Health Hazards

Mold

Risk Assessment & Remediation

Proactive management, prompt action reduce risks

By Daniel P. Mahoney and Jerome E. Spear

A PROACTIVE ASSESSMENT of building design, site selection and construction management, coupled with ongoing facility operation and maintenance can reduce the risk of developing a mold-related problem within a building. Once mold contamination has developed, potential risks can be mitigated through prompt assessment and remediation. A thorough remediation plan minimizes exposures to both building occupants and remediation workers.

"Is Your Office Killing You?" (Business Week)
"Beware: Toxic Mold" (Time)
"Attack of the Killer Mold?" (KARK, Channel 4, Little Rock, AR)

Media headlines such as these have contributed to public awareness and fear about mold contamination in buildings. Although some fungal species produce potent mycotoxins, most mold varieties cannot cause toxic effects or disease unless the exposed person is severely immunodeficient. CSP, CIH, is manager of workers’ compensation services for XL Environmental Inc., an XL Capital company located in Exton, PA. He has 21 years’ experience helping clients control occupational disease exposures, safety hazards and workers’ compensation claims, as well as extensive experience in OSHA compliance, hazard communication, industrial hygiene, and safety and health training. A member of ASSE’s Philadelphia Chapter, Mahoney earned a B.S. from Pennsylvania State University.

Jerome E. Spear, CSP, CIH, is regional technical services manager based in Houston for XL Environmental Inc., an XL Capital company. He has 13 years’ experience managing and controlling workplace hazards and exposures, helping clients evaluate and manage safety and health-related issues, including incident investigations, industrial hygiene, OSHA compliance, indoor air quality, construction safety and training. Spear holds a B.S. in Industrial Engineering, with a specialization in safety engineering, from Texas A&M University. He is a professional member of ASSE’s Gulf Coast Chapter, and belongs to both the Construction and Industrial Hygiene practice specialties.

Assessing Mold Contamination

When mold contamination has developed, the source of moisture must be identified and the scope of the problem assessed before cleanup begins. In most cases, sampling is not needed to assess mold contamination. Visible mold growing inside a building should be remediated. In some cases, however, sampling may be prudent. For example, it may be warranted in cases that involve litigation, if the contamination source(s) is unclear or to mitigate health concerns of building occupants.

Before collecting samples during a microbial
investigation, a sampling plan should be devised to ensure that useful data are collected. The following types of sampling may be incorporated into a strategy to assess mold contamination in a building:

- **Bulk sampling.** Bulk samples are materials (e.g., settled dust, sections of wallboard, carpet segments) that are tested to determine whether they contain biological contamination. These samples may provide information about the possible source of contamination and the general composition and relative concentrations in these sources (ACGIH).
- **Surface sampling (tape, swab, contact plates).** Surface samples may provide information similar to bulk samples. Surface sampling is preferred over bulk sampling when a less-destructive method is desired (ACGIH).
- **Bioaerosol sampling (culture plate, spore trap).** Bioaerosols are defined by ACGIH as airborne particles, large molecules, or volatile compounds that are living, contain living organisms, or were released from living organisms. Bioaerosol samples are collected using a suction pump to capture the contaminants onto a media (e.g., culture plate, spore trap). Culture-based sampling is the most common method; it involves capturing the contaminants on a culture plate and subsequently incubating the sample in a laboratory. ACGIH has not established threshold limit values for most bioaerosols. Consequently, interpretations of bioaerosol sampling are made by comparing the results of indoor air samples to outdoor air samples. Table 2 outlines the advantages and disadvantages of the various sampling methods.

Mold sampling should be conducted by qualified personnel experienced in designing mold sampling protocols, sampling methods and interpreting results. Samples should be analyzed by a laboratory that participates in the Environmental Microbiology Proficiency Analytical Testing Program (EMPAT) administered by the American Industrial Hygiene Assn. (AIHA).

### The Remediation Plan

A Greek proverb guides, “Act quickly but think slowly.” If water damage occurs in a building, microbial growth typically occurs within 24 to 48 hours, so action must be taken quickly in order to prevent mold growth. For example, damaged ceiling tiles or insulation must be discarded and replaced immediately. Hard-surface porous flooring may be vacuumed or damp wiped with water and a mild detergent and allowed to dry. Water may be removed from upholstered furniture with a water-extraction vacuum, and drying of such items may be accelerated by using dehumidifiers and heaters (EPA). However, if the water source is contaminated with sewage, or chemical or biological agents, additional actions should be taken (e.g., PPE, containment).

### Visible Mold Growth

When prevention has failed and visible microbial growth has occurred in a building, restoration requires the following actions:

- Remove porous and semiporous materials that contain microbial growth or that are water damaged.
- Physically remove surface microbial growth or nonporous materials to typical background levels.
- Reduce moisture to levels that do not support microbial growth.
- Perform HEPA vacuuming.
- Contain work areas.
- Dehumidify the area.
- Conduct clearance inspections and sampling (ACGIH).

In “Guidelines on Assessment and Remediation of Fungi in Indoor Environments,” NYCDH defines the potential degree of risk and provides suggested cleanup methods based on the extent of damage and

---

**Table 1**

<table>
<thead>
<tr>
<th>Mold &amp; Fungi Species</th>
<th>Health Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alternaria</strong></td>
<td>Asthma</td>
</tr>
<tr>
<td><strong>Aspergillus fumigatus</strong></td>
<td>Eye infections</td>
</tr>
<tr>
<td><strong>Aspergillus flavus</strong></td>
<td>Severe allergic lung disease</td>
</tr>
<tr>
<td><strong>Niger</strong></td>
<td>Very common allergic responses</td>
</tr>
<tr>
<td><strong>Cladosporium</strong></td>
<td>Fungal infections</td>
</tr>
<tr>
<td><strong>Penicillium</strong></td>
<td>Pathogenic rarely</td>
</tr>
<tr>
<td><strong>Mucor</strong></td>
<td>Systemic infections</td>
</tr>
<tr>
<td><strong>Cryptococcus neoformans</strong></td>
<td>Infections</td>
</tr>
<tr>
<td><strong>Histoplasma capsulatum</strong></td>
<td>Can progress to meningitis</td>
</tr>
<tr>
<td><strong>Stachybotrys chartarum</strong></td>
<td>Target AIDS patients</td>
</tr>
</tbody>
</table>

**Where Found**

- **Aging plants**
- **Cellulose tiles and wallpaper**
- **Decaying leaves**
- **Damp lining of HVAC systems**
- **Warm environments**
- **Where freestanding water is available**
- **Tile grout, bathroom sealants**
- **Ceiling with condensed water from piping**
- **Cold temperatures**
- **Refrigerated food spoilage**
- **Very common in air**
- **Grow on sugar and starches**
- **Pigeon and chicken droppings**
- **Guano fertilizer**
- **Soil containing bird and bat droppings**
- **Damp cellulose materials**
- **Greenish black appearance**
- **Water-damaged areas**

---

*PROFESSIONAL SAFETY 21*
### Advantages & Disadvantages of Sampling Methodologies

<table>
<thead>
<tr>
<th>Sampling Technique</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk</td>
<td>• Inexpensive&lt;br&gt;• Can provide rapid spore identification&lt;br&gt;• Can be quantitative&lt;br&gt;• Can identify viable and nonviable spores&lt;br&gt;• Viable assay includes organisms hidden in porous materials&lt;br&gt;• Can be cultured</td>
<td>• Usually destructive&lt;br&gt;• Removal of material may expose occupants&lt;br&gt;• Does not directly relate to airborne exposures&lt;br&gt;• May not be the source of amplification&lt;br&gt;• Laboratory process can be difficult</td>
</tr>
<tr>
<td>Swab</td>
<td>• Inexpensive&lt;br&gt;• Nondestructive&lt;br&gt;• Can provide rapid spore identification&lt;br&gt;• Can be quantitative&lt;br&gt;• Can be cultured&lt;br&gt;• Easy to perform sampling&lt;br&gt;• Sample can be collected from irregular-shaped surface&lt;br&gt;• Convenient to hold and ship</td>
<td>• Commercial swab may have preservatives to preserve spores (if so, cannot be cultured)&lt;br&gt;• Does not directly relate to airborne exposure&lt;br&gt;• May not be the source of amplification&lt;br&gt;• Fungal structures may be damaged during swabbing, making identification less accurate&lt;br&gt;• Spores may germinate before laboratory analysis&lt;br&gt;• May not capture organisms in porous materials</td>
</tr>
<tr>
<td>Tape</td>
<td>• Inexpensive&lt;br&gt;• Can provide rapid spore identification&lt;br&gt;• Quick and easy&lt;br&gt;• Convenient to hold and ship&lt;br&gt;• Nondestructive&lt;br&gt;• Easy to perform sampling</td>
<td>• Cannot culture&lt;br&gt;• Not quantitative&lt;br&gt;• Tape pressure can deform or destroy spores&lt;br&gt;• Does not directly relate to airborne exposure&lt;br&gt;• May not be the source of amplification&lt;br&gt;• Small sample area&lt;br&gt;• May be damaged in transit&lt;br&gt;• Initial equipment expensive&lt;br&gt;• Sampling is cumbersome and noisy&lt;br&gt;• Can isolate only viable microbials&lt;br&gt;• Takes seven to 10 days to complete the analysis&lt;br&gt;• Some fungi may overgrow others&lt;br&gt;• Can speciate, but takes longer&lt;br&gt;• Low recovery rate for Stachybotrys&lt;br&gt;• Media has short shelf life&lt;br&gt;• Samples are perishable</td>
</tr>
<tr>
<td>Culture Plate</td>
<td>• Can sample for both fungi and bacteria&lt;br&gt;• Relates directly to airborne exposure&lt;br&gt;• Qualitative and quantitative&lt;br&gt;• Can select different media to target specific organisms&lt;br&gt;• Can compare to bulk, swab or tape results for identifying amplification sites</td>
<td></td>
</tr>
<tr>
<td>Spore Trap</td>
<td>• Cassette is easy to store&lt;br&gt;• Cassette has long shelf life&lt;br&gt;• Provides qualitative results&lt;br&gt;• Provides semiquantitative results&lt;br&gt;• Relates directly to airborne exposure&lt;br&gt;• Rapid results</td>
<td>• Initially expensive&lt;br&gt;• Sampling is cumbersome and noisy&lt;br&gt;• Does not differentiate between viable and nonviable&lt;br&gt;• Large lab-to-lab variation in identification&lt;br&gt;• Methodology not accepted by all within the industry</td>
</tr>
</tbody>
</table>


Table 3 provides guidance on cleanup methods, as well as PPE and containment recommendations (NYCDH; EPA).

The remediation plan should be developed upon finding evidence of mold and should be based on the size of the mold and/or moisture problem and the type of damaged materials. For example, carpeting and draperies that can be removed for thorough cleaning and drying may be salvageable. Nonporous surfaces may be damp wiped or scrubbed with water and mild detergent and allowed to dry. However, remediation and removal methods should be based on the nature and extent of contamination (i.e., particular microorganisms present and the amount of material or area affected) (ACGIH).

To mitigate occupant concerns, minimize exposures and reduce cost, the remediation plan must be thorough. It should detail:

- personnel involved with the work;
- how the moisture source will/has been corrected;
- how exposure to bioaerosols to both remediation workers and building occupants will be minimized;
- specific cleanup methods;
- final cleanup inspection and clearance sampling procedures.

---

The building materials involved. These guidelines outline general abatement strategies (levels) based on the square footage of the contaminated area:

- Level I: Small isolated areas (10 sq. ft. or less)—such as ceiling tiles, small areas on walls;
- Level II: Mid-sized isolated areas (10 to 30 sq. ft.)—such as individual wallboard panels.
- Level III: Large isolated areas (30 to 100 sq. ft.)—such as several wallboard panels.
- Level IV: Extensive contamination (greater than 100 contiguous sq. ft. in an area).
- Level V: Remediation of HVAC systems.

The remediation plan should be developed upon finding evidence of mold and should be based on the size of the mold and/or moisture problem and the type of damaged materials. For example, carpeting and draperies that can be removed for thorough cleaning and drying may be salvageable. Nonporous surfaces may be damp wiped or scrubbed with water and mild detergent and allowed to dry. However, remediation and removal methods should be based on the nature and extent of contamination (i.e., particular microorganisms present and the amount of material or area affected) (ACGIH).

To mitigate occupant concerns, minimize exposures and reduce cost, the remediation plan must be thorough. It should detail:

- personnel involved with the work;
- how the moisture source will/has been corrected;
- how exposure to bioaerosols to both remediation workers and building occupants will be minimized;
- specific cleanup methods;
- final cleanup inspection and clearance sampling procedures.
### Comparison of Remediation Guidelines

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Containment</th>
<th>PPE</th>
<th>Clearance Sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYCDH: Level I (10 sq. ft. or less)</td>
<td>None</td>
<td>Disposable N95 particulate respirator, gloves, eye protection</td>
<td>None</td>
</tr>
<tr>
<td>NYCDH: Level II (10 to 30 sq. ft.)</td>
<td>Local containment (i.e., cover with plastic sheets and seal with tape)</td>
<td>Disposable N95 particulate respirator, gloves, eye protection</td>
<td>None</td>
</tr>
<tr>
<td>NYCDH: Level III (30 to 100 sq. ft.)</td>
<td>Immediate and adjacent work areas (cover with plastic sheets, sealed with tape and seal ventilation ducts/grills)</td>
<td>Disposable N95 particulate respirator, gloves, eye protection</td>
<td>None</td>
</tr>
<tr>
<td>NYCDH: Level IV (more than 100 contiguous sq. ft.)</td>
<td>Immediate and adjacent work areas (i.e., negative-pressure containment with HEPA filters, airlocks and decontamination room; seal fixtures, ventilation ducts/grills and other openings)</td>
<td>Full-face respirators with HEPA (i.e., N99) cartridges, disposable protective clothing covering head, shoes and gloves</td>
<td>Yes</td>
</tr>
<tr>
<td>NYCDH: Level V (HVAC Systems)</td>
<td>Cover with plastic sheets sealed with tape</td>
<td>Disposable N95 particulate respirator, gloves, eye protection</td>
<td>None</td>
</tr>
<tr>
<td>NYCDH: Level V (HVAC Systems—more than 10 sq. ft.)</td>
<td>Cover with plastic sheets sealed with tape; negative-pressure containment with HEPA filters, airlocks and decontamination room if contamination is more than 30 sq. ft.</td>
<td>Disposable N95 particulate respirator, gloves, eye protection; full-face respirator with HEPA (i.e., N99) cartridge and protective clothing if contamination is more than 30 sq. ft.</td>
<td>Yes</td>
</tr>
<tr>
<td>EPA: Small (less than 10 sq. ft.)</td>
<td>None</td>
<td>Limited (i.e., disposable N95 particulate respirator, gloves, eye protection)</td>
<td>Based on professional judgment of qualified person</td>
</tr>
<tr>
<td>EPA: Medium (10 to 100 sq. ft.)</td>
<td>Limited (i.e., negative-pressure containment using single layer of 6-mil, fire-retardant polyethylene sheeting from ceiling to floor; seal ventilation openings)</td>
<td>Limited or full (i.e., full-face respirator with HEPA cartridge, gloves, disposable full-body clothing with head gear and foot coverings) based on professional judgment of qualified person</td>
<td>Based on professional judgment of qualified person</td>
</tr>
<tr>
<td>EPA: Large (more than 100 sq. ft.)</td>
<td>Full (i.e., negative-pressure containment using two layers of fire-retardant polyethylene sheeting with one airlock chamber; seal ventilation openings)</td>
<td>Full</td>
<td>Based on professional judgment of qualified person</td>
</tr>
</tbody>
</table>

Source: NYCDH, EPA

---

### Remediation Personnel

EPA recommends that a remediation manager be selected for projects that involve more than 10 sq. ft. of contamination or for smaller projects if the remediation requires more than one person (EPA). This manager develops the remediation plan and selects the remediation contractor or workers. Based on his/her specific experience, the designated remediation manager may need to consult with an SH&E professional or consultant who has direct experience with the type of remediation to be performed. The top priority is to protect the safety and health of building occupants and remediation workers (EPA).

After assessing the problem's scope, the first critical management decision is to determine whether to correct the problem using in-house staff or outside contractors. Insurance companies report average payouts of $45,000 to $55,000 per claim, while reputable remediation companies report project cost averages of closer to $12,000 per claim (Allen). Because of poor workmanship and inadequate training of some mold remediators, insurance companies are often paying for the same job two or three times (Allen).

Since poor remediation practices can be costly to the building owner or insurer, the remediation contractor should be thoroughly screened to ensure that the firm has experience cleaning up mold. In addition, "reputable mold remedicators should possess one of two certifications: certified microbial remediation supervisor (CMRS) from the American Indoor Air Quality Council or the certified microbial remediator (CMR) from the Indoor Air Quality Assn." (Williams 49). Before hiring a contractor, references should be checked; once the project begins, the work should be monitored to ensure that best management practices are followed.

### Minimizing Exposure to Bioaerosols

According to the California Dept. of Health, remediation processes may expose workers to airborne mold spores from 10 to 1,000 times more than before the remediation (Reese). Therefore, the reme-
A remediation plan should specify how both occupants and remediation workers will be protected. Controlling potential exposures to bioaerosols depends largely on the cleanup method used. In addition, administrative controls and PPE should be incorporated into the plan to further minimize exposure.

ACGIH recommends that those involved in the removal of extensive microbial contamination be informed in writing by a physician of the potential health risks of bioaerosol exposure, and that immunocompromised workers should avoid remediation activities (ACGIH). Those performing major cleanup activities should receive a baseline medical evaluation using a medical questionnaire evaluated by an occupational/environmental physician as a minimum.

Individuals recovering from recent surgery and people with immune suppression, asthma, hypersensitivity pneumonitis, severe allergies, sinusitis or chronic inflammatory lung diseases should not be employed as remediation workers (AIHA). A follow-up medical evaluation using a symptom questionnaire at the completion of a project would also provide both the worker and employer assurance that any effects of exposure are likely to be detected and treated properly (ACGIH).

**Personal Protective Equipment**

The level of PPE required depends on the extent of contamination. At a minimum, remediation workers should wear disposable N95 particulate respirators, gloves and eye protection (such as goggles) for projects that have less than 30 sq. ft. of mold growth. For larger remediation projects, the level of PPE may need to increase to include full-face HEPA (i.e., N99) particulate respirators, gloves and disposable full-body clothing with headgear and foot coverings. As noted, Table 3 provides a comparison of PPE guidelines for remediation activities.

**Correcting the Source of Moisture**

Identifying conditions that contribute to microbial growth in a building is the most important step in remediation (ACGIH). Therefore, the remediation plan should detail steps to correct the moisture problem. Potential problems include high humidity, condensation problems, water leaks and maintenance issues, as well as issues related to heating, ventilation, and air-conditioning (HVAC) systems. The timing of the corrective action may be critical in minimizing exposure during remediation since sporulation increases as moisture is removed (ACGIH). Thus, when practical, the moisture should not be removed until the material is removed or cleaned.

**Cleanup Methods**

To minimize exposure to personnel not performing remediation activities, negative-pressure (full-scale) containment, local containment or no containment may be used depending on the size of the project.
Proactive Property Management: Minimizing the Risks of Mold

When buying, renting or constructing properties, many factors must be considered in order to reduce the risk of mold contamination.

- Preventive maintenance of HVAC, plumbing and other building systems can reduce the potential for mold growth. Owners that disregard maintenance of basic HVAC components—such as filter and condensate drains—face increased risk. HVAC systems that cycle off during non-occupancy hours to save energy can create fluctuations in temperature and humidity conditions, which may promote mold growth. Undersized and oversized HVAC systems are also associated with inadequate moisture control (ASHRAE 62-2001).

- Roof leaks, plumbing leaks or sewer back-ups that allow water into the structure often trigger a mold and bacteria problem. Water intrusion that occurs during construction and renovation is also associated with uncontrolled mold growth. The key to mold risk reduction is preventive maintenance of building systems, as well as regular inspections to identify leaks. Thorough planning prior to construction activities can prevent moisture from entering the structure. Consideration should also be given to protecting construction materials from precipitation once they arrive on site. Additionally, building openings should be protected when possible to reduce the amount of moisture that enters the interior of the structure during the construction process.

- Local weather conditions influence the degree of mold risk. Buildings located in areas with high precipitation or persistent high humidity must defend against outdoor conditions (Figure 1). To control indoor mold growth, the relative humidity should remain below 60 percent (ASHRAE 55-1992). Properties located within a flood plain may also need special design considerations such as sump pumps, moisture barriers and exterior grading to prevent rising surface and groundwater from entering the structure. Properties in a 100-year flood plain should be evaluated for suitability. Basements and crawlspaces that are persistently high in humidity can be sources of mold which can damage stored contents as well as structural integrity.

- Interior moisture sources can also contribute to humidity levels within a structure. Indoor pools, spas, laundries or other wet processes add a significant moisture load. Therefore, HVAC systems should be designed to remove this extra moisture from the structure.

- Buildings with a history of water leaks present a high degree of mold risk as well. Persistent small leaks that are not resolved—such as roof leaks or leaks around window frames—are commonly associated with uncontrolled mold growth. More extensive leaks that take more than two days to clean up and dehumidify are also high-risk indicators. If porous or semiporous materials have been wetted and remain within the building, these materials are likely to harbor mold growth. Buildings constructed of biodegradable materials are also likely to harbor biological activity as the building envelope and structure members can absorb moisture.

To reduce the risk of indoor mold contamination, consider the following when purchasing and managing properties:

- Avoid buildings with basements.
- Do not locate properties within a flood plain.
- Any visible mold should be less than 10 sq. ft.
- Design HVAC systems to handle excess humidity sources.
- Maintain roofs and plumbing systems to prevent sudden or chronic leaks.
- Choose nonbiodegradable building materials.
- Avoid properties that have a history of water leaks.
- Ensure that recent renovations have not allowed water intrusion or used wetted construction materials.
- Ensure that HVAC systems are maintained and run continuously to control temperature and humidity levels.

Cleanup should be performed within 48 hours using documented processing for containment dehumidification, and disposal of wet porous and nonporous materials.
should be removed from adjacent work areas (NYCDH). Other administrative controls include training remediation workers and providing ongoing communications to building occupants.

As part of a comprehensive hazard communication program, remediation workers should, at a minimum, be trained about the hazards of mold and bioaerosols, as well as about the details of the remediation plan. Such information and training should cover PPE, containment procedures, cleanup methods and actions to take if hidden mold is discovered (such as behind wallpaper). In addition, remediation workers should be trained and fit-tested in accordance with their company’s respiratory protection program. Depending on the project’s scope, more extensive training may be required. For example, NYCDH recommends that mold remediation workers be trained in hazardous waste operations if the contamination area exceeds 30 sq. ft. Status reports should be shared with building occupants before and throughout the project to minimize occupant concerns and ensure that complaints are addressed in a timely manner.

**Final Inspection**

The final inspection of the containment area should ensure that all dust and visible debris have been removed. Air sampling may also be conducted to verify that air concentrations of fungal spores are qualitatively and quantitatively similar to ambient outdoor air. Use of surface sampling is advisable to verify that only naturally occurring concentrations and types of fungi are present on porous surfaces (ACGIH). Bulk samples (e.g., settled dust) may also indicate the effectiveness of remediation efforts (ACGIH). NYCDH recommends that clearance air sampling be performed on projects which involve more than 100 contiguous sq. ft. of contamination. EPA recommends surface and/or air sampling after cleanup activities based on the professional judgment of a qualified person.

To ensure proper remediation, the final inspection should answer the following questions:

- **Are materials dry and visibly free from contamination?**
- **If clearance sampling has been conducted, are the types and concentrations of mold spores in the building similar to those found outside?**

**Conclusion**

Occurant concerns and fears are mitigated through prompt assessment and remediation of mold contamination. A thorough remediation plan minimizes exposures to both building occupants and remediation workers. This plan must designate a remediation manager; ensure that qualified and trained personnel perform the remediation; ensure that the source of moisture is corrected; specify cleanup methods that minimize bioaerosols; and detail PPE use as well as administrative controls and containment methods where appropriate. A proactive assessment of the building design, site selection and construction management, combined with ongoing building operation and maintenance can reduce the risk of developing a mold-related problem.

**References**


