to be modified or adapted. If possible, professional experience and judgement should be used to evaluate the level of mould contamination and to assess the proposed collection recovery plan.

Contrary to recommended procedures for mould remediation in buildings that advise discarding contaminated porous materials, the heritage community faces a challenge because most contaminated artifacts are cleaned and retained.

If proper precautions are taken, small (<0.3 m^2), medium-sized (0.3–3 m^2) and large (3–10 m^2) outbreaks of mould can safely be cleaned. It is, however, possible that after evaluating the information presented here, the situation cannot be resolved without professional help. In this case, consult professionals experienced with mould infestations to determine an appropriate course of action.

For extensive (>10 m^2) mould contamination in a collection, it is advisable to seek professional help. Indoor air sampling, a site inspection and an evaluation of health risks by professionals may be necessary. A conservator with experience in the recovery of mould-contaminated artifacts can advise on the safest and most appropriate way to remove the mould growth or on which outside cleaning services to consider. Removing mould from artifacts on this scale may require a containment structure to minimize dispersion of mould spores as well as specialized cleaning equipment, procedures and PPE.

There is no research that proves that one cleaning technique over another is the appropriate one for a certain level of contamination. The following information is intended as a general guideline and is subject to the judgement of professionals experienced with cleaning mould-contaminated artifacts and working in contaminated environments.

Before Cleaning

Before attempting any cleaning, consider the following:

- individuals with allergies, heart conditions, respiratory problems such as asthma and those with suppressed immune systems should not handle or clean mould-infested artifacts
- appropriate PPE must be worn
- respirators should be test fitted
- appropriate safety procedures to protect people and the work environment should be in place
- appropriate cleaning equipment and procedures should be in place
- appropriate cleaning and disinfecting solutions should be used
- washing facilities for hands should be located near the work area and must be used by staff before leaving the area
- examine the artifact for loose pieces and plan to either immediately secure these loose pieces that may come detached during cleaning or bag them and identify their location on the artifact so that the pieces can be re-attached later
- be prepared to document all actions (any treatment to remove mould should be recorded and retained as part of the documentation for the artifact; this should include details such as environmental conditions that may have led to the infestation, cleaning methodology and identification of the mould, if undertaken)

Proceed with caution and, if in doubt, consult experts. Be prepared to stop and re-assess the situation should mould levels be greater than originally anticipated. Be prepared to upgrade PPE, modify procedures or seek outside help as required.

Can the Mould be Removed?

Take steps to deactivate vegetative mould growth before attempting to clean the artifact. Consult **Section 1.3 Mould Outbreak —The First Steps** (p. 10) for information on how to do this. Test the mouldy area with a small brush to determine whether mould growth can be easily removed. In many cases, dormant mould can be removed by vacuuming and brushing. Neither vacuuming nor brushing will remove mould stains from an artifact. These stains require treatment by a conservator and may prove difficult, if not impossible, to remove.

Prevent Dispersion of Mould Spores

Mould spores are easily airborne on air currents or by HVAC systems, or they can travel on people to other areas of a collection and to clean areas of a building. Take the necessary measures to prevent mould spores from dispersing and to avoid contamination from infested artifacts spreading to non-infested or decontaminated artifacts (Florian 2000).

These measures include the following:

- where possible, dry wet, infested material in a fume hood or class 1 biological safety enclosure
- if this equipment is not available and it is necessary to dry wet, infested artifacts indoors, take precautions to prevent mould spores from dispersing by keeping artifacts covered with tissue paper during drying (this will capture any spores that become airborne as the artifact dries; if fans are used to dry mouldy artifacts, direct a gentle flow of air away from the object)
- isolate and store contaminated, dry artifacts in sealed containers or wrapped in heavy plastic until they can be cleaned
- unwrap or open the container at the mould cleaning location (i.e., inside a fume hood, a class 1 biological safety enclosure, or outdoors)
- use a vacuum cleaner fitted with a HEPA filter
- if necessary, direct the exhaust from the vacuum cleaner outside the contaminated area
- apparently uninfected artifacts also in the room, area or immediate vicinity of the mould infestation should also be cleaned because mould growth invisible to the naked eye may be present
- clean or discard contaminated packing materials
- clean and disinfect the cleaning equipment, hand tools, storage area and furniture
- remove protective clothing by turning it inside out during disrobing
- there are no special requirements for discarding mouldy materials (i.e., disposable PPE, packing materials, vacuum cleaner bags and filters); to discard contaminated material, place it directly in thick (6 mil) plastic garbage bags or two layers of thin plastic garbage bags, seal and discard the bags in an outdoor garbage container
- wash hands with soap and warm water immediately after removing protective gloves
- do not allow eating, drinking, chewing or smoking in the cleaning area

Choosing a Cleaning Location

If at all possible, clean mould-infested artifacts indoors inside a fume hood or class 1 biological safety enclosure. **Using a brush or vacuum cleaner indoors without the appropriate mould containment enclosure is not recommended.**

If a fume hood or class 1 biological safety enclosure is not available, cleaning mouldy artifacts outdoors may be an option. Choose a clear, dry day and set up away from people and the building's air-intake systems. Wear the appropriate PPE. After cleaning the artifacts or when finished for the day, clean and disinfect all work surfaces, tools and equipment before returning them to the building. Contaminated material, such as disposable PPE and any used packing or wrapping material, should be placed in thick (6 mil) plastic garbage bags or two layers of thin plastic garbage bags, sealed and discarded in the outdoor garbage.

If inclement weather prevents cleaning outdoors, the dry artifacts can be wrapped in plastic or placed in a sealed container and, until suitable weather arrives, maintained in an environment that does not support mould growth. Under these conditions, the mould growth on, and deterioration of, the artifact as a result of mould growth is stopped.

Equipment and Tools

Equipment and tools used to clean artifacts include a vacuum cleaner fitted with a HEPA filter and its accessories, brushes, a negative pressure fume hood and a class 1 biological safety enclosure.

Cleaning by Vacuuming

Close vacuuming is one of the most effective ways to remove mould growth and reduce the number of mould spores on the artifact. Be systematic and thorough when removing the mould and carefully vacuum the artifact all over, not just where mould growth can be seen. Mould growth invisible to the naked eye may be present on unsuspected areas. If possible, go over the artifact at least twice. Pass over the object the second time in a perpendicular direction to the first pass.

The following techniques should be considered for vacuuming:

- apply the vacuum suction close to, but not directly on, the artifact
- vacuum flat, fragile artifacts through a cleaning screen
- use a mini brush tool attachment or vacuum brush attachment
- dislodge tenacious mould with a soft brush, directing the mould toward the vacuum nozzle

Be vigilant and do not let the vacuum cleaner nozzle "get away from you" and accidentally touch the artifact. Vacuum suction applied directly to the artifact may cause damage. Devise a method to secure the vacuum cleaner hose when not in use during cleaning. This will keep the nozzle out of the way when the artifact is being repositioned. If working at a fume hood or class 1 biological safety enclosure, the contaminated vacuum cleaner hose and nozzle, as well as other cleaning tools, must stay inside the safety enclosure.

Vacuum cleaner fitted with a HEPA filter and accessories
A vacuum cleaner works well for cleaning mould from artifacts. It removes more spores than sweeping or dusting with a brush. To avoid dispersing mould spores into the environment, a vacuum cleaner fitted with a HEPA filter is strongly recommended. Vacuum cleaners with a variable speed control that can modify the vacuum suction are preferred.

Vacuum cleaner bags should be changed when they are half full to keep the machine's suction at its maximum strength.

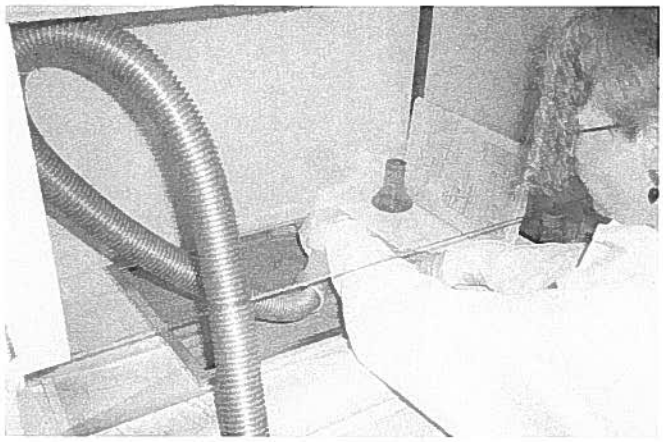

Figure 18. Conservator is working at a class 1 biological safety enclosure. The vacuum cleaner nozzle is secured inside the hood. This helps ensure the nozzle does not accidentally touch the artifact and that the contaminated nozzle remains in the enclosure.

Vacuum cleaner bags should be changed outdoors, in the fume hood or in the class 1 biological safety enclosure. Wear appropriate PPE when changing vacuum cleaning bags to avoid accidental exposure to mould spores. Discard contaminated vacuum cleaner bags (and filters) by putting them in thick (6 mil) plastic garbage bags or two layers of thin plastic garbage bags. Seal and discard the bags in the outdoor garbage.

Change the HEPA filter and pre-filter on the vacuum cleaner according to instructions provided by the manufacturer. Change the filters outdoors, in a fume hood or class 1 biological safety enclosure while wearing the appropriate PPE. Damp wipe the work surface and the exterior of the vacuum cleaner and vacuum hose to capture any mould spores.

Record the installation date of the new filters on the vacuum cleaner, in a log book or in the manual. Depending on use and the level of contamination, the HEPA filter remains effective for several years; pre-filters may need to be changed more frequently and will extend the life of the HEPA filter if changed regularly.

A useful vacuum cleaner accessory is a mini tool kit. The kit contains small brushes and nozzles that come with an adaptor to fit onto any vacuum cleaner. Inexpensive mini tool kits are available at sewing, computer and vacuum cleaner stores.

Many artifacts can be cleaned through a cleaning screen. A cleaning screen is composed of fibreglass window screen held taut in a metal frame. When placed over the artifact during cleaning, it secures and protects the artifact while permitting the user to apply the vacuum nozzle close to it. Because the screen protects the artifact during cleaning, it is suitable for flat, fragile artifacts. If the

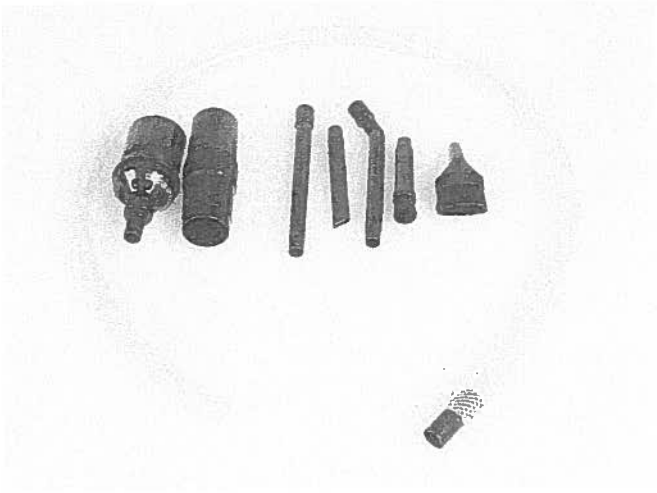

Figure 19. Mini cleaning tools for the vacuum cleaner.

artifact is large, it is possible to vacuum through the screen, cleaning the artifact section by section. Cleaning screens can be made to order at window and glass suppliers. Alternatively, the screen can be loose, not held taut in a frame, providing that the sharp edges of the screening material are covered to protect the artifact. Twill tape sewn on the edges of the screen will work. A quicker method is to cover the edge of the screen with masking tape, providing the adhesive is not exposed.

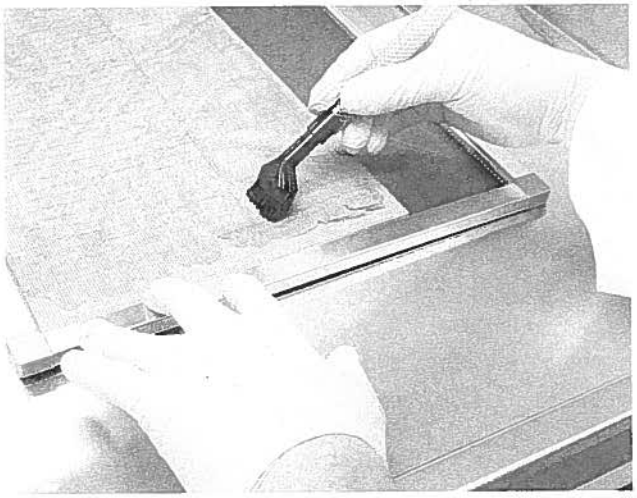

Figure 20. Conservator is using a cleaning screen, small brush attachment and low vacuum suction to clean fragile paper.

The practice of covering a vacuum cleaner nozzle with window screen, to prevent small detached pieces of the artifact from being sucked into the vacuum cleaner, is often used when vacuuming artifacts. This technique prevents the loss of detached pieces and is suitable for vacuum cleaning most three-dimensional artifacts. When vacuuming flat, fragile objects, the cleaning screen described above offers additional protection.

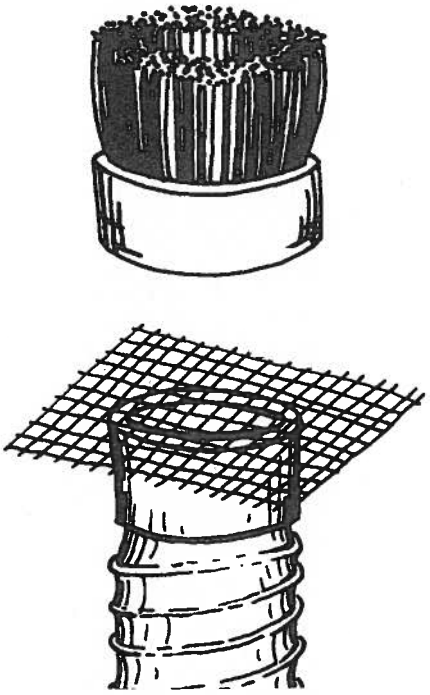

Figure 21. A protective screen over the vacuum cleaner hose.

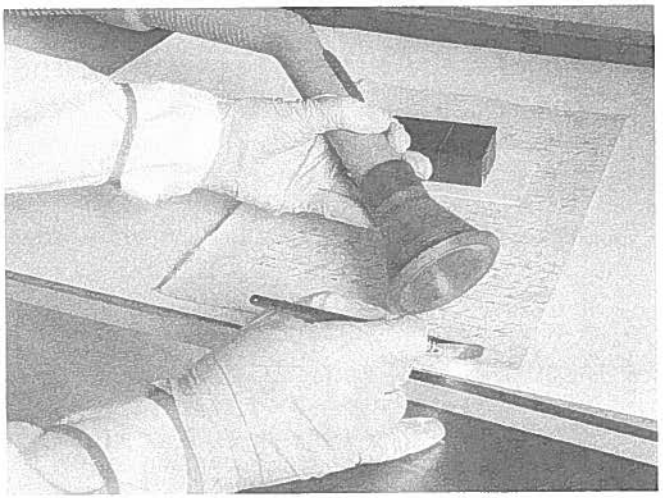

Figure 22. Conservator is using a bell-shaped attachment on the vacuum nozzle and a soft brush to remove tenacious mould from a paper artifact.

A funnel or bell-shaped nozzle attachment for the vacuum cleaner can be useful for removing mould. Compared to a straight vacuum nozzle, it is designed to smooth the airflow. This increases the efficiency and capture rate and draws in more particulate matter toward the suction than does a straight vacuum cleaner nozzle. The attachment is most useful when using a brush to direct mould towards the vacuum nozzle.

Brushes

Brushes should have firm, but not rigid bristles. It is useful to have several inexpensive brushes of different

widths so that the best brush for the item to be cleaned can be selected. If necessary, cover the ferrule (the metal piece that holds the bristles onto the handle of the brush) with Teflon plumbers' tape so the sharp metal edge cannot accidentally scratch the artifact. Brushes to remove mould should be labelled as such and not used on artifacts that are not mouldy.

Negative pressure fume hoods
A negative pressure fume hood is designed to contain hazardous vapours and gases generated inside the hood and exhaust them outside the building. Mould growth can be cleaned off objects by vacuuming them inside a negative pressure fume hood. After cleaning contaminated artifacts, the inside of the fume hood should be cleaned and disinfected so that other artifacts placed in the fume hood do not become contaminated.

Class 1 biological safety enclosure
A class 1 biological safety enclosure is a ventilated enclosure for personal protection in which the inward airflow is directed away from the operator. This type of enclosure meets health and safety guidelines for working with mould (Health Canada 1996). The unit is fitted with a HEPA filter to protect the surrounding environment. During operation, the room air is drawn into the front of the enclosure, preventing aerosols from escaping into the room. Before leaving the enclosure, air is forced through an exhaust HEPA filter so that particulate-free air recirculates into the room. A class 1 biological safety enclosure is not a chemical fume hood and cannot be used for work with solvents.

If possible, mouldy artifacts should be cleaned inside a class 1 biological safety enclosure. It is recommended before using a class 1 biological safety enclosure to have it certified to standards set by the Institute of Environmental Science by a qualified certification technician. An inflow velocity test and HEPA filter leak tests should be performed. Under normal operating conditions, the enclosure should be recertified annually. If there is a pre-filter, it may need to be changed regularly to keep the unit working efficiently. The HEPA filter should be changed by the certifier. Depending on use, the filter usually requires changing every five years. If the class 1 biological safety enclosure is moved, it should be re-certified.

Few commercially available class 1 biological safety enclosures can accommodate oversized artifacts. If necessary, consider consulting the manufacturers of these products to custom-design a larger unit specific to the user's requirements[12]. Otherwise, setting up outdoors to remove mould from oversized artifacts may be an option.

Working at a Fume Hood or Class 1 Biological Safety Enclosure
Follow the recommended practices for laboratory hoods;

Figure 23. Microzone class 1 biological safety enclosure and vacuum cleaner fitted with a HEPA filter and variable suction.

for example, keep all apparatus at least 15 cm back from the face of the hood (a strip on the bench is a good visual reminder) and do not put your head in the hood when contaminants are being generated. In order to ensure that the airflow operates at maximum efficiency, keep the slots in the hood free of obstruction and keep unnecessary items out.

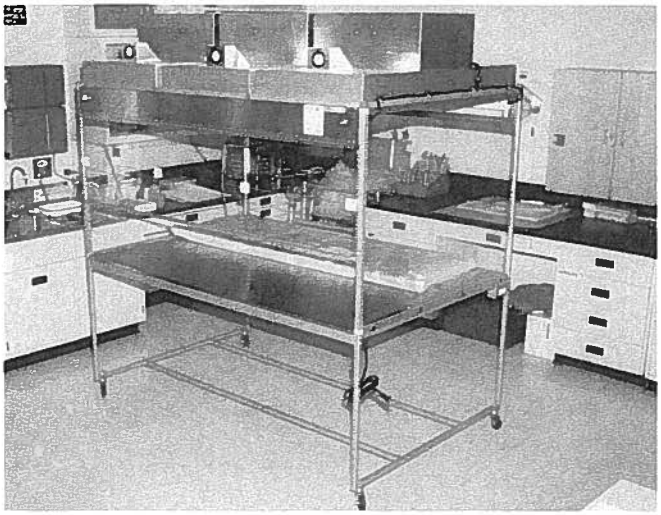

Figure 24. A HEPA-filtered safety enclosure, custom-designed to accommodate large artifacts.

In addition to safety practices for working at a fume hood or class 1 biological safety enclosure, it is important to implement a cleaning methodology that prevents dispersion of mould spores outside the laboratory hood. For example, do not unwrap or remove mouldy artifacts from the container until they are inside the fume hood or class 1 biological safety enclosure. Procedures may vary from one cleaning project to another and may depend on the number and type of artifacts to be cleaned. Providing precautions are taken, respiratory protection is not required while cleaning contaminated artifacts at a fume hood or class 1 biological safety enclosure. Protective clothing and gloves are still necessary.

Vacuuming or, if necessary, a combination of vacuuming and brushing towards the vacuum nozzle is recommended. This cleaning technique will keep the inside of the fume hood or class 1 biological safety enclosure cleaner. It may also reduce how often the class 1 biosafety enclosure or fume hood requires cleaning.

How and When to Clean and Disinfect Tools, Equipment and Work Surfaces

To remove mould spores from tools, equipment and work surfaces in the work area, fume hood or biological safety enclosure, start first by using a vacuum cleaner fitted with a HEPA filter. Follow this by cleaning with a detergent solution, then with a disinfecting solution. Use disposable cloths or wash the cleaning cloths afterwards.

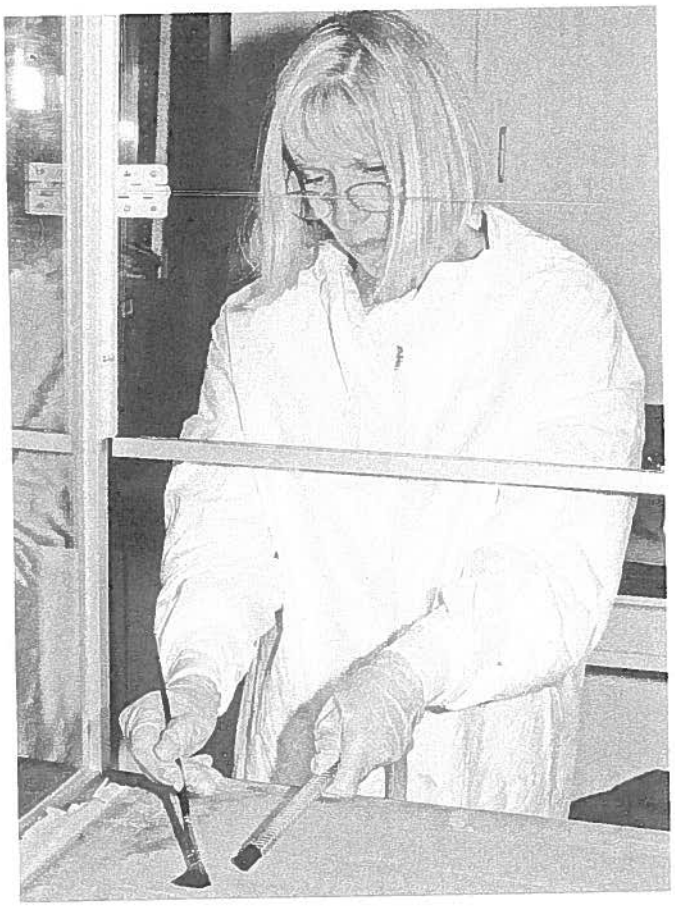

Figure 25. Conservator is working at a HEPA-filtered safety enclosure.

Cleaning solution
Work surfaces, tools and other equipment can be wiped down or washed with a water and detergent solution. Household detergent can be used.

Disinfecting solution
Work surfaces, tools and equipment can be disinfected with a dilute solution of household bleach and water. A solution of 0.5% sodium hypochlorite (household bleach) in water is recommended for disinfecting purposes[13] (Maheux 2002). The bleach is diluted by adding 1 L of a 5% sodium hypochlorite solution (5% is generally the concentration of household bleach) to 9 L of water to make a final volume of 10 L. Alternately, add 250 mL of bleach in 2.25 L of water, making a total of 2.5 L. In both examples, the bleach is diluted by a factor of 10.

Thoroughly wet the surface with the disinfecting solution. A contact time of between 15 and 20 minutes is required to ensure complete disinfection. Wear the appropriate PPE, respiratory protection, gloves and splash goggles when preparing and using a bleach solution. Once prepared, the bleach and water solution begins to lose its potency, so prepare only the amount that is required. Never mix bleach with ammonia or cleaning products that contain ammonia. The two products combine to create noxious fumes, which may be harmful.

Frequency of cleaning and labelling of equipment
During mould cleaning projects that extend over several days or weeks, clean the work surfaces and tools two or three times a week. Disinfect work surfaces and tools weekly.

When mould removal is complete, all equipment and work surfaces — the vacuum cleaner, vacuum brush attachments, cleaning screens and brushes — should be cleaned, disinfected, and thoroughly dried. Small hand tools, vacuum accessories and brushes can be stored in sealed containers. Label the container as containing equipment used to remove mould. Inexpensive or worn brushes can be discarded as contaminated garage.

2.3 Cleaning the Collection Storage Area

For small to large levels of mould contamination, the affected storage area should remain isolated, access restricted and the entrance draped with polyethylene until the area has been thoroughly cleaned. Extensive levels of contamination will require additional measures. Consultation with professionals is advised.

Investigate and correct the cause of the mould infestation before returning artifacts to the area. Clean and disinfect

the storage area before returning any artifacts. This includes the walls, floor, ceiling and any furnishings such as furniture, shelving units, books, papers, carpet, window coverings and computers. Exterior surfaces of a computer can be carefully damp-wiped with a cleaning solution. Typically, because of the airflow generated by the cooling fan, the inside of a computer is quite dusty. If a computer has been in a mould-contaminated environment, the interior may need to be cleaned. Consult a company that specializes in cleaning computers.

Use the cleaning and disinfecting solutions recommended above. Take the necessary precautions and wear the appropriate PPE.

Use cleaning methods that do not stir up dust. Damp-wipe hard surfaces, such as floors, walls and metal shelving units. Vacuum porous surfaces, such as window coverings, papers, fabric-covered furniture, with a vacuum cleaner fitted with a HEPA filter. If using a vacuum cleaner to clean the storage area, place the vacuum cleaner outside the room and use a long vacuum hose to vacuum. This will reduce air movement in the room and help prevent stirring up dust. Make several passes with the vacuum cleaner, in opposite directions on each pass, to pick up residual mould spores. Check ducts, filters and heat exchange coils in HVAC systems or other building/room features. If necessary, have them cleaned and disinfected.

Objects with porous surfaces, such as cardboard storage boxes, that have mould growth should be discarded as contaminated material and replaced. If the level of mould contamination is medium to high, vacuum the exterior of the garbage bags before moving them using the most direct route through the building to the outdoor garbage.

2.4 Cleaning Methods and Considerations for Some Artifacts

Close overall vacuuming with a HEPA-filtered vacuum cleaner is one of the most effective ways to remove mould from artifacts. Where possible, other cleaning techniques can be used to further reduce total spore amount.

Additional information and other cleaning techniques for specific types of artifacts are found in Table 3 (p. 27).

2.5 Considerations after Cleaning

After cleaning artifacts and work environments, the recovered collection must be monitored and the health risk that these artifacts still entail must be managed.

Monitoring the collection
Artifacts previously infested with mould and then cleaned may be more susceptible to mould growth than artifacts that have never been infested with mould. Artifacts themselves (or a selection of them if the numbers are large) should be visually inspected periodically (e.g., every six months). In the event of high RH or water intrusion, artifacts previously infested with mould should be inspected first.

Health concerns after cleaning
How clean is clean? Currently it is not known to what extent previously infested but cleaned material poses a health concern. Thorough and conscientious cleaning will remove mould. Careful, overall vacuuming of the artifact will reduce the total amount of spores on the artifact. Unfortunately, other than a visual examination, no simple method as yet indicates how effectively a cleaning has been done. Hence, the importance of cleaning carefully and thoroughly, with the right equipment, according to recommendations.

However, even though an artifact has been carefully cleaned, some fungal spores and fragments, particularly on porous substrates such as paper, are likely to remain and may become a health concern for some people. Individual susceptibility will vary with genetic predisposition, age, health, concurrent and repeated exposures.

There are no guidelines or regulations for handling artifacts after removing mould. It may be appropriate to adopt a cautious approach when handling and using these artifacts. For example, identify the artifact in a manner that allows users to take precautions before touching it. This should include wearing disposable gloves when handling the artifact and washing hands with soap and water afterwards.

There may be circumstances when information from mouldy books, papers and documents is transferred, under controlled conditions, to another format (i.e., photocopies). In some cases, minimal cleaning may be required before a good reproduction can be obtained. If the original material is retained it should be carefully labelled to identify it as mould infested and stored in an environment not conducive to mould growth.

Conclusion

Mould is a serious health concern and every effort should be made to limit human exposure to it. Actions to combat mould infestation should primarily focus on measures to control the environment. In the event of a mould outbreak in a heritage collection, the conscientious removal of visible mould growth and reduction of the total amount of spores from infested artifacts is necessary. If precautions are taken, small (<0.3 m^2), medium-sized (0.3–3 m^2) and large (3–10 m^2) outbreaks of mould in a collection can safely be cleaned by following the guidelines in this Technical Bulletin. For extensive (>10 m^2) mould contamination in the collection, it is advisable to seek professional help. When in doubt, always consult professionals experienced with mould infestations to determine an appropriate course of action.

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Table 3. Removing Mould from Artifacts

The following table is intended as a general guideline only. Refer to the main text for specific information regarding vacuuming, personal protective equipment (PPE) and health and safety issues pertaining to cleaning artifacts with mould. Take steps to deactivate vegetative mould before cleaning the artifact. Consult **Section 1.3 Mould Outbreak —The First Steps** (p. 10) for information on how to deactivate mould growth on artifacts. Before performing any treatment to remove mould, thoroughly examine the artifact to determine its condition and to find any loose or fragile components. If such components are found, secure them or be prepared to bag them and document their location if they become detached. Be prepared to document your actions. Any treatment to remove mould should be recorded and the documentation retained. Neither vacuuming nor brushing will remove mould stains from an artifact. These stains require treatment by a conservator and may prove difficult, if not impossible, to remove. To determine if basic cleaning techniques (beyond vacuuming and brushing) are possible, consult the appropriate CCI Notes. Conservators should refer to the conservation literature for information about specialized treatments to remove mould growth or mould stains from artifacts.

Artifact	Action
Water-damaged artifacts	Handle artifacts with care because they may be physically weak. A few artifacts can be dried by lowering the RH and increasing air circulation. Artifacts with mould growth should be air dried in a manner such that mould spores are not dispersed near people or in a building. For example, if fans are used to dry a mouldy artifact, direct a gentle flow of air away from the object and cover it with tissue paper during drying to capture any spores that become airborne as the artifact dries. Alternatively, air dry artifacts outdoors or in a fume hood or class 1 biological safety enclosure. Once the mould growth has been deactivated, the artifact can be cleaned, as described in this table and elsewhere in this Technical Bulletin. Freezing stops mould growth. Numerous water-damaged artifacts can be frozen and either freeze-dried or air dried when time and circumstances permit. The hyphae (living filaments) of the mould will be killed by freezing, but the spores (reproductive bodies) will not. Mould spores can withstand freezing temperatures while in the dormant state, although they are less resistant to alternating freeze-thaw conditions. Active mould spores, however, will be killed by the freeze-thaw treatment. This method is suitable for numerous water-damaged or mouldy artifacts provided they can be frozen and either freeze-dried or air dried when possible. For more information, refer to the conservation literature on disaster recovery for heritage collections.
Books	Inspect for mould on the inside and outside covers, the spine and throughout the text block. Mould may cause softening and weakening of the paper and cover boards. This softening will present handling and cleaning challenges. If books exhibit mould within the text block, each affected page should be examined and cleaned. If pages are not affected, keep the book firmly closed when cleaning the exterior. Use a vacuum cleaner fitted with a HEPA filter to vacuum the edges of the text block and cover boards. Mini tool attachments are useful for cleaning small crevices in the spine. Do overall vacuuming to reduce total spore amount. If necessary, dry- or damp-wipe the cover boards after vacuuming. This will remove residual mould spores. Discard or wash cleaning cloths. For more information on the care and cleaning of books, specifically how to vacuum books, refer to CCI Notes 11/7 *Basic Care of Books*.
Paper	Use a vacuum cleaner fitted with a HEPA filter. If necessary, use a brush to dislodge tenacious mould. If paper is fragile, carefully vacuum through a cleaning screen. Do overall vacuuming, on both sides, to reduce total spore amount. After vacuuming, surface cleaning the paper with recommended erasing compounds may remove embedded spores and mould fragments, as well as dirt that acts as a nutrient for future mould growth. The erasing compound will be contaminated with mould spores. Thoroughly remove it from the artifact and carefully discard it by sealing it in waste paper and placing it in the garbage. Consult CCI Technical Bulletin No. 11 *Dry Methods for Surface Cleaning Paper* for more information on surface cleaning. Washing, solvent cleaning, enzyme treatments and bleaching may be further treatment options. However, they require the expertise of a paper conservator. Even so, stains caused by mould growth may not be completely removed.
Artifacts in containers (i.e., boxes, file folders, trunks)	Remove artifact(s) from the container. Clean mouldy artifacts as described in this table and elsewhere in this Technical Bulletin. Examine the container for mould. Before discarding the container, check that it itself is not valuable. If it is, clean and retain. If not, discard the mouldy container and rehouse the artifact in a new container. Transfer any information from the discarded container. Coroplast or Cor-X boxes can be cleaned, disinfected, dried and re-used.

Artifact	Action
Parchment or vellum	Parchment and vellum are very susceptible to changes in RH. Documents may be folded, brittle and stuck together. Parchment and vellum documents should be unfolded only after careful humidification. Use a vacuum cleaner fitted with a HEPA filter. If necessary, use a brush to dislodge tenacious mould. If the document is fragile, vacuum through a cleaning screen. Do overall vacuuming, on both sides, to reduce the total spore amount. Because parchment and vellum are very sensitive to humidity, cleaning with moisture should be avoided. After vacuuming, it may be possible to surface clean the document with recommended erasing compounds to remove embedded spores and mould fragments, as well as dirt that acts as a nutrient for future mould growth. The erasing compound will be contaminated with mould spores. Thoroughly remove it from the artifact and carefully discard it by sealing it in waste paper and placing it in the garbage. Consult CCI Technical Bulletin No. 11 *Dry Methods for Surface Cleaning Paper* for more information on surface cleaning. Documents may have seals made of wax or shellac. These may be brittle and should be gently brushed rather than vacuumed. Vellum and parchment bindings in good condition can be cleaned in the same manner used to clean a book. Refer to CCI Notes 11/7 *Basic Care of Books* for more information on caring for parchment and vellum bindings.
Photographs	Remove surface mould with gentle techniques, such as using a soft brush or mini brush attachments on a vacuum cleaner fitted with a HEPA filter. Do not use water or solutions containing water because mould may have made the photograph's emulsion water-soluble. Gelatin, the major component in the emulsion of films and prints, is an excellent nutrient for fungi. Fungal growth frequently concentrates around fingerprints on prints and film due to salts in the fingerprints, which create localized moist conditions. It is not recommended to treat photographs with fungicides; therefore, it is important to control RH in areas where photographs are stored. Alternatively, a suitable frost-free refrigerator will provide an excellent humidity controlled micro-environment for storing both colour and black and white photographs. Photographs must be packaged in envelopes or boxes and placed in polyethylene bags or wrapped with polyethylene and the seams taped with freezer tape before they are placed in a frost-free refrigerator (Wilhelm 1993). Consult a photographic conservator for more information before storing photographs in this manner.
Magnetic media	Compact discs: Isolate the affected disc from the rest of the collection. Place it in a low-humidity environment until cleaning can begin. A temperature of less than 23°C and a humidity less than 50% RH (down to 20% RH is acceptable) are recommended. Remove mould from the disc with a vacuum cleaner fitted with a HEPA filter. Brush tenacious mould off in a radial direction (i.e., perpendicular to the grooves) and direct the mould towards the vacuum cleaner. Once cleaned, the CD should be copied. Retain the original and store it in an environment that is not conducive to mould growth. Magnetic diskettes: Remove the mould growth from the diskette enclosure with a vacuum cleaner fitted with a HEPA filter. Remove the diskette from the enclosure, refer to CCI Technical Bulletin No. 25 for instructions on how to do this. Follow the cleaning procedure described above for compact discs, except brush mould growth off in a circular direction. Magnetic tapes: Isolate the affected tapes from the rest of the collection. Place tapes in a low-humidity environment until cleaning can begin. A temperature of less than 23°C and a humidity less than 50% RH (down to 20% RH is acceptable) are recommended. To clean, use a vacuum cleaner fitted with a HEPA filter and remove the mould from the tape pack. Avoid any direct contact between the vacuum nozzle and the tape. Tenacious mould can be brushed from the tape pack using a soft brush. It is recommended to run the tape through a winder/cleaner because mould is very invasive and will grow between the strands of tape in a tape pack. The original tape should then be copied onto another tape. Retain the original and store it in an environment that is not conducive to mould growth. The recorder should be cleaned to avoid contaminating other tapes with mould spores (Iraci 2002). Additional cleaning procedures, such as those recommended for removing stubborn deposits from compact discs, magnetic diskettes and magnetic tapes, are possible. Consult CCI Technical Bulletin No. 25 *Disaster Recovery of Modern Information Carriers: Compact Discs, Magnetic Tapes, and Magnetic Disks* for more information.
Negatives, slides, microfilm and microfiche	Remove surface mould by gently brushing with a soft brush or with a mini brush attachment on a vacuum cleaner fitted with a HEPA filter. Remove slides from mounts (glass, cardboard or plastic), clean and return to new mounts. Wear clean cotton gloves to avoid putting fingerprints on the film. For more information, seek the expertise of a conservator.
Friable media (i.e., pastel, chalk, charcoal, powdery pigments on any object)	Friable media is at risk of being dislodged by any cleaning method. Removal of mould, if at all possible, requires a high degree of manual skill and precision while working with fine tools. Seek the expertise of a conservator. The natural binders used in the manufacture of pastels make them particularly susceptible to mould growth. The surface of a pastel is very fragile. These artworks are among the most difficult to treat for mould growth.

Artifact	Action
Paintings	Deactivate mould growth. To avoid an abrupt change and extremely dry conditions, both of which can promote cracking in oil paintings, lower the RH conditions gradually, over one to two hours, and do not lower the conditions below 40% RH. Loosely wrap the painting to prevent dispersion of mould spores. Consult a paintings conservator for further advice. Due to the complex structure of paintings, permanent damage can result from even the most cautious attempts to clean a painting by untrained personnel. For more information, refer to CCI Notes 10/1 *Cleaning Paintings: Precautions* and 10/13 *Basic Handling of Paintings*.
Textiles	Use a vacuum cleaner fitted with a HEPA filter. If necessary, brush to dislodge tenacious mould. If the textile is fragile, carefully vacuum through a cleaning screen. Mini tool attachments for the vacuum cleaner may be useful. Do overall vacuuming, on both sides, to reduce the total number of spores. Conservation treatments such as washing or dry cleaning may remove embedded spores and mould fragments, as well as stains and dirt that act as nutrients for future mould growth. Refer to CCI Notes 13/7 *Washing Non-coloured Textiles*, 13/9 *Anionic Detergent*, 13/15 *Mould Growth on Textiles* and 13/13 *Commercial Dry Cleaning of Museum Textiles* for more information. Stains resulting from mould growth may not be completely removed by washing or dry cleaning.
Basketry (i.e., items of woven plant material)	Use a vacuum cleaner fitted with a HEPA filter. If necessary, brush to dislodge tenacious mould. Mini tool attachments for the vacuum cleaner may be useful. Do overall vacuuming to reduce the total number of spores. Examine the artifact for powdery pigment and evidence of use (e.g., seeds) before vacuuming. These elements are important and should not be altered or removed. If either are present, consult a conservator before cleaning. For more information on cleaning options, refer to CCI Notes 6/2 *Care of Basketry*.
Leather	Use a vacuum cleaner fitted with a HEPA filter. If necessary, brush to dislodge tenacious mould. Mini tool attachments for the vacuum cleaner may be useful. Do overall vacuuming to reduce the total number of spores. For more information, refer to CCI Notes 8/1 *Removing Mould from Leather*.
Wood	Use a vacuum cleaner fitted with a HEPA filter. If necessary, brush to dislodge tenacious mould. Mini tool attachments for the vacuum cleaner may be useful. Do overall vacuuming to reduce the total number of spores. When vacuuming furniture, remove all drawers and open all doors in order to completely clean the interior as well as the underside and other sides of the object. Water-damaged veneer surfaces of furniture may be poorly attached or folded away from the substrate and may also be brittle. To minimize the loss of veneer pieces, use a soft brush to gently dislodge mould, directing it toward the vacuum nozzle. Be sure the vacuum cleaner nozzle is covered with screening material. Additional cleaning techniques, such as surface cleaning and damp swabs for unfinished wood and damp cloth or solvent cleaning of painted finishes in good condition, may be possible. For more information, refer to CCI Notes 7/1 *Care and Cleaning of Unfinished Wood* and 7/2 *Care of Furniture Finishes*.
Ivory, bone, horn and antler	Use a vacuum cleaner fitted with a HEPA filter. If necessary, brush to dislodge tenacious mould. Mini tool attachments for the vacuum cleaner may be useful. Do overall vacuuming to reduce the total number of spores. Additional cleaning possibilities are found in CCI Notes 6/1 *Care of Ivory, Bone, Horn and Antler*.
Glass and ceramics	Organic residues on non-porous surfaces will support mould growth. Use a vacuum cleaner fitted with a HEPA filter. If necessary, brush to dislodge tenacious mould. Mini tool attachments for the vacuum cleaner may be useful. Do overall vacuuming to reduce the total number of spores. Glass and ceramic objects in good condition may be further cleaned by washing. Refer to CCI Notes 5/1 *Care of Ceramics and Glass* for information on how to proceed.
Metal	Organic residues on non-porous surfaces will support mould growth. Use a vacuum cleaner fitted with a HEPA filter. If necessary, brush to dislodge tenacious mould. Mini tool attachments for the vacuum cleaner may be useful. Do overall vacuuming to reduce the total number of spores. For additional cleaning possibilities, refer to the following CCI Notes: 9/3 *The Cleaning, Polishing and Protective Waxing of Brass and Copper*, 9/4 *Basic Care of Coins, Medals and Medallic Art*, 9/6 *Care and Cleaning of Iron*, 9/7 *Silver - Care and Tarnish Removal* and 9/9 *Care of Objects Made of Zinc*.
Rubber and plastic	Organic residues on non-porous surfaces will support mould growth. Use a vacuum cleaner fitted with a HEPA filter. If necessary, brush to dislodge tenacious mould. Mini tool attachments for the vacuum cleaner may be useful. Do overall vacuuming to reduce the total number of spores. For additional cleaning possibilities, refer to CCI Notes 15/1 *Care of Objects Made from Rubber and Plastic*.

Endnotes

1. Fungi, members of the Kingdom Fungi, are organisms that feed on organic matter. They include moulds, yeast, mushrooms and toadstools. Fungal growth is often commonly called mould. In this Technical Bulletin, the terms fungi and mould are used interchangeably.

2. For example, see: V. Daniels, and B. Boyd, "The Yellowing of Thymol in the Display of Prints," *Studies in Conservation* 31 (1986): pp. 156–158; Mary-Lou Florian, *Heritage Eaters: Insects & Fungi in Heritage Collections*, London: James & James Ltd., 1997; Ralph Gustafson, "Fungicidal Efficacy of Selected Chemicals in Thymol Cabinets," *Journal of the AIC* 29 (1990): pp. 153–168; M. Nittérus, "Fungi in Archives and Libraries - A Literary Survey,"*Restaurator* 21 (2000): pp. 25–40; M. Nittérus, "Ethanol as Fungal Sanitizer in Paper Conservation," *Restaurator* 21 (2000): pp. 101–115; T. Strang, and J. Dawson, *Controlling Museum Fungal Problems*, Technical Bulletin, No. 12, Ottawa: Canadian Conservation Institute, 1991; J. Wellheiser, *Nonchemical Treatment Processes for Disinfestation of Insects and Fungi in Library Collections*, München: K.G. Saur, IFLA Publication 60, 1992.

3. For more information on using biocides in mould remediation refer to: Environmental Protection Agency, "Remediation," in *Mold Remediation in Schools and Commercial Buildings*, Washington, DC: Office of Air and Radiation, Indoor Environments Division, 2001, pp. 19–26; E.C. Cole, and Karin K. Foarde, Chapter 16, "Biocides and Antimicrobial Agents" in *Bioaerosols: Assessment and Control* (J. Macher, ed.), Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists (ACGIH), 1999.

4. Conidia refers to the asexual spores produced at the end of a hypha. These are more common in air than are the specialized sexual spores released by some of the same mould organisms. In this publication, the more common term spore is used.

5. Dew point is the temperature at which the moisture in the air condenses on a surface.

6. Genus refers to a relatively small group of similar organisms. Genera (the plural of genus) are divided into species.

7. Aggressive air sampling is usually done by disturbing the area before sampling, using compressed air aimed at the floor or a horizontal surface. This allows spores and material, which have settled, to become airborne and collectable.

8. The American Industrial Hygiene Association runs a program of proficiency and accreditation for laboratories. These programs are the Environmental Microbiology Proficiency Analytical Testing (EMPAT) and Environmental Microbiological Laboratory Accreditation Program (EMLAP). A laboratory participating in one or both of these programs has demonstrated a high level of expertise and proficiency.

9. HEPA is a descriptive term for filters that have been tested to assure removal of 99.97% of particles 0.3 microns in size.

10. A qualified individual is someone who has successfully completed the appropriate course covering test fitting of respirators. These courses, according to the Canadian Standards Association, are often given by the manufacturer of respirators.

11. A metabolite is a substance formed in or necessary for metabolism to occur. Metabolism is the chemical process that occurs within a living organism resulting in energy production.

12. A complete discussion of fume hoods and class 1 biological safety enclosures is beyond the scope of this Technical Bulletin. For more information pertaining to design and correct face velocity for fume hoods and class 1 biological safety enclosures, consult: *Industrial Ventilation - A Manual of Recommended Practice*, 24th ed., Cincinnati, Ohio: American Conference of Government Industrial Hygienists, 2001; *Laboratory Biosafety Guidelines*, 2nd ed., Ottawa: Health Canada Laboratory, Centre for Disease Control, Health Protection Branch, 1996.

13. The recommendation to use a sodium hypochlorite solution for disinfection is also found in the *Laboratory Biosafety Manual*, 2nd ed., Geneva, Switzerland: World Health Organization (WHO), 1993; and E.C. Cole, and Karin K. Foarde, Chapter 16, "Biocides and Antimicrobial Agents," Section16.2.4.2, "Hypochlorites" in *Bioaerosols: Assessment and Control* (J. Macher, ed.), Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists (ACGIH), 1999.

Suppliers

personal protective equipment (PPE)
(including respiratory protection, goggles, gloves, protective clothing, head and shoe coverings, ear protection, back support belts)

Fisher Safety Canada
1-800-234-7437 (customer service)
or 1-877-676-3639 (safety customer service)
www.fishersci.ca

Lab Safety Supply
1-800-356-0783 (Canada and the United States)
1-800-356-2501 (technical assistance)
608-754-7160 (International)
www.labsafety.com

Canadian Standards Association
(for more information regarding respirators)
CSA Standard Z94.4-02
"Selection, Use, and Care of Respirators"
416-747-4000 or 1-800-463-6727

vacuum cleaners fitted with a HEPA filter
some brands of household vacuum cleaners are fitted with HEPA filters and may be appropriate for small cleaning projects; check local hardware, department stores and vacuum cleaner stores

Carr McLean
461 Horner Avenue
Toronto ON
M8W 4X2
1-800-268-2123
1-800-268-2138 (en français)
www.carrmclean.ca

Nilfisk-Advance Canada Company
396 Watline Avenue
Mississauga ON
L4Z 1X2
Tel.: 905-712-3260
Fax: 905-712-3255

Nilfisk-Advance America Inc.
300 Technology Drive
Malvern PA 19355
USA
Tel.: 610-647-6420
Fax: 610-647-6427
www.pa.nilfisk-advance.com

Lab Safety Supply
1-800-356-0783 (Canada and the United States)
1 800-356-2501 (technical assistance)
608-754-7160 (International)
www.labsafety.com

bell/funnel-shaped nozzle for vacuum cleaner
can be custom made, available from:
Safe-T-Air Inc.
1137 Tighe Street
PO Box 36
Manotick ON
K4M 1A2
613-692-2070

mini tools attachments for vacuum cleaner
sewing, computer and vacuum cleaner stores

brushes
local hardware or art stores

window screen, cleaning cloths, garbage bags (heavy duty)
local hardware, department and grocery stores

sodium hypochlorite (household bleach in Canada is generally 5% sodium hypochlorite)
local grocery and hardware stores

class 1 biological safety enclosures
Microzone Corporation
Box 11336, Station H
25F Northside Road
Nepean ON
K2H 7V1
613-829-1433

Labconco Corporation
8811 Prospect Avenue
Kansas City MO 64132
USA
1-800-821-5525
www.lanconco.com

custom-designed safety enclosure with HEPA filter exhaust hood
Design Filtration Inc.
101-195 Stafford Road, West
Nepean ON
K2H 9C1
613-820-9686
www.designfiltration.com

Web Sites and Other Sources of Information

General Information

Health Canada
Dampness, Mould and Indoor Air
www.hc-sc.gc.ca/iyh-vsv/environ/air_e.html

Fungal Contamination in Public Buildings: Health Effects and Investigation Methods
www.hc-sc.gc.ca/ewh-semt/pubs/air/fungal-fongique/index_e.html

Canada Mortgage and Housing Corporation (CMHC)
Indoor Air Quality
www.cmhc-schl.gc.ca/en/corp/faq/faq_005.cfm

Fighting Mold - The Homeowner's Guide
www.cmhc-schl.gc.ca/en/co/maho/yohoyohe/momo/momo_005.cfm

Canadian Centre for Occupational Health and Safety (CCOHS)
www.ccohs.ca/oshanswers/biol_hazards/iaq_mold.html#_1_6

U.S. Consumer Product Safety Commission (CPSC)
Biological Pollutants in Your Home
www.cpsc.gov/cpscpub/pubs/425.html

U.S. Environmental Protection Agency (EPA)
Indoor Air Quality - Mold Resources
www.epa.gov/mold/moldresources.html

American Industrial Hygiene Association (AIHA)
Mold
www.aiha.org/Content/Topics/mold/

Guidelines

Health Canada
Fungal Contamination in Public Buildings: A Guide to Recognition and Management
www.hc-sc.gc.ca/ewh-semt/pubs/air/fungal-fongique/index_e.html

Manitoba Department of Labour, Safety & Health Division
Guidelines for the Investigation, Assessment & Remediation of Mould in Workplaces
www.gov.mb.ca/labour/safety/pdf/mouldguide.pdf

New York City Department of Health
Bureau of Environmental & Occupational Disease Epidemiology
Guidelines on Assessment and Remediation of Fungi in Indoor Environments
www.ci.nyc.ny.us/html/doh/html/epi/moldrpt1.html

Laboratories

AIHA Accredited Labs
www.aiha.org/Content/LQAP/accred/AccreditedLabs.htm

Aerotech Labs
www.aerotechpk.com

Environmental Microbiology Laboratory, Inc.
www.emlab.com

Paracel Laboratories Inc.
www.paracellabs.com

Miscellaneous

Stachybotrys chartarum: The Toxic Indoor Mold
www.apsnet.org/online/feature/stachybotrys/

Hiring a Conservator

Canadian Association of Professional Conservators
www.capc-acrp.ca/

American Institute for Conservation of Historic and Artistic Works
aic.stanford.edu/public/select.html

Disaster Recovery Services

Rosco Document Restoration
www.roscodoc.com

Munters The Humidity Expert
www.munters.com/

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