CONSERVATION CENTER
for Art & Historic Artifacts

MANAGING A MOLD INFESTATION: GUIDELINES FOR DISASTER RESPONSE

Introduction

This bulletin offers guidelines for response to the outbreak of mold activity in public and private collections. Consulting a conservator is always recommended, whether the problem appears large or small. While it is intended to be useful for institutions and private collectors, this bulletin should not be considered a substitute for professional expertise.

Origins of a Mold Problem

Cause for Concern: Mold, a form of fungal growth, is one of the most serious sources of damage to library, archival, and museum collections, as well as a potential health threat to the people who care for collections.

Molds are attracted to starches, such as those found on adhesives, sizings, and cloth; proteins, such as leather, parchment, gelatin, and animal glues; and cellulose, which is the main component of paper. In collections, mold can attack books, documents, art on paper, photographic prints and negatives, and other paper-based artifacts.

As mold grows and digests collection materials, it compromises and weakens them. In addition to the immediate damage, many molds contain colored substances capable of staining the material on which they grow. Once an item has been attacked by mold, it will be more susceptible to future damage. The weakened organic material absorbs water more easily, resulting in an ongoing cycle of damage.

Mold Growth: Although we can't see them, mold spores are everywhere. They simply need the right environmental conditions to germinate.

Two things are needed for mold to germinate: 1) an organic substrate (host material on which to grow) and 2) moisture.

Mold will grow on any organic material offering suitable nutrients, including paper, adhesives, cloth, wood, and leather. Superficial soiling deposits (including skin cells, clothing fibers, external dirt, oily substances, and industrial pollutants) found on shelves and storage furniture, as well as on collections material, can also be a nutrient source for mold growth. All of the above materials are hygroscopic—their ability to attract and retain moisture makes them optimal substrates for fungal activity.

Seasonal Concerns: The outdoor environment is a factor in mold growth. Outside air is continually circulated though buildings by HVAC (heating, ventilating, and air conditioning) systems. For this reason, it is important to be aware of the increased possibility of mold growth

during times of year when temperatures begin to drop and the amount of moisture in the air tends to be higher (typically August through October in the Northern Hemisphere). Institutions should be especially careful during these months to monitor environmental conditions.

A Mold Bloom: Since mold spores exist in most environments at almost all times, a sudden mold bloom in a collection indicates that an environmental change has occurred, causing the spores to germinate. Such concentrated outbreaks can be caused by triggers including faulty HVAC systems, water leaks, flooding, and other climactic changes. In instances of water damage to collections or buildings materials, action within 24-48 hours is necessary to prevent mold growth.

The mold species that most commonly attack paper-based material are at the greatest risk to germinate and grow when the relative humidity reaches or exceeds 70% and remains at this level for several days. As relative humidity increases, hygroscopic materials absorb water to reach equilibrium with the surrounding environment. High temperatures, poor air circulation, dim or no light, and accumulated soiling assist and accelerate the growth of mold once it has germinated, but only high relative humidity of the environment and moisture contents of the substrate can initiate and sustain mold growth.

The United States Environmental Protection Agency (EPA) recommends maintaining indoor relative humidity levels below 60% (ideally 30-50%), a goal that is compatible with standards for the long-term preservation of paper-based collections.[1]

If the relative humidity drops below 70% and the materials lose their high moisture content to the atmosphere, most molds will stop growing and become inactive or dormant. However, the spores will remain viable on the host material, and will become active and begin growing again if the relative humidity rises.

If it is suspected that a collection has a mold outbreak, human safety and proper personal protective equipment should always be the priority. See the section on first response procedures for more information on personal safety.

In-House Assessment: The first step in responding to a mold bloom is to determine that the observed problem is mold. Accumulations of dirt, dust, stains, cobwebs, and condition issues such as fatty acids leaching out of oiled leather bindings and printing inks, are sometimes mistaken for mold.

Check temperature and relative humidity in the area. Are there any visible signs of water damage? Mold is active and will grow when the relative humidity reaches or exceeds 70% and remains there for a period of time. Under some circumstances, mold growth can occur within 24-48 hours.

- Does the material feel damp? Smell musty or moldy? Some molds produce and emit compounds called microbial volatile organic compounds (mVOCs). While a musty smell may not always indicate active mold, these mVOCs are the source of the musty odors often associated with mold.

- Examine under magnification. Does it look like mold? In the early stages of growth, mold appears as a fine web of filaments (hyphae) on the surface or in the structure of the host

material. In later stages, the mold develops a furry, bushy appearance, and fruiting bodies containing spores are clearly visible under magnification. Mold can be almost any color.

Foxing: Is it mold? The reddish-brown discolorations found on much rag paper created in the sixteenth to nineteenth centuries are known as "foxing" or "fox spots." Unfortunately, there is not a simple answer to the question, "Is it mold?" Many fox spots do have a fungal element, while many are distinguished by the presence of iron and acidic content. Some instances of foxing may have both indications of fungi and metallic inclusions. It is safe to say that most fox spots seem to be exacerbated by an increase in relative humidity.

The good news is that any staining associated with foxing is not usually indicative of a current mold bloom. While it may have caused unattractive, permanent stains to many older items, mold spores that led to foxing were likely introduced during the paper production process. Foxing can, however, migrate from adjacent pages in books or in materials stored together in a folder or box. Interleaving between pages can decrease the possibility of stain migration.

Decisions on How to Proceed: Small to moderate outbreaks involving a limited number of items can often be handled in-house if no highly toxic mold species are present. Toxicity of mold species can only be determined by a certified mycologist; a local university or hospital can provide a referral for a mycologist.

The amount of outside assistance required will depend upon the extent of the outbreak, toxicity of the mold involved, resources of the institution, and the type of material affected.

The EPA has defined guidelines for cleanup methods and the protection/containment required based on size of outbreak as follows:[2]

- Small area: Less than 10 square feet affected.
- Medium-sized isolated areas: 10-100 square feet affected.
- Large areas: 100 or more square feet affected. Only properly trained mold remediation workers should attempt clean-up and containment at this volume.

A major bloom involving a large area of a collection or one involving highly toxic mold species will require outside professional advice and assistance to stop the mold growth, clean the collection, and render the affected area safe for use again. Professional expertise should also be sought when collections may have been exposed to water contaminated with sewage, chemical, or other biological agents, or when it is suspected that the HVAC system is contaminated with mold.

Additional criteria for choosing method(s) of response might include:

- Type of material (will the material be reformatted rather than cleaned and retained?).
- Extent and severity of outbreak.
- Current weather conditions at the time of outbreak.
- Type and functioning of HVAC.

- Access to freezing, freeze-drying, desiccant-drying facilities, and professional services.
- Presence of concurrent insect infestation.
- Staffing resources.

Personal Safety

After establishing personal safety of all people involved in the effort, first response procedures should focus on locating the humidity source, lowering the humidity, and isolating affected materials.

Personal protection should always be the priority when entering a potentially mold infested area. All mold outbreaks should be treated as potential health hazards. Regardless of the mold species present, individuals with serious allergies, diabetes, asthma, respiratory problems, or compromised immune systems, among other conditions, should avoid the affected area and materials.

Mold spores enter the body by inhalation or ingestion and through small breaks in the skin. Exposure to any molds, even those that are not highly toxic, can have serious health consequences, including respiratory problems, skin and eye irritation, and infections. The EPA reports that exposure to some mold odors have been linked to headaches, nasal irritation, dizziness, fatigue, and nausea. Even mold that is dormant can cause allergic reactions in susceptible individuals. Implement appropriate personal protection precautions from the preliminary assessment through all subsequent stages of remediation.

The following protective gear and procedures are necessary for safely dealing with small and medium-sized outbreaks (less than 100 square feet). The United States Center for Disease Control and Prevention (CDC) provides more detailed guidelines for protection level, based on the nature of nearby activities and personal risk factors.[3]

For small outbreaks, use the following equipment:

- N95 disposable respirators: They offer the minimum level of required protection.
- Disposable plastic gloves: Gloves should be long enough to cover any exposed skin on the arms. Be sure the glove material provides an appropriate level of protection if using chemical cleaning solutions. Nitrile gloves are hypoallergenic for many people and are chemically resistant to many solvents.
- Full-seal goggles or protective eyewear.

For a medium-sized outbreak, additional precautions should be instituted. The following equipment is recommended:

- Half- or full-face air-purifying respirator with a high efficiency particulate air (HEPA) filter attached. Please note: OSHA requires training, medical clearance, and fit testing by a trained professional for the use of half- and full-face respirators.
- Coveralls or laboratory coats, preferably disposable.

- Foot and head covers for very dirty situations.

After use, remove coveralls, laboratory coats, and protective gear in a designated “dirty” area. Periodically disinfect non-disposable gear to avoid spreading mold spores and contaminating nearby areas; wash laboratory coats, coveralls, and other washable items in hot water and detergent and/or bleach. Routinely wipe respirator mouthpieces with hydrogen peroxide to sterilize, and change HEPA filters regularly. Place disposable protective gear in sealed, polyethylene bags prior to removing these items from the “dirty” area for immediate disposal.

First Response for a Mold Bloom

1. Locate the high humidity source: Moisture is imperative to the growth of mold. In the event of a water emergency, responding with speed is critical. Action within 24-48 hours is recommended to slow or stop potential mold growth.

- Look for a moisture source such as a leaky roof or pipe, external wall with condensation, broken window, damp basement floor, blocked gutters, or interior fountains.

- Check the HVAC system, especially the heat-exchange coil and drip pan. Have an HVAC engineer inspect and ensure that the problem is not in the ductwork. If there is no obvious leak in the area, an elevated relative humidity may indicate a problem with the HVAC system.

2. Lower the humidity and increase air circulation: Use any appropriate combination of the following tactics.

Please note: In a flood scenario, personal protective equipment and containment of contaminated water are required by the United States Occupational Safety and Health Administration (OSHA). The EPA does not recommend the use of any fans unless the water is clean.

- Fix or adjust the HVAC system if it can dehumidify the air. If the system is thermostatically controlled or is a fan coil system that cools outside air and then circulates it, turn it off. These types of systems can increase relative humidity because they cool air without removing significant amounts of moisture. Do not run the HVAC system if you suspect it is contaminated with mold.[4]

- Install dehumidifiers, being careful to arrange continuous drainage or to empty them frequently.

- Open windows if outside humidity is lower than inside. Keep the lights on when safely possible.

- Use fans to increase air circulation in the affected area; the use of several fans at low speeds is recommended. To avoid damaging material and dispersing mold spores, do not point fans directly at the problem area.

Following immediate efforts, monitor the humidity and temperature several times a day and keep a log.

3. Isolate affected materials: This step is essential for reducing dispersion of spores and protecting people.

- For small to moderate blooms, when safely possible, it is best to carry out drying and inactivation in-situ to reduce contamination. Avoid moving collections material out of the affected area. Increased rates of mold growth have been observed when wet or contaminated items are transported off-site, and other collections could be affected. In preparation for appropriate inactivation procedures, temporarily cover wet items with a moisture permeable material (such as Tyvek) to prevent spores from spreading. Items that remain dry and unaffected can be placed in plastic bags (6-mil polyethylene is recommended) for protection. Place disposable materials that can be discarded in polyethylene bags and seal them prior to disposal. Do not reuse contaminated packing materials.

- For large blooms, quarantine the area and contact outside professional help immediately. Close all doors, hang plastic sheeting between affected and unaffected areas, and reduce air circulation from the affected area to the rest of the building.

After the cleanup is complete, follow-up procedures can be critical to preventing a new mold bloom:

- Thoroughly clean the entire affected area, including all floors, work surfaces, and shelves, using one of the following disinfectants:

    - a solution of 0.5% household bleach (sodium hypochlorite) by volume in water
    - a solution of at least 40% isopropyl (rubbing) alcohol by volume in water
    - a solution of 70% ethyl alcohol by volume in water

Leave the disinfectant on the surface for 15 to 20 minutes before wiping dry or rinsing. Make sure the area is completely dry before returning materials. Have the HVAC system components inspected, cleaned, and disinfected.

- Monitor all affected materials on a regular schedule to check for renewed mold growth or effects of treatment or cleaning.

- Monitor the environment in the affected area regularly. Be sure housekeeping and air circulation remain adequate. Ensure that there are no active water leaks.

- Relocate materials that were stored in unstable areas such as along outside walls or in damp basements.

- Undertake necessary repairs of faulty equipment and upgrades to the physical plant to prevent recurrence.

Fungicides and Fungistats: Extreme caution should be used with fungicides and fungistats. In the past, various fungicides (chemicals that kill mold) and fungistats (chemicals that stop mold growth) were recommended and widely used for control of mold in library, archival, and museum collections. In recent years, however, use of these substances has been more carefully evaluated and is no longer recommended. Their use raises concerns about toxicity and long-term negative effects on collection materials. Toxic components can prevent direct handling and complicate future conservation treatments. In addition, it has been determined that fungicides

and fungistats give no residual protection to collections materials, suggesting that the benefits do not outweigh the risks.

In the case of major blooms affecting a significant part of the collection or outbreaks involving highly toxic mold species, outside professionals may advise using specialized fungicides legally registered for use in public buildings when applied by a licensed professional to disinfect HVAC systems and ductwork. It should be noted, however, that none of these substances have been tested for their long-term effects on permanent collections materials.

Inactivation

The procedures outlined below are necessary to inhibit and inactivate mold growth on collection items. They should be followed if first-response actions are not successful in stopping a mold bloom, if the environment and/or the materials remain damp, and/or if the number of affected materials is large. Although these procedures inactivate mold, dormant spores will remain viable. Inactivation must be followed by mold remediation to minimize future occurrences.

1. Small-scale air drying of damp books and other paper materials: This can be accomplished using standard disaster recovery procedures: spread paper items on tables and stand books on end and open them like a fan. Use fans to circulate air and to speed drying. To reduce dispersion of the spores, fans should be positioned to circulate the air without blowing directly on the affected material. Drying will inactivate the mold. It should be done in an isolated area that will later be thoroughly cleaned. Do not attempt to fan-dry books that have absorbed enough water to become wet and waterlogged – this method is for damp books only.

2. Freezing affected materials at temperatures below -20°C: Freezing is not appropriate for all types of materials – always consult a conservator before freezing. Very low temperatures stop active mold growth and prevent new mold growth. Many materials can be frozen as an interim step before the appropriate drying method is chosen. Temporary freezing can be done in-house for small outbreaks; for moderate to large outbreaks, long-term freezing should be done by an outside vendor.

3. Ultraviolet (UV) radiation/sunlight exposure: Using extreme caution, this tactic can effectively inactivate mold and aid drying. UV radiation accelerates aging and is damaging to all library, archival, and museum materials, but for small outbreaks it can be an acceptable treatment step. Items can be exposed on interior windowsills if necessary, or outside on a sunny, dry, non-windy day. Items should be carefully monitored and thoroughly surface-cleaned afterwards. Placing an ultraviolet germicidal irradiation cleaner (UVGI) in the contaminated space can be effective in inactivating mold. UVGIs are sometimes installed as part of an HVAC system.

4. Desiccant drying: This strategy is sometimes used by a disaster response or environmental control company for moderate or large outbreaks. With this method, moist air is pumped out of the affected area and circulated through a desiccant drying system, which removes excess moisture. The dry air is then reintroduced into the space. Commonly used desiccants include silica gel, activated charcoal, calcium sulfate, calcium chloride, and montmorillonite clay.

Cleaning the Collection: Mold Removal

To determine the course of action to take when cleaning a collection affected by mold, test pieces in the collection with a small, natural-hair brush. Is the mold dry and powdery (dormant) or soft and smeary (active)? Active mold will continue to grow and damage collections. Dormant mold will cause no further damage unless spores germinate and it becomes active again, which may happen if the relative humidity increases. Cleaning or mold removal should be done after mold is inactivated. Inactive mold can be readily vacuumed or wiped away using dry surface-cleaning methods with minimal additional damage.

Consulting a conservator prior to cleaning is highly recommended. A conservator can advise on appropriate approaches to inactivation and mold removal based on types and condition of collections materials and can provide necessary training for in-house staff. The physical condition of an artifact should always be considered when selecting a mold removal method.

Vacuuming with a HEPA vacuum is the most effective method for quickly removing dry, inactive mold residues from storage furniture and boxes and from some collection materials, such as papers or books that are in stable condition. Vacuuming avoids spreading or further embedding the mold. A vacuum with variable suction controls is always recommended. For fragile or particularly valuable materials, use a small, soft brush to gently loosen the mold from the artifact's surface, and then direct it into the nozzle of the vacuum. Dry cleaning using a grated vinyl eraser or vulcanized rubber sponge may be necessary for thorough cleaning after vacuuming has removed most of the residue.

There may be circumstances in which it would be expedient to clean active mold. Cleaning active mold is a delicate, specialized process: always contact a conservator. Attempting to clean active mold from paper or other porous materials tends to embed the mold in the paper; unless great care is taken to avoid embedding the mold, the result can be further damage. A conservator will often use specialized equipment such as an aspirator, which utilizes a small compressor attached to a flexible hose with a pipette nozzle to gently suck the mold off the surface of the artifact. Cleaning procedures should use the following guidelines:

- A vacuum equipped with a HEPA filter should be used to prevent spreading spores. Any vacuum or aspirator used to remove mold should have a trap of this type to reduce redistribution of the mold. The exhaust should be directed into a fume hood or outdoors. A homemade ventilation system can be rigged, if necessary, by working at a table below a window with a strong exhaust fan.

- Always use a respirator, goggles, and gloves.

- Any parts of vacuums that come in direct contact with moldy surfaces/materials should be cleaned with isopropanol (rubbing alcohol) or detergent afterwards. Rags used during the cleaning process should be changed frequently. Used rags should be placed in a closed container and washed in detergent and/or bleach or discarded. Any blotters or papers used for drying or protecting surfaces should be discarded. Place all disposable cleaning supplies in sealed, polyethylene bags prior to removing these items from the "dirty" area for disposal.

- Tables, counters, and work surfaces should be regularly cleaned with at least 40% isopropyl (rubbing) alcohol by volume in water.

For valuable and/or fragile collections materials, the techniques below should be carried out by a conservator or a skilled technician.

To clean paper and porous material:

- Lift inactive mold with a soft, natural-hair brush into a variable-suction vacuum device, or vacuum papers through a fiberglass screen held down over the paper with weights.

- If vacuuming is followed by dry-eraser surface cleaning methods (using grated vinyl erasers or vulcanized rubber sponges), brush used eraser crumbs into the vacuum. It is important to be aware that the paper structure and media surface can be physically compromised and weakened by mold damage; always handle artifacts very gently and carefully.

To clean bindings and boxes:

- Direct vacuuming using controlled suction is acceptable for boxes and books in stable condition. Adjust the suction of the vacuum to correspond to the condition of objects. Books should be vacuumed in-situ (on shelves) prior to removal for more thorough cleaning.

- After vacuuming, bookbindings and boxes can be thoroughly wiped with dry rags or cleaned using vulcanized rubber sponges to remove additional mold residue, if necessary.

- Books should be held firmly closed during cleaning. The pastedown and flyleaf inside the cover can be vacuumed or surface cleaned as necessary.

- For rare and/or fragile materials the techniques described for cleaning paper may be employed, always following the recommendations of a conservator.

To clean photographs:

- Mold damages and destabilizes the emulsion that forms the photographic image of most prints and negatives. Photographs, therefore, should not be cleaned without the advice of a conservator.

- If only the back of a print exhibits mold residues, it can be very carefully cleaned in the same manner as paper.

Mitigating Future Risk

Procedures for recovery from a mold outbreak should be part of any disaster plan but many steps can be taken to lessen the likelihood of an outbreak or mitigate the extent of the damage. Examination and treatment of new acquisitions, and treatment of small outbreaks should be standard staff procedures.

An institution’s disaster plan should include criteria for choosing method(s) of response, contingency plans for a major outbreak, and preventive measures. Make sure all employees are familiar with the disaster plan.

Planning and preventive measures that mitigate the likelihood and severity of a mold outbreak include:

- Regarding new acquisitions: Will new material be accepted if it arrives with mold? Does the institution have a space separate from collections storage where new acquisitions can be placed and monitored for possibility of mold growth (and pest infestation)? All new acquisitions should be quarantined and carefully inspected for mold or insect activity.

- HVAC maintenance: This should include regular inspection and cleaning of heat-exchange coils, drip pan, and ductwork where mold can develop, and frequent changes of high-efficiency air filters to reduce dust and mold spores. Filters are prime sources for moisture and mold growth. Seasonal adjustments to HVAC controls/settings should be made as necessary.

- Building maintenance: This is essential for identifying trouble areas and preventing leaks and dampness.

- Storage: Storage next to poorly insulated exterior walls should be avoided, especially in areas at or below grade. In addition, storage in damp areas such as basements should be avoided. Store collections at least four to six inches above the floor.

- Environmental monitoring: The environment should be regularly monitored for temperature and relative humidity.

- Maintaining good air circulation: This is particularly important when HVAC humidity control is inadequate or nonexistent. Use of fans, including "whole-house" fans that keep air moving through a building, can be very effective. Consider opening compact shelving units to prevent the formation of stagnant air-pockets.

- Regular dusting: Consider protective dust covers for shelving units, and boxing collections materials as able.

- Keeping collections areas as clean as possible: Floor should be vacuumed rather than swept to prevent scattering dust. Keep the collections areas completely free of food and plants.

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National Air Duct Cleaners Association (NADCA); www.nadca.com; 202-737-2926

National Institute for Occupational Safety and Health (NIOSH); www.cdc.gov/niosh; 800-35-NIOSH (800-356-4674)

Occupational Safety and Health Administration (OSHA); www.osha.gov; 800-321-OSHA (800-321-6742)

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[1] An example of ideal environmental conditions for storage of paper-based collections: Temperature: 65°F +/- 2-3°; Relative Humidity: 45% +/- 3-5%. For collections composed of primarily of photographic materials, lower temperature and RH levels are typically recommended.) Source: Wilson, William K. “Environmental Guidelines for the Storage of Paper Records.” NISO TR01-1995. Bethesda, MD: National Information Standards Organization, 1995. http://www.niso.org/sites/default/files/2017-08/tr01.pdf

[2] See http://www.epa.gov/sites/production/files/2014-08/documents/table2.pdf and http://www1.nyc.gov/assets/doh/downloads/pdf/epi/epi-mold-guidelines.pdf

[3] See table: Population-Specific Recommendations for Protection from Exposure to Mold in Buildings Flooded After Hurricanes Katrina and Rita, by Specific Activity and Risk Factor,” https://www.cdc.gov/disasters/mold/report/pdf/2005_moldtable5.pdf

[4] See EPA guidelines: “Should You Have the Air Ducts in Your Home Cleaned?” https://www.epa.gov/indoor-air-quality-iaq/should-you-have-air-ducts-your-home-cleaned#deciding