

**CLEANING PROCEDURES FOR MOLD
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ABSTRACT

Successful cleaning of mold requires an understanding of the location of contamination and the reason why fungal growth initially occurred. In buildings with extensive moisture damage, the extent of hidden mold colonization is almost always greater than that which is readily visible in the occupied space. In buildings with extensive moisture damage it is generally necessary to open-up and inspect representative structural components in order to estimate the extent of mold growth to be removed by cleaning. Basic steps in mold cleaning include the physical removal of colonized materials, the removal of associated dusts and debris, the prevention of dusts and spores generated during clean-up from entering occupied or clean areas, and the use of appropriate protective equipment by knowledgeable clean-up workers. When surfaces are cleaned emphasis must be placed on thorough physical removal of dusts and mold residues rather than on use of microbiocidal agents. A clear pathway for data evaluation including an informed inspection should proceed any sampling performed in buildings including those undergoing cleaning. The limitations of the sampling methods should be understood (e.g., a negative air sampling result does not prove the absence of hidden growth in a wall cavity). The procedures used to clean mold are highly influenced by variables such as the kind of occupant (e.g., very conservative guidelines are used for cleaning of mold in health care centers), the kind of building (e.g., generally more wood framing is used in small residential buildings), or kinds of materials in a building (e.g., library and archival materials are difficult to clean). Special protocols are needed for mold cleaning in these different types of buildings. Finally, the ultimate success of mold cleaning is dependent upon prevention of leaks and dampness that can lead to new growth.

KEY WORDS: Cleaning, Fungi, Inspection, Mold, Renovation

INTRODUCTION

A problem building in the context of mold growth almost certainly means that chronic leaks or dampness conditions exist. Filamentous fungi will likely grow on biodegradable water-damaged or damp finishing and construction materials. The necessity for clean-up of mold in a building implies that extensive biodeterioration or growth has already occurred. Almost all mold contamination problems in buildings are caused by failure to keep infrastructure clean and dry, and/or by failure in the design, operation, and maintenance of building systems.

This paper describes cleaning procedures for mold beginning with a review of consensus documents. The importance of an informed inspection prior to cleaning or renovation is emphasized. General principles for removal of colonized materials as well as sampling as a component of the inspection process are reviewed.

Review of Consensus Publications

International workshop on health implications of fungi in indoor environments.

This workshop held in Baarn, the Netherlands in 1992 [1] presented recommendations with regard to cleaning and removal of fungal growth in buildings. It was agreed that the health risks

of biocides are not adequately understood and therefore biocides should be used only as a last option for controlling fungal growth indoors. In addition, the inhalation of fungal spores and other mycological byproducts should be avoided when handling contaminated materials.

NYC Stachybotrys Guidelines. A panel in 1993 in New York City discussed appropriate remediation actions when visible Stachybotrys chartarum growth occurs on interior surfaces [2]. It was recommended that materials visibly colonized by mold should be removed by persons using appropriate personal protective equipment including respirators and gloves. The use of containment barriers (plastic sheeting) and negative pressurization was recommended for removal of moldy materials with a surface area greater than about 3m². Smaller amounts of moldy materials should be removed or cleaned by simpler methods. A proposed revision of the 1993 document has been widely discussed but not yet published. Some highlights of the proposed revision are (a) all fungi that may colonize interior surfaces, not just Stachybotrys chartarum must be considered during clean-up. The inspection process of the building for water damage and mold colonization is the most important step in designing remediation and clean-up strategies. Four size areas of mold colonization (<1 m², 1 -3 m², 3-10 m², >10 m²) with more conservative containment strategies (proportional to area colonized) have been proposed.

Health Canada [3] Fungal Contamination Guide. Health Canada published a guide to assist investigators in managing fungal contamination issues in buildings. An appendix in the guide recommended the use of personal protective equipment by persons doing clean-up of moldy materials. For large-scale (colonized surfaces greater than about 10m²) clean-up operations, physical isolation and negative pressurization of the clean-up area from both the HVAC system and from the interior spaces was recommended. Evacuation of building occupants should also be considered in large-scale fungal remediations.

ISIAQ Task Force Report. A 1996 ISIAQ report [4] reviewed previous publications on fungal remediation and recommended additionally that soft porous materials that are visually colonized should be discarded [5]. Cleaning and remediation should not render interior surfaces sterile, but rather return the building to a condition where normal (background) kinds and concentrations of fungi occur.

ACGIH bioaerosols committee. The ACGIH 1999 publication [6] classifies the extent of fungal colonization in buildings as minimal, moderate, and extensive without assignment of numerical surface area guidelines. During clean-up plastic sheeting barriers and negative pressurization should be used to contain dusts when extensive colonization is removed.

The Building Inspection

Successful cleaning of mold requires an understanding of the location(s) of contamination and the reason(s) why fungal growth has occurred. The informed building inspection is central to the clean-up process. Components of the inspection process include identifying those building materials affected by both fungal growth and moisture damage. Literature on identification of moisture and fungal growth problems in buildings [4, 6-10] should be reviewed prior to the inspection process.

The location and extent of visible fungal colonization must be determined during the inspection [11, 12]. An inventory of visibly moldy interior surfaces should be made including the extent (m²) and location of colonized materials. It should be realized that fungal micro-colonies invisible to the unaided human eye may extend outward for considerable distances (approximately 0.5m) from moldy materials such as paper fiber gypsum board [13]. The presence of mycelia or

fruiting structures as seen by direct microscopic examination (e.g., cello tape samples) verifies that visible contamination is of fungal origin [6, 14].

During the inspection it should be determined if materials that are highly susceptible to biodeterioration such as those containing amorphous cellulose are hidden in damp moist niches in building components. In moisture-damaged buildings, the extent of hidden colonization is almost always greater than that which is readily visible in the occupied space [15]. In buildings with substantial moisture damage it may be necessary to open-up and inspect floor, wall and ceiling structural components in order to estimate the extent of hidden mold growth. Precautions must be taken during destructive opening of building structural components to protect occupants and investigators from spores that may be aerosolized if hidden colonization is found. Demolition of structural components may be required to expose pockets of contamination (e.g., sewage contaminated water) for adequate cleaning and drying [16].

As an aid to finding locations of hidden mold growth a clear understanding of locations of moisture damage as well as reasons for the damage is necessary. Cleaning of the building will ultimately be ineffective if moisture problems persist. A moisture meter can be used to determine if some finishes and construction materials which appear superficially dry actually contain significant amounts of moisture [17]. Literature on condensation and dampness problems in building envelopes in hot humid or cold climate/seasons should be reviewed in order to understand the reasons for consequential mold growth [9, 10]. Moisture problems associated with below grade structures and the building foundation especially if biodegradable materials are used in construction (e.g., wood joists and framing) must be revealed during the inspection in order to plan a strategy for cleaning.

Principles for Mold Clean-up

Important components of mold cleaning are (a) the physical removal of colonized materials, (b) removal of settled dusts containing spores that may have previously been dispersed from moldy surfaces, (c) prevention of spores and dusts generated during clean-up from entering occupied or clean areas, and (d) use of appropriate personal protective equipment by clean-up workers.

Porous materials such as paper fiber gypsum board, ceiling tiles, insulation, wallpaper, carpet, pressed wood products etc., that are visually moldy should be discarded. Mold growth that may be present on non-porous surfaces such as sheet metal, ceramic tiles, glass, etc., is physically removed by cleaning. Tap water with detergents or surfactants should be effective for most cleanings of non-porous materials.

The method used to remove colonization on semi-porous materials such as wood framing depends on the degree to which fungi have penetrated the substrate. Lumber that is dry rotted or wet rotted [17] is discarded. Wood that is sound with the exception of colonization of the outer surface may be sanded, planed, refinished, and reused. The principle for reuse is the absence of hyphae and fruiting structures (over and above that normally present in sound wood) in the wood cells of the timber being salvaged.

The airborne concentration of spores can exceed $10^6/m^3$ when moldy materials are disturbed [18-19]. Consequently those persons involved in clean-up activities must use personal protective equipment. The use of a N-95 respirator and gloves is adequate during the clean-up of minimal (small surface area) colonization [6]. For remediations involving extensive colonization the use of full body disposable protective clothing and P-100 respirators is essential.

The use of containment barriers, depressurizing techniques, and dust suppression methods during removal of moldy materials is required to prevent dissemination of spores into occupied or clean areas [20]. The extent of the surface colonized (minimal, moderate, extensive) in a room or in one area of a building is the most important factor to be considered with regard to selection of containment methodology or dust suppression methods [6]. When moldy materials are removed or cleaned the area where the clean-up is occurring should be depressurized (negative air machine for large scale containment; nozzle of a HEPA vacuum for source containment) so that the flow of air is always from clean areas into the location where cleaning is occurring. Additional factors important in determining the dust containment methods employed during a remediation include (a) the presence of highly susceptible occupants [21] and (b) the likelihood that hidden colonization may be uncovered within building components.

A principle common to guidelines on fungal remediation [2, 4, 6] is that building maintenance personnel with proper training can perform clean-up involving minimal and moderate surface area colonization. Interior surfaces with minimal fungal growth (e.g., 1 or 2 ceiling tiles, 0.1 or 0.2m² paper fiber gypsum board) can be removed by properly trained persons wearing gloves and a respirator. The colonized or moldy surface can be covered with a sticky sheeting (sticky surface makes contact with colonized surface), removed in one piece, bagged, and discarded.

Any technique that reduces dust (spore) emission from the colonized surface should be considered during cleaning. Thus, application of an encapsulant to a colonized surface prior to removal may be useful. The application of a gentle water mist to colonized surfaces may be effective in dust suppression so long as hydrophobic spores are not dispersed into the air by impaction of droplets. Water mists and sprays, if used, must not wet sound infrastructure.

Spores from colonized surfaces in one area of a building may have been dispersed by air currents into areas of the building unaffected by moisture problems. A combination of damp wiping and HEPA vacuum cleaning should be adequate to remove dusts from non-porous surfaces. Professional judgment is required to determine if porous surfaces can be cleaned by HEPA vacuuming. Specific protocols have been recommended for dust removal from some porous materials such as carpet [5].

The objective of clean-up is to remove colonization and associated mold laden dusts, but not to sterilize or disinfect interior surfaces. As such the use of biocides and disinfectants is to kill cells during clean-up is unnecessary unless infection is perceived as a health concern. The use of biocides and disinfectants during cleaning may confound efforts to determine cleaning efficiency when clearance sampling is based on culture techniques [22]. The physical removal of moldy materials plus the removal of associated dusts by vacuum cleaning and damp wiping should be adequate for cleaning [4, 6] in most buildings. If disinfectants are used in the clean-up of moldy surfaces, it is essential during the final cleaning process to remove dead residues that may potentially be allergic or toxic [23].

Sampling and Mold Cleaning

Sampling for fungi during building evaluations has been reviewed elsewhere [6, 24, 25]. Sampling for fungi in buildings undergoing mold cleaning must be preceded by a clear evaluation pathway that outlines how analytical data will be interpreted. For example, when the objective of air sampling is to determine if exposure conditions after a clean-up in a building are “normal”, the collection of samples at many locations and at various times indoors as well as concurrently in the outdoor air is minimally required for data interpretation. The collection of one or a few samples seldom characterizes environmental mycological conditions [6, 24].

Comparison of air sampling data obtained both before and after clean-up with the knowledge that moisture problems have been fixed and that visually moldy materials have been physically removed adds to the strength of possible data interpretations. Awareness of limitations in sampling and analytical methodology is always important in data interpretation. For example, if the objective of sampling is to determine if Stachybotrys is present, then exclusive use of culture based methods may overlook non-culturable spores detectable only by direct microscope methods (e.g., cellotape and spore trap sampling).

During building evaluations including those involving cleaning, the results of an informed inspection are of greater value than sampling results alone obtained without the benefit of inspection. Table 1 shows the results of sampling by spore trap in a room with a history of chronic water leaks around windows. While Cladosporium accounted for the vast majority of spores collected in the room, a few Stachybotrys spores were also detected. The data might be interpreted to indicate that fungal reservoirs were present somewhere in the building. Alternatively, some investigators might interpret the sampling data as indicative of a ? normal? situation because of a predominance of Cladosporium. Subsequent destructive opening of the building envelope around windows showed that about 50% of the surface area of the hidden construction materials (e.g. wall cavity side of paper fiber gypsum board, asphaltic building paper, etc.) were colonized by fungi including Stachybotrys and Chaetomium. The sampling results in Table 1 could thus be more clearly interpreted namely that the Stachybotrys found in the room air had likely originated from reservoirs within the envelope. In addition, cleaning of room surfaces alone can not fix the mold problem in the envelope.

Table 2 presents sampling data on culturable fungi present in settled dust in a home where water damaged furniture had been stored for several weeks. Some mold had grown on the stored furniture as well as on flooring material. Cleaning of floors with a household vacuum cleaner had occurred subsequent to removal of furniture. The dominating presence of non-phyloplane fungi such as Aspergillus versicolor in settled dust indicated that cleaning for mold was ineffective.

Air sampling for fungi can be used to assist in determining if microbial particulate is being effectively kept out of occupied space during clean-up. Table 3 presents sampling data collected during removal of approximately m³ of moldy wallboard (mostly Stachybotrys) from a water damaged envelope wall. The concentration of Stachybotrys increased by several orders of magnitude within the containment when moldy wallboard was being removed from the envelope wall. It is significant that some Stachybotrys spores were entering the occupied space indicating a deficiency in containment procedures. This finding indicated that spores were not adequately being confined within the containment during clean-up.

Table 1. Airborne fungal spores in room with a history of chronic leaks around windows

Spore Type	Spores/m ³
<u>Cladosporium</u>	2,900
<u>Penicillium/ Aspergillus</u>	650
<u>Stachybotrys</u>	70

Collected by spore trap with a flow rate of 0.01 m³ /minute

Table 2. Culturable fungi in settled dust in house where water damaged furniture had been temporarily stored

Predominant species	Frequency (%)
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<u>Aspergillus versicolor</u>	50
<u>Penicillium citrinum</u>	26
<u>Cladosporium cladosporioides</u>	4
<u>Aspergillus niger</u>	3
<u>Aspergillus ustus</u>	3
other species	14

Rank order frequency of species recovered on malt extract agar by dilution plating

Table 3. Airborne Stachybotrys spores inside and outside a containment during clean-up

Location	<u>Stachybotrys</u>	Total Spores
	(spores/m ³)	
Inside containment, moldy materials not being handled	340	2,700
Inside containment, during handling of moldy materials	69,000	70,000
Outside containment	15	400

CLEANING OF MOLD - SPECIAL SITUATIONS

Hospitals. For more than two decades it has been known that incidence of infection (aspergillosis) among immunosuppressed patients is reduced when air entering a building is filtered [26]. Epidemics of aspergillosis in immunocompromised patients have been associated with the presence of fungal growth on surfaces in HVAC systems and with dust emissions associated with soil excavation, new construction, and interior renovations [21, 27].

Very conservative guidelines have been recommended to control and prevent exposure of immunocompromised patients to essentially all culturable fungal spores [21]. Procedures such as the following are recommended during renovation and clean-up work in hospitals: (a) isolate and negatively pressurize the remediation/clean-up area; rigid floor to ceiling, critical barriers are used to isolate patient areas from potential sources of culturable fungi, (b) administrative procedures are used to prohibit tracking of dusts into patient areas, (c) high quality air (spores absent) is provided to highly susceptible patients by point of discharge filtration in supply air ductwork, and (d) patient rooms are positively pressurized relative to areas containing fungal colonization and dusts aerosolized during cleaning and renovation. The conservative actions used to reduce incidence of fungal infection among immunocompromised patients provide a framework for guidelines that may be necessary in clean-up situations when highly susceptible people may be present in non-medical facilities.

Books, Paper, and Archives. The clean-up of books, paper, and archives damaged by floods and dampness involves a combination of discarding moldy items, drying out of wet materials, and removal of settled dusts. Fungi can grow rapidly on many of these materials because of the adhesives, gums, starch, etc., often present in book jackets and bindings and also because of the presence of delignified cellulose substrate.

Because of the susceptibility of books, paper, and archives to biodeterioration, the drying of

water damaged or damp materials is of critical importance. Freeze drying of water soaked material can be used in restoration because low temperatures arrest fungal colonization and evaporation of water molecules (subliming) lowers available moisture so that growth can not recur [28, 29]. A goal of restoration is to lower the moisture content of paper to its normal range, 5 - 7%, [30] where fungal growth does not occur.

Several simple techniques are available for removing superficial colonization from valuable materials. Miniature aspirators capable of applying a gentle suction to surfaces by a pipette nozzle can be used to carefully remove spores [28]. A small vacuum cleaner can be used to remove spores where a fine screen is placed firmly over the fragile material being cleaned [28]. All cleaning activities involving manual removal of colonization should be performed by persons with adequate personal protective equipment and preferably in a biosafety cabinet.

The cleaning of library materials which are not visually colonized but which were stored in buildings with mold growth problems is a challenge because of the enormous amount of paper surface potentially involved. The following activities can be effective in cleaning dusty library materials that had been stored in a moldy environment: (a) Vacuum (HEPA instrument) the top, bottom, and sides of books and files to remove settled dusts. (b) Vacuum and damp wipe the surfaces of shelves, file cabinets, desks and other non-porous fixtures. The visual presence of dust on books and on non-porous surfaces (e.g., shelves) in the library indicates unsuccessful cleaning. (c) Fan the pages of the books, files, and other archives in the immediate vicinity of the suction orifice of a HEPA vacuum. The objective is to reduce the amount of dust present on surfaces of library materials.

Residences. As a general principle, it is recognized that people should not live in moldy homes [5]. Clean-up of fungal colonization in residences differs from that in most large buildings because of occupancy and construction reasons. Occupants may be present 24 hours a day, 7 days per week in homes. Occupants of residences may also be specially sensitive or susceptible to fungal exposure (e.g., persons with immunosuppression diseases).

Most residences are smaller in volume than commercial and public buildings. In comparison to a large office building, a residence has a greater ratio of envelope surface (roof, exterior walls, basement) to air volume. There is a greater envelope surface where moisture may enter from precipitation or from the soil. Fungal growth problems in residences are increased by the use of porous biodegradable materials in damp locations such as basements.

Residences differ from office buildings because of the greater use of wood framing and pressed wood products in the former. Consequently wood rot fungi are more likely to be present in a residence with persistent moisture problems. Cleaning of mold in residences is often logistically difficult because of problems with access to biodeteriorated wood structural members in crawl spaces and attics.

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