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 (ACGIH). However, nearly all types of mold can cause allergenic effects in sensitized individuals and some types (although a relatively small number) may produce mycotoxins. Table 1 lists some common indoor molds and their associated health hazards.

Prompt investigation, assessment and remediation (if needed) must be performed when mold contamination is discovered or suspected. Proactive property management can reduce the potential for mold contamination within a building. Mold risk assessment efforts that address facility design, site selection, construction, operation and maintenance can play a large part in reducing the potential for mold.

The New York City Dept. of Health (NYCDH) has published "Guidelines on Assessment and Remediation of Fungi in Indoor Environments," citing ASHRAE 55-1992; these guidelines state:

> In all situations, the underlying cause of water accumulation must be rectified or fungal growth will recur. Any initial water infiltration should be stopped and cleaned immediately. An immediate response (within 24 to 48 hours) and thorough cleanup, drying and/or removal of water-damaged materials will prevent or limit mold growth. If the source of water is elevated humidity, relative humidity should be maintained at levels below 60 percent to inhibit mold growth. Emphasis should be on ensuring proper repairs of the building infrastructure so that water damage and moisture buildup do not recur (NYCDH Section 3: Remediation).

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

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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).

Table 1
Common Indoor Molds & Health Hazards

Mold & Fungi Species	Health Impact	Where Found
Alternaria	•Asthma •Eye infections	•Aging plants •Cellulose tiles and wallpaper
Aspergillus *fumigatus* *flavus* *niger*	•Severe allergic lung disease	•Decaying leaves •Damp lining of HVAC systems •Warm environments
Cladosporium	•Very common allergenic responses	•Where freestanding water is available •Tile grout, bathroom sealants •Ceiling with condensed water from piping
Penicillium	•Fungal infections	•Cold temperatures •Refrigerated food spoilage •Very common in air
Mucor	•Pathogenic rarely •Systemic infections	•Grow on sugar and starches
Cryptococcus neoformans	•Infections •Can progress to meningitis •Target AIDS patients	•Pigeon and chicken droppings •Guano fertilizer
Histoplasma capslulatum	•Infections •TB-like lung disease	•Soil containing bird and bat droppings
Stachybotrys chartarum	•Debatable/health effects •Fatigue, rashes, headache, nausea, coughing, diarrhea	•Damp cellulose materials •Greenish black appearance •Water-damaged areas

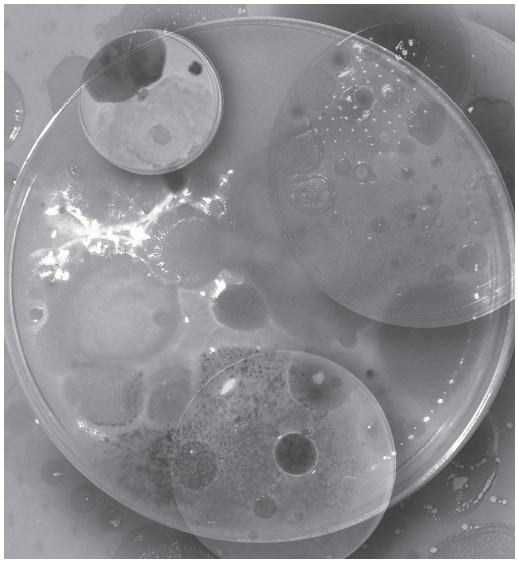


PHOTO CREATED BY JENEAN MILLS

Mold risk assessment efforts that address facility design, site selection, construction, operation and maintenance can play a large part in reducing the potential for mold.

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 2

Advantages & Disadvantages of Sampling Methodologies

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

Source: Wiles, C. "Strategies for Conducting Meaningful Microbial IAQ Investigations." American Indoor Air Quality Council seminar, Sept. 2001.

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.

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.

Table 3

Comparison of Remediation Guidelines

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

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).

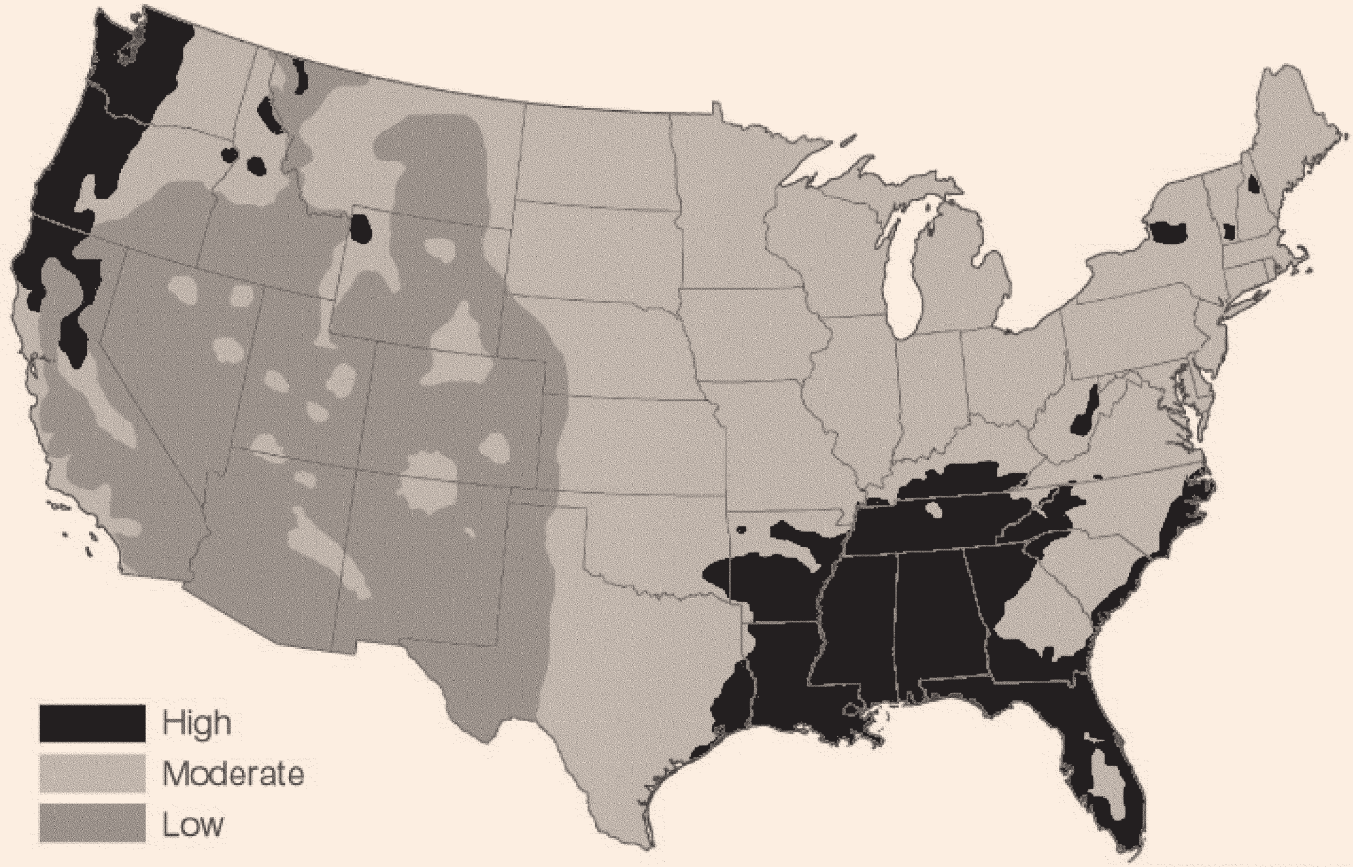
Since poor remediation practices can be costly to the building owner or insurer, the remediation contractor should be thoroughly screened to ensure that the firm has experience cleaning up mold. In addition, "reputable mold remediators should possess one of two certifications: certified microbial remediation 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-

Figure 1

Regional Weather Conditions: Mold Risk Based on Precipitation & Humidity



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diation 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 sporation 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.

NYCDH recommends local containment (i.e., cover the contamination area with plastic sheets sealed with tape) for projects with 10 to 100 sq. ft. of mold growth. The agency recommends that full-scale negative pressure containment (with airlocks and a decontamination room) be erected for projects with more than 100 sq. ft. of mold growth (NYCDH). EPA recommends negative-pressure containment if more than 10 sq. ft. of contamination is present. Table 3 offers a comparison of containment guidelines for mold remediation activities. In all cases, contaminated materials should be bagged and sealed immediately in the containment area.

Since drying the contamination area may cause increased levels of airborne mold spores, the moisture should not be removed until the material is removed and/or water misting (not soaking) is applied to the contaminated area. Other cleanup methods include wet vacuuming, damp wiping and HEPA vacuuming. Water-extraction vacuums can be used to remove water from floors, carpets and hard surfaces where water has accumulated. These devices should only be used when materials are still wet, however, as they may spread spores if sufficient liquid is not present. Vacuum tanks, hoses and attachments should be thoroughly cleaned and dried after use since mold spores may stick to the surfaces of the equipment (EPA).

In most cases, mold may be removed from nonporous surfaces by wiping or scrubbing with water, or water and detergent. These surfaces should be quickly and thoroughly dried to prevent further mold growth. Porous materials that are wet and have mold growing on them should be discarded (EPA). HEPA vacuums are recommended for final cleanup of remediation areas; this should occur after materials have been thoroughly dried and contaminated materials have been removed. Appropriate PPE should be worn when changing the filter. Use of biocides is not generally recommended since dead mold spores are still allergenic, and some dead mold spores are potentially toxic (EPA). In addition, "the effectiveness of bleach in reducing allergenic and toxigenic materials in remediation work has not been demonstrated" (AIHA). Furthermore, the use of some biocides may create additional indoor air quality issues due to vaporization of respiratory irritants such as chlorine, ammonia products and volatile organic compounds.

Administrative Controls

If feasible, remediation activities should be scheduled during off-hours when building occupants are less likely to be affected. In all cases, infants (age 12 months and younger), and people with suppressed immune systems or chronic inflammatory lung diseases, or who have undergone a recent surgery

Proactive Property Management: Minimizing the Risks of Mold

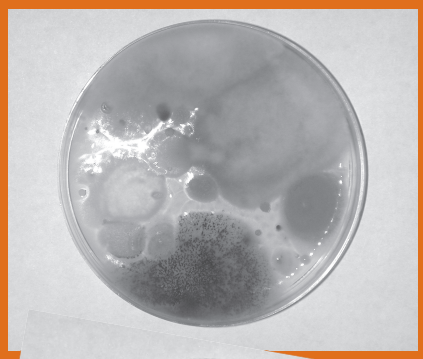
When buying, renting or constructing properties, many factors must be considered in order to reduce the risk of mold contamination.

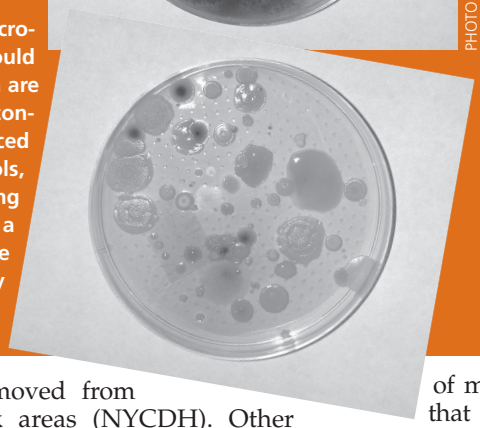
- Preventive maintenance of HVAC, plumbing and other building systems can reduce the potential for mold growth. Owners that disregard maintenance of basic HVAC components—such as filter and condensate drains—face increased risk. HVAC systems that cycle off during non-occupancy hours to save energy can 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 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.

PHOTO BY JOHN ROLLETTE





PHOTOS BY BRIAN MAHONEY

Before collecting samples during a microbial investigation, a sampling plan should be devised to ensure that useful data are collected. 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.

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:

- Has the moisture or water problem been fixed?
- Is mold visible, or are water-damaged materials or moldy odors present?
- 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

Occupant 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. ■

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