

Invasion of the Giant Mold Spore

It's a quiet, peaceful day. You stroll complacently through the aisles of books, contemplating the neat rows of colored cloth and leather. A bit of sunshine glimmers through the distant stacks. A little tune is wandering through your thoughts. Suddenly, a shiver runs down your spine. You stop. Something is wrong; you sense danger. Slowly you turn and peer down the rows of books, half afraid of what you will find. You cautiously step forward, and there it is, lurking in the dark, slowly creeping down a row of books. It slithers from one volume to the next, maliciously victimizing innocent and helpless books. The air is filled with a vaguely unpleasant odor. Books become untouchable -- they are slimy, they are furry, they are distinctly icky. Who knows, it may spread to the carpet, the walls, the curtains, the chairs, even your office; it may take over the whole library! It's the attack of the awful mold!

Before you panic, calm down. Although it won't be easy, mold can be stopped. You can protect yourself from it. This leaflet will provide you with strategies for the prevention and control of mold. Before we come to the strategies, though, we need to analyze our foe. What is mold? Where does it come from? What does it do to books and paper?

I. What is Mold? And Where Does It Come From?

Mold is a type of fungus. It grows on surfaces in masses of branching threads which resemble dense cobwebs. The fertile threads, those which produce spores, often stand up from the surface into the air to release their spores. Spores are carried by air currents or by adhering to insects or animals. Active mold can be any color, depending on the species and the substrate upon which it is growing. *Mildew* is another type of fungus, similar in structure to mold, but distinct as one species of fungus is distinct from another. The terms "mildew" and "mold" are not interchangeable; they are most often used in the common names of various fungi. *Fungi* is a kingdom of organisms, with a single division, Mycota. The fungi have traditionally been classified with plants but are now considered a distinct group of organisms. Unlike plants, which produce their own food, fungi absorb nutrients from dead or living organic matter. Fungi also lack photosynthetic pigments. There are over 100,000 known living species of fungus, some of which are beneficial to mankind. Mycologists estimate that there may be as many as 200,000 more unidentified species of fungus. Yeasts, molds, mildews, rusts, and mushrooms are types of fungus.

The spores of fungi that become mold or mildew are always present in the air and on objects. When the temperature and moisture in the environment are suitable for germination, the fungus spore bursts and grows into a thread-like filament called a hyphae. Using the object it is growing on as a food source, the hyphae form a mass, called a mycelium, and within a short time begin to produce spores. At maturity,

spore sacs burst and release spores, which eventually land on other material and begin the reproductive cycle again.

In libraries, optimum conditions for mold and mildew development exist when temperature is above 70° Fahrenheit **and** relative humidity is above 55%. However, some common molds can grow at temperatures as low as 50° Fahrenheit and in relative humidity as low as 45%. It is also possible for molds to begin growing in conditions of high relative humidity and temperature and then continue growing in environments with significantly lower relative humidity and temperature.

II. What Does Mold Do To Books and Paper, and to People?

Basically, mold and mildew eat library materials. Books and paper provide a source of nutrition through such components as cellulose, starch adhesives, and starches in sizing. The mold and mildew excrete digestive enzymes that allow them to eat starches and cellulose, grow, and produce more spores. Cellulose in paper is difficult to digest; so many molds prefer the starch in cloth-coverings on books and in paper sizing. In book collections, mold is often noted on the bindings long before it grows on text blocks. Molds grow rapidly, although they generally grow at a slower rate when relying on only cellulose for food.

Conditions that promote mold and mildew growth (high humidity and warm temperatures) will also, in and of themselves, increase the rate of book/paper deterioration by accelerating the aging process and the formation of acids. Furthermore, mold and mildew can irreversibly stain books and paper. Such stains destroy text and images. Books and paper can also be seriously softened and weakened by mold, making them difficult to handle.

Mold and mildew can have an adverse effect on people. Those with allergies, asthma or other respiratory problems should stay away from infested areas, as many fungi will seriously irritate and inflame lungs. Some fungi can cause skin and eye irritation and infections. Prolonged exposure to germinating molds in closed areas (which exist in many library collections) can damage the lungs, mucous membrane, cornea, respiratory tract, stomach, intestines, and skin. Some varieties of mold are highly toxic, such as the strain found in 1990 in the basement of the New Museum of Contemporary Art in New York City.

III. The Repulsion of the Giant Spore, or How To Rid One's Collection of Mold.

The **ONLY** way to permanently protect your collections from mold is to control the environment by keeping the temperature within 68°-72° Fahrenheit and the relative humidity within 40%-55%. Prevention is the key, but if you do experience a mold outbreak there are non-chemical means for clean-up and recovery (see section III.B.2.). Some chemicals kill mold, but the only safe and effective way to keep it from coming back is to modify the environment which contributed to the development of mold. **Some of the chemicals used in the past by libraries to kill mold are no longer recommended, because many are harmful to both people and collections.**

III.A. What is a Mold-Preventive Environment?

There are a number of factors which influence the growth of mold: environmental humidity and moisture content of materials, temperature, air circulation, light, and the chemical composition of potential substrates. Each of these is discussed here in relation to the environments which will inhibit or promote mold growth.

III.A.1. Humidity. The most important environmental factor to control is the amount of moisture in the air and consequently in books and paper. Books and paper naturally contain a certain amount of water. They are hygroscopic, so that when relative humidity goes up, they absorb water to achieve equilibrium. At 50% relative humidity, the moisture content of paper is approximately 7%; at 70% relative humidity, it is approximately 10%. Moisture enables mold to absorb nutrients from book and paper substrates, so the more moisture a book contains, the greater are the chances for fungus spores to germinate at room temperature. The potential for mold or mildew development on wet books is one important reason for quick freezing of books damaged by water.

High relative humidity can easily lead to mold growth; for safety, it is generally recommended that libraries keep their relative humidity below 55%. Relative humidity below 40%, however, can cause books and paper to become fragile from dryness. Hence the acceptable range is 40% to 55%. It is also possible for some molds to begin growing at 70% relative humidity or higher and then continue growing at relative humidity of less than 70%. Because of this, new acquisitions should be checked for mold and treated, if necessary, prior to storing them with the rest of the collection.

Consistency is also important within the 40% to 55% range. As books and papers absorb or release water into the atmosphere with changes in relative humidity, they also change their shapes. They expand or contract, although different parts of a book will do so at different rates, as will different types of paper. For example, a vellum binding may expand quickly as it absorbs water, but the paper inside will expand more slowly, and the adhesive used in binding may expand at an intermediate rate. Fluctuations in humidity, when necessary due to, for example, seasonal changes, should be slow and carried on over time. Generally, it is recommended that relative humidity remain at 50% with a maximum change of plus or minus 5% per month.

III.A.2. Temperature. Most molds thrive at warmer temperatures. When combined with high levels of humidity, temperatures of 70 to 75° Fahrenheit can cause mold to develop. Temperatures below freezing will not kill mold, but they do make it dormant. Few molds will be active at temperatures of less than 50° Fahrenheit. Mold can also grow in conditions up to 140° Fahrenheit. High heat will kill mold, but it will also severely damage library materials.

For patron comfort, temperatures of 70° Fahrenheit plus or minus 2° are acceptable in libraries, provided relative humidity is kept at 50%.

III.A.3. Air Circulation. In conjunction with humidity and temperature control, adequate air circulation will help prevent mold growth. Air circulation helps control moisture levels through evaporation.

Installing a heating/ventilation/air conditioning (HVAC) system with humidity control can solve all three problems of humidity, temperature, and air circulation at the same time. Such systems are not easy to install, simple to maintain, or inexpensive. But they provide the most effective means of preserving your collections. Not only do suitable HVAC systems assist in mold prevention, but they also stabilize the environment and hence eliminate the distortion of materials due to fluctuating temperature and humidity. Furthermore, maintenance of a stable environment slows down processes of deterioration caused by acid, light, and pollution. An HVAC system's control of the environment can also help in controlling insect infestations.

If you cannot install or improve an HVAC system in your library, there are a few alternatives which, although not as effective, will help. Fans can be installed to improve air circulation. They are best placed near outside walls and close to floor level. Portable dehumidifiers can be used, particularly for localized problems. Although you can invest in several units, portable dehumidifiers tend not to be as effective in large spaces as a centralized HVAC system with humidity control. Fans and vents in attics will increase air circulation by pulling air through the building. This is particularly useful when it is necessary to leave windows open. Desiccants (such as silica gel) can be used to absorb moisture in humid environments. They should not, however, be used where young children are able to reach them because ingestion may be dangerous. Desiccants are most useful for localized problems, especially those that can be contained in a small, enclosed space.

Sometimes an older air circulation system can actually be the origin of your mold problems. When conducting a visual inspection for mold, it is important that duct work and the age of a building be taken into account. Ceiling tiles should also be inspected; if a damp or stained ceiling tile is in evidence, leaky ductwork may be the culprit, and mold can grow on the ceiling tiles in dark crawlspaces. Paper or insulation lining the ductwork and old filters that are not regularly replaced are all growth supporting materials for mold.

III.A.4. Light. Light. Sunlight, and in particular ultra-violet radiation, generally inhibits mold growth. Sunlight and ultra-violet radiation, however, cause serious fading of library materials and can increase the growth of some kinds of mold. They also speed up chemical reactions leading to the formation of acids in paper; hence prolonged increases in the exposure of library materials to light are not recommended.

III.A.5. Chemical Composition. Mold growth can also be affected by the chemical composition of the book or paper substrate. Many fungi prefer slightly acidic material. They will also interact with non-cellulose matter within paper, such as iron particles, leading to staining and further deterioration. The chemical composition of most library materials is not something which can easily or even should be changed. But it does make some parts of collections more susceptible to mold growth than others.

III.A.6. Miscellaneous Environmental Modifications. There are several modifications that can be made to the building or its internal environment which will assist in preventing mold outbreaks.

a. Don't shelve books directly against an outside wall. Due to temperature and humidity differences between inside and outside environments, moisture may

develop along walls. Allowing air to circulate against the walls will enable the moisture to evaporate.

- b. Keep the quantity of indoor plants to a minimum and don't allow indoor planted areas.
- c. Waterproof basements and walls below ground level. And use water-sealant paint on floors and walls.
- d. Place or adjust outside gutters and drains so that water does not collect near the outside walls. Check gutters and drains regularly to avoid clogs. Place lawn sprinkler systems so that they do not soak outside walls.
- e. Regularly inspect your collection for mold or mildew. This will allow you to catch any infestation before it becomes large. And continue to monitor potentially hazardous areas until the environment can be stabilized in an appropriate state.
- f. Install the best filters you can afford in your library's heating and cooling vents. In recent years the cost of quality HEPA filters has decreased dramatically. When good HEPA filters are replaced regularly, they can decrease the amount of mold spores as well as dust and other materials that allow for mold growth.

III.B. What Can You Do If You Have a Mold Outbreak?

There are a number of things you can do when faced with mold in your collection, but first you need to determine whether the mold is active or inactive. Active mold can be colorful, and it's damp, slimy and web-like and had a musty odor. Inactive, or dormant mold is dry and powdery. Try looking at it under a microscope, does it appear web like? Or, try brushing it with a soft brush, active mold will smear. Take a sample of the mold to a mycologist to identify the species.

Your second response should be to isolate affected materials. If a small quantity of books is moldy, seal them in air-tight plastic bags. If the infestation is large, quarantine the area.. Isolating moldy books and papers serves two purposes: it minimizes the spread of mold, and it protects those persons who may have allergies or respiratory problems from harm.

Third, determine the source of the outbreak. Check the humidity and temperature. Chances are good that, for a large infestation, the cause at least partially lies there. When the Denver Public Library found mold in its off-site storage facility in 1984 (it was visible on approximately one-third of the books there), relative humidity was 60% and temperature was 78° Fahrenheit. Also look for a source of water, such as an unnoticed leak, a broken window, moisture along outside walls. A third place to check is the heat-exchange coils in the heating/air conditioning system; they are a prime area for fungus growth and spore distribution. They can be cleaned using a commercial EPA registered cleaning solution designed for coils and following the manufacturer's direction for use. It's recommended to have coil cleaning performed by an experienced individual. You need to pinpoint whatever caused the mold to develop and then fix it, because until you solve that problem, mold will continue to grow, no matter how often you treat the affected material.

Every library and archives should have at least one tool for measuring relative humidity -- a hygrometer, sling psychrometer, or hygro-thermograph. Used regularly and properly, these tools can alert you to increases in relative humidity before mold growth begins so that you may effectively modify the environment to prevent mold. During an outbreak, hygrometric tools should be used regularly (two to four times a day) to monitor the environment and the effectiveness of your modifications, and to make readjustments as necessary.

Increase air circulation and lower humidity. Open windows, provided it is not raining outside and the relative humidity outside is lower than that inside. Set up fans to increase air circulation. Set up dehumidifiers or re-adjust the HVAC system to lower the relative humidity. If you have a thermostat-controlled cooling system or one which simply lowers the temperature of outside air prior to ventilating it through the building, turn it off. This kind of "air conditioning" or cooling system does not provide humidity control and will in fact increase internal relative humidity because cold air cannot hold as much water as warm air. Furthermore, the moist heat-exchange coils in this system may be providing a fertile ground for the growth of mold, the spores of which are then distributed throughout the building via its ventilation system.

After you have readjusted the environment, you can look at available means for removing mold and cleaning the collections. There are both chemical and non-chemical means to treat mold. Effective treatments can be fungistatic or fungicidal. Fungistatic treatments are those that prevent the mold spores from germinating, but do not kill the mold. Freezing is one such method. Fungicidal treatments kill the mold and its spores. No safe large-scale treatment, however, imparts lasting, or residual, mold control. That is why it is so important to change the environment so that it inhibits mold growth. Furthermore, there is some evidence that books and papers treated with fungicides may be more susceptible to mold after treatment than they were prior to the outbreak. **For these reasons, the use of chemicals to treat mold is no longer recommended for library, archival, and museum collections.** In addition, many chemical treatments that seem benign, such as Ozone, may be hazardous to the health of workers, and can cause chemical reactions to some materials in your collection.

III.B.1. Health Issues. Some of the molds commonly found in library and archival collections can cause serious health problems including respiratory infections, headaches, nausea, and eye and skin irritation. People predisposed to upper respiratory problems such as allergies and asthma should not be exposed to areas affected with mold, even if they wear a respirator. For health reasons, even a small mold outbreak should be taken seriously. You should wear disposable rubber or plastic gloves, a lab coat and a respirator whenever handling moldy materials. Ordinary dust masks are not sensitive enough to filter mold spores, use a respirator with a HEPA (high efficiency particulate arrestant) filter. Be aware that respirators are ineffective if used improperly, for example people with facial hair will not be protected because they can't get a tight fit. Training staff about proper fitting and use of respirators is essential. Wash protective clothing in hot water and bleach.

III.B.2. Mold Control and Eradication.

Freezing or air-drying followed by cleaning, do not involve the application of chemicals to the books or paper in solid, liquid, or vapor form, and are the current recommended practices. Any type of treatment must include some temporary

modification of the environment. Non-chemical treatments are preferred to chemical treatments because they do not interfere with the chemical composition of the materials, they do not leave residues in treated materials, and they are non-toxic to humans. Many non-chemical means have been discussed and experimented with; I mention the more commonly known of them here. The first step is to inactivate the mold so it can be easily cleaned from the item.

III.B.2.a. Freezing involves placing the moldy books in an atmosphere of below freezing temperatures. It is a fungistatic, not fungicidal treatment, meaning it will halt growth but will not kill spores. Freezing presents an option for halting the spread of mold while you prepare for cleaning.

III.B.2.b. Air Drying of damp, moldy items will inactivate the mold, though it should be done in an area that is vented to the outside or isolated, to prevent the spreading of spores.

III.B.2.c. Cleaning Books and Paper is appropriate once the mold has been inactivated. Vacuuming is the most effective way to remove mold spores from books and paper because it doesn't spread the spores around. You must use a vacuum with a HEPA (high efficiency particulate air) filter. Ordinary vacuums should not be used, as their filters don't trap mold spores, but rather circulate them back into the air. The use of "wet" or "rainbow" vacuums is not recommended as the water in the tanks of these machines can cause the mold spores to further germinate before releasing them back into the air. Vacuum mold from flat paper documents through a screen to avoid damage. For books use the nozzle or brush attachment covered with cheesecloth. If needed, residual mold can be wiped from bindings with dry cloth.

You can also clean mold with a soft bristled brush or clean rag, but this technique in some instances can cause increased staining. When wiping off mold, be careful not to brush it into the air indoors or onto other objects; this can be accomplished by wiping books or papers off outdoors or under a fume hood. Replace rags frequently and store used rags in sealed plastic bags until they can be washed in bleach for re-use. For fragile and rare materials, or if you're unsure about how to treat an item don't hesitate to consult a conservator. In some cases it may be necessary to remove active mold which is done through a technique called aspiration and should be conducted by a trained conservator.

III.B.2.d. Low Oxygen Environments are commonly used for pest control. The procedure involves placing the infested item in an airtight plastic bag or fumigation chamber with an oxygen scavenger such as Ageless™ for a prescribed period of time. This treatment for mold is fungistatic, in that it causes it to inactivate or become dormant, but will not kill the mold spores.

III.B.2.e. Gamma Radiation has been used to sterilize surgical equipment and food. Experiments in irradiation of books to kill mold have been conducted by Johns Hopkins Medical Institutions and by the State Central Archives of Czechoslovakia. Although it does kill mold and does not leave residues, there is evidence that gamma radiation softens leathers and adhesives and breaks down the internal structure of paper. The folding endurance of paper decreases with higher levels of radiation. Mold can be killed at lower levels of radiation when heat is applied; heat, however, can also decrease paper strength. Studies indicate that the effects of individual radiation exposures add up, hence repeated disinfection of books and papers with radiation is

not recommended. Special chambers and corresponding operator training are necessary for irradiation, sources which are not easily accessible or necessarily affordable for most libraries. Because of the possibility of damage and the difficulty of accessing equipment, gamma radiation as a fungicide for books is not commonly used or recommended.

III.B.2.f. Ultra-violet light. Ultra-violet light, as mentioned earlier, inhibits mold growth and may kill mold. It is not, however, recommended as a full-scale treatment for mold on books and papers because the amount of exposure necessary to kill mold would induce fading and accelerate aging. The process is no longer recommended, as ultraviolet light can cause some molds to experience additional growth.

III.B.3. Activities to be Carried out in Conjunction with Treatment.

III.B.3.a. Cleaning the Storage Area. While books are being treated, the area in which they were stored should be cleaned. Begin by vacuuming the area. Then, shelves, floors, walls, ceilings, and windows should be cleaned with a mold and mildew killing solution, such as Lysol, Clorox, or X-14. Make sure the area is properly ventilated while cleaning. Don't return treated books to the area until it has been cleaned. It may also be necessary, depending upon how serious the infestation is, to clean carpets and drapery. Ducts, filters and heat-exchange coils in HVAC systems should be checked and replaced or cleaned with a mold-killing household cleaner.

III.B.3.b. Odor removal. Charcoal and/or baking soda can be used to remove the odor of mold, if the treatment has not done so. Simply place briquettes and/or bowls of baking soda in the area to absorb the odor. Do not wipe the books or paper with the charcoal or baking soda. Natural zeolites are formed from the altered volcanic ash. Zeolites have the ability to adsorb and desorb water, and gas molecules (odors) much the same way as charcoal or baking soda.

III.B.3.c. Monitoring. Continue to monitor the area and the treated books and papers after clean-up and recovery. Changes in the environment should have been made (either before or during treatment) to reduce the possibility of future outbreaks; i.e., humidity and temperature control established, air circulation improved, leaks fixed or other sources of moisture removed. Nonetheless, careful watch should be kept over treated collections to prevent new outbreaks.

III.B.4. Chemical Treatments.

There is now a much greater awareness of toxicity to humans and residual damage to books when applying chemical fungicides. Several chemicals that are fungicidal are not used on book collections because of their toxicity and instability. Some examples are mercuric chloride, highly toxic and legally restricted in the United States; hydrogen sulfide, an explosive; and methyl bromide, which leaves an irreversible foul odor, softens adhesives, and is toxic.

Many chemicals that have been used in the past for killing mold in libraries and archives are no longer considered safe because of the health risks to people, and the potential harm to collections. Consulting a conservator is recommended prior to treating large mold infestations in rare book or manuscript collections. Do not use chemical treatments unless you have had training by a professional conservator.

Many chemicals can cause severe health problems, and some treatments widely practiced as recently as two decades ago are no longer used, and subject to strict regulation by OSHA.

IV. Concluding Recommendations

Most authorities agree that fumigating collections with toxic chemicals is rarely necessary for dealing with mold and mildew problems. Storing collections in appropriate environmental conditions should prevent the need for fumigation. To quote Dr. Thomas Parker, of Pest Control Services, Inc.:

"Fumigation will not control mold and mildew if the library materials are placed back into the same conditions from which they came. In most instances library materials that have been fumigated are then stored in areas which do not have an environment conducive to mold growth. The success of the fumigation is given as a reason for the control of the mold and mildew, when in fact, the new area in which the materials are stored is the governing factor as to why mold and mildew is now being controlled."

Maintenance of proper environmental conditions will prevent mold growth. And if mold does occur, a relatively gentle form of cleaning along with improving the environment will solve the problem in most situations. I recommend that you try the following instead of chemical treatments.

1. Determine the cause: check temperature and relative humidity levels; check to see if the material has been wet and, if so, why; check heat-exchange coils in air conditioning units.
2. Isolate materials: place individual items in sealed plastic bags; quarantine stacks; for large and heavy infestations, it may be necessary to restrict access to the building/room. Don't leave materials in plastic bags for extended periods of time, follow up with cleaning as soon as possible.
3. Modify the environment: readjust relative humidity to the best of the HVAC system's ability; set up fans to keep air circulating in the affected area; install portable dehumidifiers in the affected area if the HVAC system cannot be controlled; turn lights on in affected areas for as long as possible during periods of obvious mold growth. Continuously record temperature and relative humidity until they stabilize at an acceptable level.
4. Clean: Vacuum with a HEPA vacuum, then wipe books or papers with a clean dry rag or a soft brush (wearing proper protective apparel); clean shelves, walls, and floors, with a weak bleach solution; use fans following the cleaning. Air conditioning heat-exchange coils, and air vents and ducts, etc., should be cleaned by a HVAC professional.
5. Monitor: keep watch on the affected area for several months beyond the mold outbreak and clean-up, even after the environment has been restored to conditions which inhibit mold growth.

Research and testing continue to assess the effectiveness of fungicides, to determine appropriate treatment procedures, and to identify molds and mildews and their characteristics. Studies may result in changes to existing procedures for mold control in the future. The SOLINET Preservation Program is able to provide advice and assistance in dealing with mold infestations in specific situations. Please call if we can help.

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Footnotes

1. See "Deadly Fungus..." in *Abbey Newsletter*, 1994.
2. Silica gel is a buffering substance, absorbing or releasing moisture into the environment to maintain a chosen level of relative humidity. It is frequently used in exhibit cases. See Lafontaine, *Silica Gel*, for procedures to condition and use silica gel.
3. Parker, "Integrated Pest Management for Libraries," p.21.

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