

Chapter 29b. Laundering or Dry Cleaning for Mold

Laundering or Dry Cleaning for Mold

In most cases, the processes of laundering and dry-cleaning items is quite effective in removing mold spores and fragments that have settled onto clothing and other thin cloth materials present in homes. Yet there are multiple postings on the internet from mold sensitive people reporting that they have thrown all their clothing away and started over after having mold contamination of their home. It is my impression that there are a number of reasons for these failures to return clothing and linens to an acceptable condition or for it to appear that laundering or dry-cleaning was ineffective. This chapter presents a strategy for best practices for successfully laundering or dry-cleaning mold contaminated textiles, choosing a laundry or dry-cleaners and for judging those situations where laundering or dry-cleaning are likely to be successful.

Textiles with Visible Damage From Mold Growth

The longer a material stays wet, the greater the amount of mold that will develop and grow. Visible mold growth will typically contain more than a million spores and associated growth structures in each square inch. When the growth has reached this level of density it is unlikely that multiple launderings or dry- cleanings will successfully return materials to an acceptable condition. Microscopic examination has shown that as mold grows the hyphae become intertwined with the fabric fibers. Acids and enzymes released by the mold growth begins to digest the materials in order to release nutrients. The cloth fibers are weakened, and unsightly blotches develop.

Museum conservators and restoration specialists have developed methods to prevent further deterioration, but it is unlikely that physically damaged items with actual mold growth can be returned to a serviceable condition. The preventative measure is to maintain materials below humidity or moisture levels that allow mold to grow. In addition, when items get wet to make sure they dry thoroughly and quickly. According to the Smithsonian Museum Conservation Institute: "Generally, stagnant air above 80% Relative Humidity will support mold on cellulose -- cotton or linen. Above 92%, on wool and silk will be affected." ¹ Since synthetic fibers such as nylon and polyester do not significantly absorb moisture, they are less likely to develop mold growth within the fibers but they can still support less invasive molds that use nutrients from settled dust and dirt as a food source. Lower levels of humidity for a longer period can also result in growth. "Requirements for spore germination vary with species. Growth is noted when the RH is above 50%, and rapid spread occurs above 80% RH. Temperature is another critical factor for germination. Generally, spore activity begins above 24°C (75°F), increasing with higher

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temperatures. Some microorganisms can grow in significantly lower temperatures and at lower RH levels. Poor air circulation or stagnant air exacerbates problems." ²

There may be situations where historical items or those with sentimental value may justify the costs and heroics involved in salvaging them to prevent further deterioration, but it is unlikely they would be returned to a functional condition. Even if the mold growth were removed and the acids and enzymes neutralized, it would still be necessary to stabilize the damaged fibers and remove the staining caused by both the mold and water. From a practical standpoint textiles damaged by visible mold growth are not cost effectively salvageable and should be discarded.

Sub-Visible Levels of Mold Growth

Natural fiber fabrics that are at the beginning stages of being colonized and synthetic fabrics with mold growth developing on surface dust may be able to be effectively cleaned. In these cases, the material typically develops a strong musty odor, but will not have visible mold growth or damage. Examining the cloth under a microscope may reveal that mold growth has just begun. Spores that have germinated begin sending out their root-like hyphae, but the material fibers are still intact or might only have microscopic fraying or digestion that is barely evident. This is what frequently happens when wet or damp clothing is left in a gym locker, hamper or on the closet floor for a few days. In these cases, a strong musty odor is the first indication that damage is beginning. The initial odor is likely from metabolic gases released by the bacteria, which can begin multiplying within a few hours. Bacteria have a much shorter lag period than mold. ³ When mold spores first become damp enough to support germination and growth, the lag period may be from two to three days or longer depending on the type of mold, the quantity of moisture and the length of time that the spore remains damp. If a damp or musty item is cleaned and dried quickly the germination cycle

Resources

The Smithsonian Museum Conservation Institute ¹ collects and disseminates information about conservation practices and resources on a wide variety of topics including addressing clothing and other materials that have been affected by mold growth. The information provided by the Institute can help conserve and preserve items of historical or sentimental value to prevent further deterioration by arresting the decay, but will not necessarily return them to a functional condition or make them acceptable for day-to-day use by persons with mold sensitivities. Stabilized items may be able to be stored or displayed in ways that can prevent further exposure.

Museum Support Center, 4210 Silver Hill Road, Suitland, Maryland 20746

Telephone: (301) 238-3709

e-mail: MCIweb@si.edu

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is arrested and less biomass from mold develops. The lesser the amount of biomass imbedded in the fabric the greater the chance for its return to an acceptable condition.

Sub-visible levels of mold growth can often be cleaned to remove much of the growth. Immediate laundering and rapid drying may be effective in arresting the deterioration process before significant additional damage occurs. The key to prevent mold growth is to keep items dry or dry them quickly enough to prevent growth from occurring. Even the fastest growing molds take a couple of days of elevated moisture to germinate. Once they germinate, they typically need several more days to develop visible amounts of mold growth. Addressing musty clothing before the mold has colonized and become well developed allows people that aren't hypersensitive to launder items using conventional detergents to easily clean and continue using those items.

In most cases, a second laundering with detergent followed by two rinses can reduce levels to a point where the garment or bedding will be acceptable. In addition to the density of growth or quantity of settled spores and fragments, the need for a second cycle can also depend on the type of mold and the degree and type of individual sensitivity.

Type of Mold

Some types of mold spore that settle on fabrics will be more difficult to clean. A study published in the *Journal of Occupational and Environmental Hygiene* discusses these differences. When cloth material swatches were cleaned to simulate laundering after being inoculated with high concentrations of several types of mold, approximately 1% of *Chaetomium* remained. Other molds like *Stachybotrys*, *Penicillium chrysogenum*, and *Aspergillus niger* were completely removed from the fabric by a single laundering cycle.⁴ *Chaetomium* type molds have a sac-like covering called the perithecia surrounding the spores they produce. The perithecia is covered with hair like structures. It is likely that *Chaetomium* is more difficult to launder away because the hair like projections of the perithecia became entangled in the fabric fibers. A second cycle of detergent laundering with two rinse cycles increases the likelihood that residual particles of *Chaetomium* and other low levels of contamination will be removed.

[Insert drawing of *Chaetomium*.]

Degree of Individual Sensitivity

There are practical limitations to predicting the quantity of allergen a person who is specifically allergic or hypersensitive to an individual type of mold will be able to tolerate. The level of

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exposure generally considered acceptable is the background levels commonly found in the outdoor air. Of course, some people do not tolerate some types of mold at normal background outdoor levels at certain times of the year when they suffer from seasonal allergies. In addition, skin contact can also be a problem for sensitive individuals.

- In general, it is agreed that if mold growth has developed to a point where it is visible and has penetrated and damaged the fibers, then the linen or clothing item should be discarded regardless of the degree of sensitivity of the person using the item.
- Items that have developed sub-visible levels of mold growth may be able to be successfully laundered or dry-cleaned. This is especially true if they are discovered and addressed when the mold growth has barely begun to develop. As more time elapses and greater amounts of colonized growth is present, sensitized people may require repeated rounds of laundering for successful cleaning. The question becomes how much cleaning is necessary for a person that is hypersensitive to mold to be able to use the item?
- Items that have collected settled spores, but have remained dry, are usually able to be successfully laundered or dry-cleaned to a level that is acceptable to those with hypersensitivities to mold. It has been my experience that two laundry cycles of cleaning is usually able to make laundered items acceptable.

Thick, Quilted, or Layered Fabrics

There is some evidence that clothing items such as heavy jackets, comforters or quilted items and other very thick or stuffed items such as pillows may be difficult or impossible to adequately remove mold spores, fragments and other allergens by routine laundering. This depends significantly on the ability of particles such as mold spores and fragments to penetrate the material that covers the item and mix with the internal stuffing. These items should be evaluated on a case-by-case basis to determine if cleaning will be adequate for returning the item to an acceptable condition for the hypersensitivity level of the persons using or around them. An inexpensive decorative stuffed pillow is unlikely to be cost effectively restored. A pillow that has sentimental value because it was painstakingly embroidered, crocheted, or knitted and then stuffed by great grandmother may be worth carefully undoing a seam, discarding the filling and cleaning the covering before re-stuffing with a new filling.

Laundering By the Numbers

There are a number of factors that influence the removal of mold spores and fragments from clothing.

In the past, washing machines have used as much as 40 gallons of water per load of laundry. Today's more efficient washers are using approximately 25 gallons per load and the most efficient have been reported to use as little as 15 gallons per load.

- Assume a washing machine has a capacity to launder 8 pounds of dry clothing and uses 10 gallons of water for the initial wash cycle and 10 gallons of water for two rinses (a total of 30 gallons of water per load).
- Since water weighs 8.34 pounds per gallon, we have approximately 80 pounds of water to 8 pounds of clothing. As the washer goes through the agitation-cycle the dirt and particles contained within the clothing becomes mixed with the water.
- When the washer goes through its drain, spin cycle, most of the water along with the mold spores, and fragments are removed. The amount of water that is spun out of the laundry will vary depending on the machine, but let's assume 8 pounds of water remains in 8 pounds of laundry. This is a 90% reduction in the amount of water remaining.
- Assuming the dirt spores and fragments were fully emulsified in the water the mold level in the clothing would now be reduced by 90%. As an example, if the kids had been rolling around in the dirt outside. They could commonly end up with an average of 1000 mixed types of mold spores per square inch mixed with the dirt on their clothing. At the end of the first spin cycle a 90% reduction would result in 100 spores per square inch remaining.
- The first rinse adds another 10 gallons of water (80 pounds) to the 8 pounds of clothing with additional agitation and spinning off the water. This results is another 90% reduction. In our example, the level has now been reduced to 10 spores per square inch.
- The second and final rinse repeats the process, thus reducing in the final level of spores to an average of one spore per square inch.

If these assumptions are correct then we would have a 99.9% reduction in mold spores and fragments by running laundry through one complete cycle. This is supported by a Journal of Occupational and Environmental Hygiene study cited earlier which showed a better than 99% reduction with a single washing of fabric followed by two rinse cycles.⁴ Laundering with laundry detergent and water has proved to be very effective at removing settled spores from clothing.

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Mycotoxins and Laundering

Mycotoxins are produced and concentrated in the spores and hyphae. Laundering with detergent does a good job of removing these particles from clothing and other materials. As these components of mold are rinsed away, the mycotoxins go down the drain with the rinse water. Furthermore, most mycotoxins are water-soluble. This means that the laundering process not only removes spores and fragments, but that water-soluble mycotoxins that have migrated into the clothing will be diluted more than 99% during a standard laundering cycle with a double rinse.

Some mycotoxins such as the trichothecenes produced by *Stachybotrys* are fat-soluble. It is possible that these toxins will migrate into the oils secreted by our bodies or from lotions, deodorants or other personal care products into the clothing fabric. Using soap or laundry detergent emulsifies the oils or grease and removes the fat-soluble mycotoxins from our clothing at the same time. *Stachybotrys* is unlikely to colonize linens and clothing because it requires the types of cellulose found in paper, cardboard, straw and corn husks. Since *Stachybotrys* doesn't grow on most fabrics, the type of contamination is likely to be settled spores. Even if the spores germinate, they are unlikely to find sufficient cellulose nutrients to support their continued growth.

Advantages of Soaps or Detergents

In addition to emulsifying grease and fats, there is an additional advantage to using surfactants such as soaps or detergents when laundering fabrics to remove particles such as dirt, spores and mold fragments. According to a recent study, the use of soaps or detergents first loosens the particles from fibrous materials. "Rinsing with fresh water then sets up a surfactant gradient within the fabric pore space".⁵ This pulls the contaminant particles out of the fabric into the fresh water rinse.

Essentials

The Essentials - Information Boxes provide quick practical guidance for important information with a minimum amount of technical explanations.

During my practice I have had a number of clients that report that only using vinegar, baking soda, or borax does not return their mold contaminated clothing and linens to an acceptable condition. This makes sense because vinegar, baking soda and borax are unable to remove grease or set up the surface gradient that helps pull contaminants from deep within the fibers. Using soap or detergent for laundering items appears to be a critical component in the successful cleaning of washables. The reasons that using vinegar, baking soda, borax or other non-toxic cleaners alone is ineffective for removing mycotoxins is discussed in more detail in the chapter on Cleaning Products.

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Essentials - Laundering to Remove Molds Spores, Fragments and Mycotoxins

Laundering can be an effective way to remove settled mold spores, fragments and mycotoxins from clothing. The following information summarizes how!

1. Items with a heavy accumulation of dust should be HEPA vacuumed or shaken outside before laundering (by someone that is not mold sensitive).
2. Items stored and protected from dust and moisture are usually fine - but the outside of the storage container should be cleaned outdoors before opening it to remove items.
3. Use Laundry detergent in each load. This helps to emulsify and remove fat-soluble mycotoxins, and helps pull spores fragments from deeper within the fabrics.
4. Vinegar, baking soda, borax and other non-detergent cleaners do not pull contaminants from materials and they don't emulsify fat soluble mycotoxins. (See chapter on Effective Cleaning Products for information on when and how to use).
5. Follow the information on the laundry detergent and make sure it is compatible with the item to be laundered. As an example 7th Generation™ Free and Clear and Ecover™ Zero are laundry detergents for use in cold or hot water.
6. Follow the information on clothing and linen care instructions tags. These will tell you the proper information regarding water temperature, proper cleaning and care instructions for the item.
7. Determine the number of cleaning cycles (one cycle equals one wash cycle with laundry detergent and two rinse cycles). Use extra cycle for laundering items:
 - to be used by mold sensitive persons.
 - stored or used in areas with high levels of settled mold spores and fragments (for example a closet with visible mold growth on the walls).
 - when *Chaetomium* type mold has been identified as a contaminant.
8. Sort items before laundering in the usual way, but also by the level of contamination. Wash items needing two cycles separately.
9. Don't cross contaminate clothing items after they are laundered. Using a clothes dryer within a contaminated building pulls spore and fragments in the air through the cloth and redeposits contaminants on freshly laundered items. If your clothes dryer is in a contaminated area, use a clothesline or dry them elsewhere.
10. If moving clothing and other washables from a mold contaminated home to a clean environment, it is important not to cause a cross contamination. One way to break the cycle of contamination would be to launder the items immediately prior to transport, and then launder a second time at the new place.

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Dry-cleaning

Dry-cleaning is not really a dry process. It is instead a method for wet cleaning items with solvents or chemicals that are able to remove dirt, grease and other particulates from items of clothing or other types of cloth where the appearance or function of the item may be harmed by water. The most common chemical used today by about 90% of dry-cleaning businesses is perchloroethylene or perc for short. Perc has been in use for about 75 years and became a popular replacement for the ozone depleting CFC-113 and 1,1,1-trichloroethane that was originally used. People with chemical sensitivities may not tolerate the chemical residues in recently dry-cleaned items. In some cases, allowing the clothing to air out after cleaning will allow additional solvents to outgas and make items more acceptable. Modern dry-cleaning equipment is able to remove and recycle about 98% of the perc used in each batch.⁶

A 2016 study published by the Japanese Journal of Infectious Diseases found that the dry-cleaning process introduced bacterial contaminants to the dry-cleaned laundry in two of the fourteen facilities studied.⁷ The study was conducted by testing brand new linens for bacteria, then submitting them for dry-cleaning and reassessing the contamination levels. Initial bacteria levels were less than one bacteria per square centimeter. After dry-cleaning two of the fourteen dry-cleaners showed an increase to 7 to 10 bacteria per square centimeter. There are a number of possibilities that could have resulted in the contamination being transferred to the linens. All fourteen of the dry-cleaners were reported to use batch-type equipment. The most obvious cause for increased levels of contamination would be if highly contaminated items were cleaned with uncontaminated items. Although the study looked at bacterial contamination levels, the same potential problem could exist for mold.

In most dry-cleaning facilities, perchloroethylene is used to wash fabrics in a sealed tumbler. The solvent solution is continuously fed into a dry cleaning tumbler during the cleaning cycle. A typical batch contains between 20 and 100 pounds of material and uses approximately 200 gallons of solvent. As the solvent cycles through the tumbler it picks up dirt, debris and contaminants. The recovered solvent passes through a filter before being cycled back through the equipment.⁸ Filtration removes most dirt, debris and residues, but it does not remove the microscopic mold spores or fungal fragments, nor does it remove mycotoxins. This means that the contaminants would not be removed from the dry-cleaned items. The filtered solvent can be further purified using distillation.

During the 2018 *AAEM Mold Conference* Dr. Michael Gray reported that "in one study, dry cleaning moldy clothes seven times did not clear the tricothecenes present in those clothes."⁹ This could easily be explained by the use of dry cleaning using filtration and not continuous distillation. Distillation completely removes the spores, fragments and mycotoxins from the cleaning fluid. The problem is that the use of distillation by dry-cleaning establishments varies. Some dry-cleaners rely primarily on filtration and distill the cleaning fluids every night. Cut-rate

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dry-cleaners may only distill once a week or may wait even longer to improve their profit margin. It is important that dry-cleaners used for cleaning mold contaminated clothing use "continuous batch mode distillation" in order to ensure that the maximum amount of mold contamination is removed. Continuous distillation can be inconvenient and more expensive, but it does have the advantage of eliminating the need for filtration. Otherwise contaminants that remain can transfer and leave a low level contamination on previously uncontaminated clothing. The study did not discuss the way the cleaning solvents were processed. This could also lead to a cross contamination from highly contaminated items to clean materials.

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Essentials - Dry-Cleaning for Mold

1. Some specialty cleaners that specialize in fire and water damage restoration are also trained to clean mold spores and fragments from clothing. They will come to the contaminated house and sort and pack the items for cleaning. They may be able to store cleaned clothing until you are ready for it to be returned to your home.
2. Choose a dry cleaner that uses continuous distillation to purify their dry cleaning fluids after every use. Filtration only results in mold spores, fragments and toxins remaining in the reused dry cleaning fluids
3. Clothing and other items that have a "funky" or rancid chemical odor after cleaning have likely been cleaned using filtered fluids that have not been recently distilled.
4. Heavily contaminated items may need two rounds of cleaning. The cleaning fluid must be distilled (continuous distillation) between loads or contaminants will redeposit in the items that are being dry-cleaned. Therefore, the second round of cleaning does not reduce the levels further.
5. Most dry cleaners use "batch" type cleaning where multiple customer items will be combined into a load and then separated back out after cleaning. This may result in cross contamination from heavily contaminated items to less contaminated items.
6. Many dry cleaning establishments act as a collection point and send items to the actual cleaning facility. The personnel at the collection point usually don't know the details of how your items will be cleaned. Try to use a cleaner with an onsite plant. This increases the chances that you will be able to learn how their process works.
7. Just like with laundering, there are detergents that can be added to dry cleaning fluids to help increase the removal of fats and oils along with fat-soluble mycotoxins. The detergent should only be used in the first part of the dry cleaning cycle. The rinse solution should be free of detergent additives and freshly distilled.
8. Laundering is preferable to dry cleaning. It is better for the environment and better tolerated by chemically sensitive individuals. Laundering doesn't risk the re-use of dry cleaning fluids.
9. There are now types of "Green Dry Cleaning" being advertised. Carbon Dioxide cleaning is beginning to become available and has tested by me and found to be successful in removing mold spores and fragments. Because carbon dioxide easily becomes a gas - it will automatically separate from the contaminants after each batch which helps avoid recontamination between batches.
10. Other new dry-cleaning methods have not been evaluated for effectiveness for mold.

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