CONSERVATION CENTER for Art and Historic Artifacts

Mold

TECHNICAL SERIES NO.1

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- FIRST RESPONSE
- INACTIVATION PROCEDURES
- FUNGICIDES
- CLEANING AND DISINFECTING
- PREVENTION PLANNING

Managing a Mold Invasion: Guidelines for Disaster Response

Mold, a common term for fungal growth, is one of the most serious and underappreciated sources of damage to library, archival, and museum materials. Mold will grow on any organic host material offering suitable nutrients, including paper, adhesives, leather, dust, and sooty dirt. Some types of mold prefer the easily digested starches, gums, and gelatin found in book bindings, paper size, and some design media, whereas others attack and digest the cellulose that composes paper, causing irreversible weakening and staining. Although mold sometimes appears on only a few items in a collection, it often affects many items in a particular area, resulting in a mold bloom.

Since the spores from which mold grows are everywhere in the environment, a sudden mold bloom in a collection indi-

For demonstration purposes, this gelatin-sized paper with pastel drawing was exposed to air in a normal room environment and then placed in a humidity chamber with over 90 percent relative humidity. Mold was visible after 3 days. The paper was removed from the chamber after 10 days and placed in an environment where the relative humidity was 50 percent. The bushy mold growth began to shrivel and fade within an hour, and no further growth occurred.

cates that a change has occurred in the environment to cause the spores to germinate. The mold species that most commonly attack library and archival materials, art on paper, photographic prints and negatives, and other paper-based artifacts germinate and grow when the relative humidity reaches or exceeds 70–75 percent and remains at this level for several days. High temperatures, poor air circulation, dim light, and accumulated grime assist and accelerate the growth of mold once it has germinated, *but only high relative humidity and moisture content of the substrate can initiate and sustain mold growth*. If the relative humidity drops below 70 percent and the materials lose their high moisture content to the atmosphere, these molds will stop growing and become inactive or dormant, but the spores will remain viable on the host material. They will become active and begin growing again if the relative humidity rises. This bulletin provides guidelines for recovering from a mold outbreak for archivists, librarians, museum personnel, and private collectors.

Is It Really Mold?

The first step in responding to a mold bloom is to ensure that the observed problem is mold. Accumulations of dirt, dust, stains, and cobwebs are sometimes mistaken for mold. The second step is to determine whether the mold is active or dormant.

- Check 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 bushy appearance, and fruiting bodies containing spores are clearly visible under magnification. Mold can be almost any color.

- Does the material feel damp? Smell moldy?

- Check temperature and relative humidity in the affected area. Mold is active and will grow when the relative humidity reaches or exceeds 70–75 percent and remains there for some period of time. Elevated temperatures increase the rate of growth.

- Test with a small, soft camel-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 an increase in relative humidity to 70–75 percent or more causes dormant spores to germinate and the mold to become active again.

- Note that foxing on paper is a closely related phenomenon that can be confused with mold. Foxing involves various agents of biodeterioration, including mold. Its appearance is characterized by red-brown stains in either discrete spots or irregular splotches, usually with no visible hyphae or mold structure. Like mold, it appears in susceptible papers exposed to high relative humidity.

Minor Outbreak or Major Bloom?

Small to moderate outbreaks involving a limited number of items (2,000 to 4,000 volumes or 100 to 300 cubic feet of records) can often be handled in-house if no highly toxic mold species are present. As discussed below under "Health Concerns," toxicity must be determined by a mycologist. The amount of outside assistance obtained will depend upon the resources of the institution and the type of material affected. A major bloom involving a large area of the 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. The information provided in this bulletin is applicable primarily to small and moderate outbreaks that do not involve highly toxic species. A list of outside professional resources is included at the end of this bulletin.

Health Concerns

Some molds found in library and archival collections, such as certain *Aspergillus* species, can cause serious illness or even death in susceptible individuals. Therefore, *any* outbreak or bloom, regardless of size, should be assessed by a mycologist to identify the species present. A local hospital can provide a referral. Also, regardless of the species present, individuals with serious allergies, diabetes, asthma, respiratory problems, or compromised immune systems, as well as those taking steroid therapy, should avoid the affected area and materials.

Even exposure to molds not highly toxic can have serious health consequences, including respiratory problems, skin and eye irritation, and infections. Mold spores enter the body by inhalation and through small breaks in the skin. Major blooms and those involving highly toxic species require outside professional help. The following protective gear and procedures are necessary for safely dealing

with minor outbreaks after a mycologist has determined that no highly toxic species are present.

- Respirator with a HEPA (high efficiency particulate arrestant) filter, NOT a dust mask.
- Disposable plastic gloves.
- Goggles or protective eyewear.
- Coveralls or laboratory coats, preferably disposable.
- Foot and head covers for very dirty situations.
- Remove coveralls, laboratory coats, and protective gear in a designated "dirty" area.
- Periodically disinfect nondisposable gear. Wash laboratory coats, coveralls, and other washable items in hot water and bleach. Wipe respirators with isopropanol (rubbing alcohol), denatured alcohol, or Lysol, and change HEPA filters regularly.

First-Response Procedures for Active Mold Growth

The goal of first-response procedures is to slow or stop the mold's growth.
Note: Speed is critical for mold disaster recovery.

1. Isolate affected materials to reduce dispersion of spores and protect people:

- For small blooms, place materials in plastic bags (garbage bags), move them to a dry area, and proceed with appropriate inactivation procedures. Materials should not remain in plastic bags.
- For large blooms, quarantine the area and contact outside professional help immediately. Close doors; hang plastic sheeting between affected and unaffected areas; and reduce circulation of air from the affected area to the rest of the building.

2. Consult a mycologist to identify the mold species that are present.

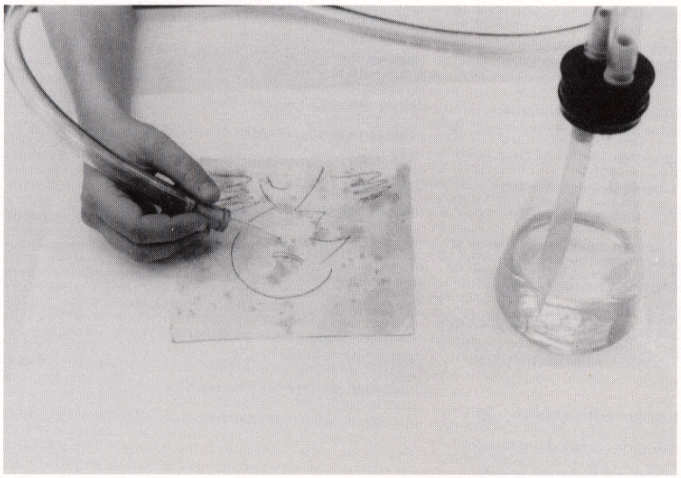
3. Locate the high humidity source:

- Look for a moisture source such as a leaky roof or pipe, broken window, damp basement, blocked gutters, or interior fountains.
- Check the *heating, ventilating,* and *air conditioning* system (HVAC), especially the heat-exchange coils, drip pan, and ductwork. These areas are prime sources for moisture and mold growth.

4. Lower the humidity and increase air circulation using any appropriate combination of the following measures. Monitor humidity and temperature several times a day and keep a log:

- Fix or adjust HVAC *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.
- Use fans to increase air circulation in the affected area.
- Open windows if outside humidity is lower than inside.
- Install dehumidifiers, being careful to arrange continuous drainage or to empty them frequently.

5. If there is a major event, such as a flood or leak, and materials are very wet, response in 24 hours is critical to prevent a mold outbreak. Freezing materials is an essential initial response.



Mold spores and residues can be removed from fragile materials using an aspirator. The opening of the glass pipette is placed next to the mold residue, which is sucked gently into the flask of the aspirator. This treatment should be done in a fume hood.

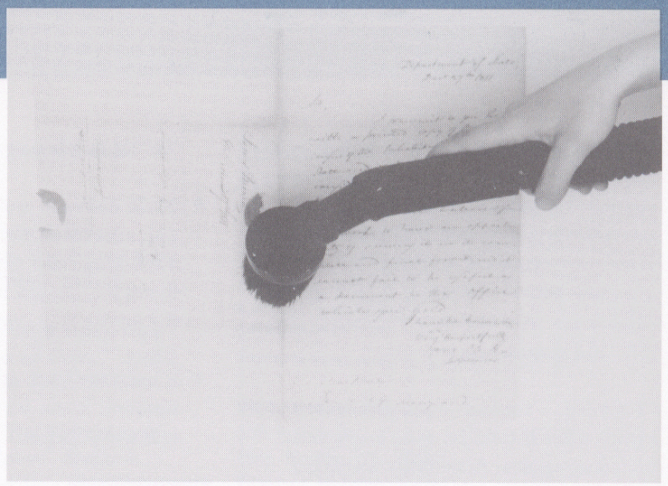
Inactivation Procedures

The goal of inactivation procedures is to stop mold growth if first-response measures have not controlled the outbreak. These procedures are necessary if the environment remains damp, if the number of affected materials is large, or if moldy materials are damp. These procedures will inactivate mold but will not kill it.

1. Small-scale drying of damp items can be accomplished using standard disaster recovery procedures: spread papers on tables; stand books on end and open them like a fan; interleave papers and books with blank newsprint and/or blotters; and 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 infected material. Drying will inactivate the mold. It should be done in an isolated area that can later be thoroughly cleaned.

2. Vacuum drying, useful for small to moderate-size outbreaks, can be done in old fumigation chambers. Most chambers will not create a vacuum intense enough to kill mold, but will dry materials and inactivate mold while isolating materials. Alternate the vacuum phase with aeration, using air that is below 60 percent relative humidity. Experiment with the chamber before you need to use it.

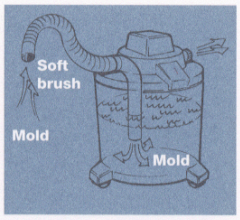
3. For moderate or large outbreaks, desiccant drying can be done by a disaster response company. With this method, dry air is pumped into the affected area and moist air is pumped out. A large area can be dried quickly and the mold inactivated. Solex Environmental Systems and Munters Moisture Control Services (see list at end of bulletin) can provide this service, setting up rapidly for short- or long-term use.



Mold residues can be removed from archival materials by placing them under a fiberglass screen and vacuuming them through the screen. The screen should be stretched on a wooden or aluminum frame to facilitate handling.

4. Freezing stops mold growth and will kill active growth, but not spores. Freezing can be done in-house for small outbreaks or by an outside vendor for large outbreaks when the environment or circumstances preclude prompt deactivation by drying. Material can be freeze-dried, vacuum freeze-dried, or thawed and air-dried. The guidelines and decision making for freezing and drying mold-damaged materials are the same as those for water-damaged materials. Freezing is also effective against insects, given proper temperature and duration. Freezing and freeze-drying are not recommended for most photographic materials, so in such cases a photograph conservator should be consulted.

5. Ultraviolet light/sunlight exposure can effectively inactivate mold. Ultraviolet light is damaging to most library, archival, and museum materials, but it can be used as a reasonable treatment for small, localized outbreaks. Exposure to sun also aids drying. Material can be exposed on interior windowsills if necessary. Active mold usually changes color and responds within 10 minutes. Exposure should not exceed 30 minutes.



Alterations to a standard wet-dry vacuum will trap some of the mold mycelia and prevent them from being exhausted into the room. A tube attached to the base of the intake hose should extend into a reservoir of fungicide in the tank. The exhaust should be sent through a hose out a window.

Fungicides and Fungistats

Over the years, various fungicides and fungistats have been recommended and widely used for control of mold in library, archival, and museum collections. Ethylene oxide, a fungicidal fumigate, will kill most mold and its spores with a high degree of effectiveness and reliability. Fungistatic compounds such as thymol or ortho phenylphenol inactivate certain molds and discourage their growth. In recent years, however, use of these substances has been more carefully evaluated and is no longer recommended for libraries, archives, and museums. The reasons include concerns about both toxicity and long-term negative effects on collection materials, as well as the realization that, since none of these compounds and procedures impart any residual protection to collection materials, the only way to stop mold damage is to control the relative humidity and clean affected materials.

In the case of major blooms affecting a significant part of the collection or outbreaks involving highly toxic species, outside professionals may advise using specialized fungicides legally registered for use in public buildings when applied by a licensed professional. These fungicides are most typically used to disinfect HVAC systems and ductwork. Some can also provide residual protection to collection materials and storage areas for a limited time period. None, however, have been tested for their long-term effects on permanent collection materials, so direct application or misting should be avoided unless there are no other viable options.

Cleaning the Collection

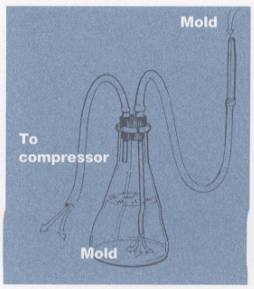
Cleaning should be done after mold is inactivated. Inactive mold is dry and powdery and can be readily vacuumed or wiped away with minimal additional damage or disfigurement. In the case of a major bloom or an outbreak involving highly toxic species where a fungicide will be used, inactivation and cleaning should precede use of the fungicide and should be done by outside professionals.

In some situations, it may be necessary to clean active mold. Cleaning will result in more rapid inactivation and potentially less damage if conditions are such that inactivation would be a slow process due to adverse environmental conditions. However, cleaning 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 worse disfigurement and loss of legibility.

The preferred method for cleaning active mold from porous materials is aspiration, which is time consuming but avoids further embedding of mold into the paper. Aspiration typically utilizes a small compressor attached to a flexible hose with a pipette nozzle the size of an eyedropper to gently suck the mold off the surface of the paper into a trap or collection bottle. Vacuuming through a screen, described later in this bulletin, may also be an option, depending on the circumstances.

For quickly removing dry, inactive mold residues from papers or books, vacuuming is the most effective, least damaging method. Vacuuming avoids spreading or further embedding of the mold. Aspiration or gentle brushing may be required for fragile or particularly valuable materials. Dry cleaning using traditional eraser-type materials may be necessary for thorough cleaning after vacuuming or aspiration has removed most of the residue. Cleaning procedures should use the following guidelines:

An aspirator can be constructed from a glass flask, a rubber stopper, glass tubing, a glass pipette, and plastic tubing. A fungicide should be placed in the flask to prevent mold from being drawn into the compressor.



- If possible, clean materials outdoors or under a fume hood or exhaust vacuum through a window to the outdoors to avoid spreading spores. Rig a homemade ventilation system if necessary by working at a table below a window with a strong exhaust fan. Always use a respirator, goggles, and gloves.

- Preferably, a vacuum equipped with a HEPA filter should be used to prevent spreading spores. A specially modified wet-dry commercial-strength vacuum can be used. Place several gallons of a fungicide such as Lysol (which contains ortho phenylphenol as its active ingredient) diluted with water according to label instructions into the tank. A plastic tube from the hose inlet should extend into the solution so that incoming moldy air passes through the solution. 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.

- Any rags used during the cleaning process should be changed frequently. Discarded rags should be placed in a closed container and washed in detergent and bleach.

To clean paper and porous materials:

- Vacuum papers through a fiberglass screen held down over the paper with weights.

- Use an aspirator to gently remove mold from valuable or deteriorated material. This generally should be done by a conservator or a skilled technician.

To clean bindings and boxes:

- For vacuuming books, use a nozzle or brush attachment covered with a cheesecloth or fiberglass screen filter to catch any detached pieces. Adjust suction of vacuum to condition of object. Boxes can be vacuumed directly.

- After vacuuming, bookbindings and boxes can be thoroughly wiped with dry or slightly moistened rags 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 wiped as necessary.

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 cleaned in the same manner as paper.

Cleaning and Disinfecting the Storage Area

Clean the storage area (shelves, walls, floor) thoroughly:

- First vacuum, then wipe all surfaces with a Lysol-type fungicide diluted as recommended on the product container. Be sure the area is well ventilated. Do not return collection materials to their places until the area is thoroughly dry and the environment is stable. Have carpets and drapes cleaned if necessary.

- Have heat-exchange coils, filters, drip pan, and ductwork of the HVAC system cleaned and disinfected if necessary.

Follow-Up After the Disaster

Follow-up procedures after the cleanup is complete can be critical to preventing a new mold bloom:

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

- Monitor the environment in the affected area regularly. Be sure housekeeping and air circulation remain adequate.

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

- Undertake necessary repairs and upgrades to the physical plant to prevent a recurrence.

Planning for Next Time

Procedures for recovery from a mold outbreak should be part of any disaster plan. Treatment of small outbreaks and of new accessions should be standard staff procedures. Contingency plans for a major outbreak and criteria for choosing a method(s) of response should be included in any plan. The process is similar to decision making for water- or fire-damaged materials.

The criteria might include:

- Type of material. Will the material be reformatted rather than cleaned and retained? This consideration might also apply to moldy new acquisitions.

- Extent and severity of outbreak.

- Current weather conditions.

- Type and functioning of HVAC.

- Availability of freezing, freeze-drying, vacuum chamber, desiccant drying facilities, and professional services.

- Presence of concurrent insect infestation.

Preventive measures in the plan should include:

- HVAC maintenance, including 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.

- Building maintenance to prevent leaks and dampness.

- Avoiding storage next to poorly insulated exterior walls, especially in areas at or below grade.

- Avoiding storage in damp areas such as basements.

- Quarantining and careful inspection of all new acquisitions for mold or insect activity.

- 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.

- Regular dusting.

- Monitoring the environment.

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CONSERVATION CENTER
for Art and Historic Artifacts
264 South 23rd Street
Philadelphia, PA 19103
215.545.0613

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Services for Mold Disaster Recovery

American Freeze Dry, Inc.
411 White Horse Pike
Audubon, NJ 08106
Contact: John Magill
609-546-0777
Freeze-drying; cleaning of materials; fumigation

BMS Catastrophe
303 Arthur St.
Fort Worth, TX 76107
Contact: Rebecca Cesa
800-433-2940
Freeze-drying; cleaning of interiors; document reproduction; fumigation

Conservation Center for Art and Historic Artifacts
264 S. 23rd St.
Philadelphia, PA 19103
Contact: Glen Ruzicka
215-545-0613
Mold recovery advice; cleaning and treatment of damaged materials

Document Reprocessers
5611 Water Street
Middlesex, NY 14507
Contact: Eric Lundquist
800-437-9464
Freeze-drying; cleaning of materials; fumigation

Munters Moisture Control Services
4636 SW Loop 820, Suite 209
Fort Worth, TX 76109
Contact: Theresa Williams
800-422-6379
Desiccant drying; dehumidification; air-drying of materials

Thomas A. Parker, Ph.D.
Pest Control Services, Inc.
14 E. Stratford Ave.
Lansdowne, PA 19050
Contact: Thomas Parker
610-284-6249
Mold recovery advice and services; integrated pest management surveys and control

Solex Environmental Systems
(formerly Airdex)
P.O. Box 460242
Houston, TX 77056
Contact: Don Hartsell
800-848-0484
Desiccant drying; dehumidification; air-drying of materials

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