

Karen H. Perce, BSN, RN, MBA, Guest Editor

Addressing Environmental Health Implications of Mold Exposure After Major Flooding

by Tricia A. Metts, PhD, MS, BS

ABSTRACT

Extensive water damage resulting from major flooding is often associated with mold growth if materials are not quickly and thoroughly dried. Exposure to fungal contamination can lead to several infectious and noninfectious health effects impacting the respiratory system, skin, and eyes. Adverse health effects can be categorized as infections, allergic or hypersensitivity reactions, or toxic-irritant reactions. Workers and building occupants can minimize their exposure to mold by avoiding areas with excessive mold growth, using personal protective equipment, and implementing environmental controls. Occupational health professionals should encourage workers to seek health care if they experience any symptoms that may be linked to mold exposure.

Extensive water damage resulting from major floods, hurricanes, and other events (e.g., burst water pipes or sprinkler activation) is often associated with mold growth if materials are not quickly and thoroughly dried. Following the hurricanes in the New Orleans area in 2005, many buildings remained flooded for weeks, creating conditions favorable for mold growth and thereby posing a health risk to both residents and remediation workers. Mold exposure is associated with several adverse health effects, including asthma, allergic rhinitis, aspergillosis, sinusitis, and hypersensitivity pneumonitis (Bush, Portnoy, Saxon, Terr, & Wood, 2006).

The purpose of this article is to provide general guidance to occupational health professionals, who may be better able to protect workers exposed to mold at home or in the workplace following major flooding events.

BACKGROUND

Mold Levels and Mold Taxa in Flooded Buildings

Molds reproduce by spores, microscopic reproductive bodies dispersed by air currents and able to survive

adverse environmental conditions (e.g., temperature extremes or dryness). Mold growth may occur when spores land on a wet area. As reported in a government study (Centers for Disease Control and Prevention [CDC], 2006a), approximately 46% of homes in New Orleans and the surrounding parishes had some mold contamination; approximately 17% of homes had heavy mold contamination.

Indoor and outdoor spore counts such as those measured in the flooded areas of New Orleans can be especially high and are likely to be associated with significant adverse health effects (Solomon, Hjelmroos-Koski, Rotkin-Ellman, & Hammond, 2006). For example, spore counts in some unremediated New Orleans homes were higher than 700,000 spores/m³ (Chew et al., 2006; Schwab et al., 2007; Solomon et al.). In comparison, spore counts in homes without mold problems typically range from 68 to 2,307 spores/m³ (Gots, Layton, & Pirages, 2003). Outdoor spore counts in flooded areas may also be elevated. The mean outdoor airborne spore count (66,167 spores/m³) measured in New Orleans was approximately double that found in nonflooded areas (Solomon et al.).

In addition to elevated spore counts, the extremely wet conditions resulting from floods can cause a change

ABOUT THE AUTHOR

Dr. Metts is Assistant Professor, Department of Environmental Health, East Tennessee State University, Johnson City, TN.

Health Conditions That May Present After Major Floods and Hurricanes

Irritation (upper and lower respiratory)
 Allergic rhinitis
 Conjunctivitis
 Asthma
 Sinusitis
 Hypersensitivity pneumonitis
 Allergic bronchopulmonary aspergillosis
 Humidifier fever
 Organic dust toxic syndrome
 Pneumonia (*Fusarium*, *Aspergillus*, and *Scedosporium* species infection)
 Blastomycosis
 Posttraumatic skin infection (*Scedosporium apiospermum*)
 Ocular pain, redness, photophobia
 Brain abscess caused by *S. apiospermum*

Note. Data from the Centers for Disease Control and Prevention (2006b).

in the type of mold spores present. For example, the predominant mold genera in samples taken from moldy buildings in the New Orleans area were *Aspergillus* and *Penicillium* (CDC, 2006a; Chew et al., 2006; Rao et al., 2007; Schwab et al., 2007; Solomon et al., 2006). These spore genera were different from the normal mix of spores found in ambient air (nonflooded areas) and could conceivably have a greater impact on the health of individuals with allergies than spore counts alone (Rao et al.; Solomon et al.).

Potential Health Effects of Mold

Exposure to fungal contamination can lead to several infectious and noninfectious adverse health effects impacting the respiratory system, skin, and eyes. Exposure may occur via ingestion, inhalation, or contact with skin and mucous membranes. The 1999 flooding from Hurricane Floyd in North Carolina led to an increase in the number of individuals reporting asthma symptoms, perhaps caused by mold exposure (CDC, 2000). The CDC (2006b) has identified potential conditions that may present after major floods and hurricanes (Sidebar). Although many of these conditions are relatively rare, the CDC (2006b) recommends that clinicians have a “high index of suspicion” to recognize these conditions among their patients following major hurricanes and floods.

According to Bush et al. (2006), molds can cause illness through a variety of mechanisms, which can be classified into three groups: direct infections, generation of

a harmful immune response (allergic or hypersensitivity reactions), and toxic-irritant reactions.

Fungal Infections. Although common in healthy individuals, superficial mycoses (infections limited to the outermost layers of skin and hair) usually occur due to changes in skin barriers or resident microflora and do not generally result from environmental exposures (Bush et al., 2006). Only a small number of mold species are aggressive pathogens in healthy individuals and are generally associated with specific outdoor exposures. However, those with compromised immune systems are at greater risk for infection from a broader group of opportunistic fungi (Bush et al.). For this reason, it is advisable to restrict workers with compromised immune systems from mold-contaminated environments.

Allergic or Hypersensitivity Reactions to Mold. It is well-known that mold can cause allergic reactions in humans. Hypersensitivity reactions result from immunologic responses to mold antigens (Storey et al., 2004); responses may be immediate (allergic) or delayed (hypersensitivity). The most common types of mold-related illnesses are allergic rhinitis and asthma (Storey). The 1999 flooding from Hurricane Floyd in North Carolina caused an increase in the number of individuals reporting asthma symptoms, perhaps caused by mold exposure (CDC, 2000). Mold exposure is also associated with several forms of hypersensitivity pneumonitis, also known as extrinsic allergic alveolitis. Hypersensitivity pneumonitis occurs when an allergen is inhaled as an organic dust; normally, high-dose or chronic exposures are required to cause disease. Thus, many cases of hypersensitivity pneumonitis are associated with occupational exposures (Bush et al., 2006).

Toxic-Irritant Effects of Mold Exposure. Mold growth can result in the production of a variety of volatile organic compounds. These microbial volatile organic compounds are a diverse mixture of compounds (e.g., alcohols, aldehydes, and aromatics) and are responsible for the distinctive, musty odor associated with mold growth. Although often only a nuisance, at high concentrations microbial volatile organic compounds can irritate mucous membranes and cause a variety of symptoms, including, but not limited to, rashes, eye irritation, rhinitis, and cough (Storey et al., 2004).

Under supportive environmental conditions, some molds can produce mycotoxins (secondary metabolites) that may cause toxic effects in humans. Sometimes, molds capable of producing toxins are referred to as “toxic mold” or “black” mold. Use of these terms is discouraged because they can create a sense of panic among the general public. Although it is well established that mycotoxins can cause severe illness if ingested in large amounts (from eating contaminated foodstuffs), inhalation of mycotoxins at the levels normally found in homes or offices is not believed to cause toxic effects. However, anecdotal reports exist of illnesses and even deaths among occupants of buildings with excessive mold growth (Storey et al., 2004). Because mycotoxins are not volatile compounds, they must be inhaled with spores or other particulate matter (Bush et al., 2006). Workers engaged in remediation and demolition activities may be at risk for

organic dust toxic syndrome, an illness caused by inhaling either mycotoxins or bacterial endotoxins (Storey et al.).

RETURNING TO A HOME OR BUILDING AFTER A FLOOD

On return to homes or workplaces after a flood, it is important, although not always possible, to immediately (preferably within 48 hours) clean and dry building interiors to limit or prevent mold growth. Natural ventilation, fans, and dehumidifiers can be used to facilitate the drying process. According to the Environmental Protection Agency (EPA), four basic methods are available for remediating damage resulting from moisture and mold growth; the method (or group of methods) used depends on the type of material affected (EPA, 2001):

1. Wet vacuum (used to remove accumulated water from surfaces).
2. Damp wipe (water or water-detergent used to remove mold from nonporous surfaces).
3. High-efficiency particulate air vacuum (recommended for final cleanup of dust).
4. Discard (damaged items are removed and sealed in plastic bags).

Items that cannot be thoroughly cleaned and dried within 48 hours should be discarded, and items needed for insurance claims should be temporarily relocated. Items that generally should be discarded include carpet and carpet padding, drywall, upholstery, insulation, ceiling tiles, food, and other porous materials. Discarded items should be placed in plastic trash bags, which are sealed and placed in trash receptacles. Salvaged items made of glass, metal, plastic, or other hard, nonporous materials should be cleaned and allowed to air dry. Semiporous items such as wooden furniture can sometimes be salvaged, depending on the extent of damage.

Detergent and water is generally adequate for cleaning small mold-covered areas (< 10 ft²). However, disinfection with sodium hypochlorite bleach and water (1 cup of household bleach per 5 gallons of water) is recommended for cleaning mold from contaminated surfaces that may contain infectious microorganisms from flood waters (CDC, 2006b). Before the bleach solution is applied, items should be thoroughly washed with a detergent and potable water and thoroughly rinsed with potable water. Disinfected items should be allowed to air dry. Once items have been dried, relative humidity levels should be maintained below 60% to prevent regrowth of mold.

Spore concentrations may remain elevated for months in flood-damaged buildings, even after cleaning has occurred. Pearce et al. (1995) periodically measured spore levels in six flooded homes in Minnesota following the spring and summer flooding of 1993 in the Midwest. The researchers found that elevated mold spore levels persisted for several months after the homes were cleaned and dried. Although most homes returned to normal after approximately 1 year, pockets of contamination persisted. The researchers concluded that merely cleaning, disin-

fecting, and drying wet surfaces may not be sufficient to prevent persistent mold contamination; more extensive, and destructive, remediation may be necessary to decontaminate hidden surfaces.

USE OF BIOCIDES AND ANTIFUNGAL AGENTS

Biocides are chemical or physical agents that can kill or inactivate one or more types of microorganisms. Biocides sometimes used in mold remediation include sodium hypochlorite bleach, chlorine dioxide, ozone, and ultraviolet radiation. Antifungal agents, also known as biostats, such as borate formulations are chemicals applied or incorporated into a material to suppress fungal growth (Chew et al., 2006). Some antifungal agents are EPA-registered fungicides and some states require that only licensed pesticide applicators apply these chemicals in schools, commercial buildings, and homes (Chew et al.). The EPA (2001) does not recommend the routine use of biocides for mold remediation. The purpose of mold remediation is to remove mold contamination. Simply killing mold is not adequate; some nonviable molds are still allergenic and possibly toxic (Solomon et al., 2006). However, biocides may be useful if other pathogenic microorganisms are present, as is often the case in flooding situations. If biocides or antifungal agents are used, appropriate safety precautions should be taken because these products are toxic to humans and many animals and can have environmental effects.

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment is recommended for remediation workers, homeowners, and building occupants exposed to significant mold and mold spores. In addition, proper use of personal protective equipment will protect individuals from other hazards, including dust and particulates generated during remediation work and biocidal solutions used during the cleaning process. In addition to mold, other hazards may be present, such as jagged objects, electrical hazards, contaminated floodwater, and human or animal remains (National Institute for Occupational Safety and Health [NIOSH], 2005). The use of personal protective equipment may be required for workers. Workers and their employers should refer to the applicable Occupational Safety and Health Administration (OSHA) standards and NIOSH guidelines. The level of personal protective equipment depends on several factors, including the health of the individual, type of work, amount of mold-containing material and mold in material, and type of biocide used (CDC, 2006b). Because the relationship between the amount of mold contamination and adverse health outcomes has not been clearly established, occupational health professionals must often rely on professional judgment when determining the personal protective equipment needed. To assist individuals in making these decisions, the CDC considered OSHA, EPA, and New York City Department of Health guidelines and other factors to prepare a table of population-specific recommendations for protection from mold exposure follow-

ing hurricanes and major floods. What follows summarizes some of the CDC's general recommendations regarding personal protective equipment for individuals in good health.

Skin and Eye Protection

Gloves should be worn to protect individuals from both mold and irritating cleaning solutions. Ideally, gloves should extend to the middle of the forearm. The type of glove material depends on the type of cleaning solution used. For most biocides (e.g., chlorine bleach) and strong cleaning solutions, gloves of natural rubber, neoprene (DuPont, Wilmington, DE), nitrile, polyurethane, or polyvinyl chloride may be used. Rubber boots should also be worn when using chlorine bleach. Ordinary household rubber gloves may be used for mild detergents. If infectious materials are present, latex or non-latex examination gloves should be worn. Hands should be thoroughly washed with soap and water after gloves have been removed. Goggles or a full face shield should be worn to protect the eyes from dust and other small particles as well as cleaning solutions. Safety glasses or goggles with open vent holes do not provide adequate protection and should not be worn.

Protective clothing should be worn to shield street clothing and skin from mold and chemicals as well as to prevent cross-contamination between remediation areas and clean areas. Disposable clothing should be discarded into impermeable bags after use. Reusable clothing should be cleaned in accordance with the manufacturer's recommendations. Individuals wearing protective clothing, especially in hot climates, should be mindful of the increased risk of dehydration and take appropriate steps to remain hydrated.

Respiratory Protection

Remediation work should be conducted in a well-ventilated area. In addition, a water mist can be used to suppress dust. Respiratory protection should be used if engineering and administrative controls are not adequate to protect individuals from mold, spores, and other particulate matter generated during remediation work. Generally, respiratory protection should be used during any activity that disturbs dust or mold, such as breaking apart porous materials, recovering moldy possessions, removing debris, and cleaning. Standard surgical masks will provide protection from only large particles and should not be used for mold protection. Recommendations are different for workers and the public (nonworkers). Workers whose employers require them to use respiratory protection must wear NIOSH-certified respirators, be properly trained, be medically cleared, and be fit-tested in accordance with the OSHA respiratory protection standard (29 CFR 1910.134). The choice of respirator depends on the anticipated contamination level. The CDC recommends an N-95 disposable respirator for workers cleaning small and isolated areas. For large areas (> 10 ft²), extensively contaminated areas (> 100 contiguous ft²), areas with substantial dust generation, or areas with substantial mold growth, the CDC recommends work-

ers wear full face-piece respirators with N100, R100, or P100 particulate filters or powered air-purifying respirators with high-efficiency particulate air filters. Respirators, even when properly worn, do not provide absolute protection against mold spores or submicron fungal fragments (Chew et al., 2006).

Although remediation workers are often knowledgeable about the need to don respiratory protection, many do not consistently or correctly use respirators. The CDC (2006a) found that many workers did not consistently wear appropriate respiratory protection during remediation efforts following the New Orleans hurricanes in 2005. Of 69 workers surveyed who had engaged in mold cleanup activities, 24 (35%) did not always use appropriate respirators, citing discomfort as the major reason. In addition, almost half of the workers reported they had not been fit-tested for respirator use.

Although nonworkers (i.e., the public) should ideally avoid exposure to dust, if necessary, they can wear a NIOSH-approved N-95 particulate respirator, available at most hardware or home improvement stores. To be effective, respirators should fit correctly and be worn properly. However, only 24% of randomly selected members of the public were able to demonstrate the proper use of an N-95 filtering face-piece respirator in post-hurricane New Orleans (Cummings, Cox-Ganser, Riggs, Edwards, & Kreiss, 2007). Healthy nonworkers not involved in remediation or other mold-disturbing activities generally will not need to use respirators.

Both workers and the public should be aware that these respirators protect against particulates only. They do not protect against gases.

INDIVIDUALS AT HIGH HEALTH RISK FROM MOLD EXPOSURE

The above personal protection recommendations were designed for healthy individuals. However, some individuals have special health concerns or are unable to wear respirators. These individuals must exercise caution when entering moldy environments, especially when mold-disturbing activities are occurring. The CDC (2006b) recommends that individuals with extreme immunosuppression (e.g., transplant recipients, individuals with neutropenia, or those with CD4+ lymphopenia) avoid mold-contaminated environments completely. Individuals with immunosuppressive diseases but no profound impairment in immune function; individuals receiving immunosuppressive drug therapies such as chemotherapy and corticosteroid therapy but with no neutropenia or CD4+ lymphopenia; pregnant women; children younger than 12 years; elderly individuals older than 65 years; and individuals with chronic, obstructive, or allergenic lung diseases should avoid exposure to areas where mold is disturbed but may tolerate small amounts of mold exposure. They should consult their health care providers.

SAMPLING

Because mold is ubiquitous in the indoor environment, indoor air quality experts generally do not recom-

mend microbial sampling as a screening tool before remediation (EPA, 2001). Exposure to mold-contaminated materials should be assumed to present a potential health risk, regardless of the type of mold. Instead, buildings should be inspected for the presence of mold, water damage, or musty odors. If found, the water source should be immediately stopped, water-damaged materials, if salvageable, thoroughly dried, and mold-damaged materials properly remediated.

Sometimes, bulk or surface sampling may be useful (EPA, 2001). For example, it may be necessary to identify specific fungi as part of a health evaluation if individuals are exhibiting symptoms of mold exposure. It may also be helpful to conduct sampling if results of a visual inspection are inconclusive or the source of a musty odor cannot be found (e.g., mold growth behind walls). Finally, it is prudent to conduct sampling if litigation is expected. Samples should be collected by trained environmental health professionals and analyzed by an accredited laboratory specializing in mycology.

EVACUATION OF WORK AREAS

When mold remediation is being performed, the work area should be occupied by only those workers involved in remediation activities. The EPA (2001) has provided guidelines for containment of work areas based on total contaminated surface area. The purpose of containment is to protect both remediation workers and building occupants from the release of mold spores into the air. Briefly, areas of less than 10 ft² generally do not require containment, areas of 10 to 100 ft² require limited containment, and areas of greater than 100 ft² require full containment.

WHO SHOULD PERFORM MOLD REMEDIATION?

For small to mid-sized isolated areas (<10 ft² of mold growth), remediation can be conducted by the building maintenance staff or homeowner (EPA, 2002). An industrial hygienist or other qualified environmental health and safety professional should train staff in accordance with the OSHA Hazard Communication Standard (29 CFR 1910.1200), including proper remediation methods, proper use of personal protective equipment, and health hazards. Large, extensive contamination areas require contractors who are specially trained in remediating mold (EPA) and follow the guidelines of the American Conference of Governmental Industrial Hygienists as well as state licensing requirements for contractors.

CONCLUSION

Unless materials are thoroughly dried within 48 hours, major flooding is likely to result in mold contamination. Individuals, especially those with underlying health conditions, should minimize their exposure to molds as much as possible because such exposure may cause numerous infectious and noninfectious health conditions. Occupational health professionals should encour-

IN SUMMARY

Addressing Environmental Health Implications of Mold Exposure After Major Flooding

Metts, T. A.

AAOHN Journal 2008; 56(3), 115-120.

- 1 Mold growth is likely to occur following a major flooding event, especially if materials are not quickly and thoroughly dried. Mold exposure may occur via ingestion, inhalation, or contact with skin and mucous membranes and can potentially lead to adverse health effects, including infections, allergic or hypersensitivity reactions, or toxic-irritant reactions.
- 2 Personal protective equipment is recommended for remediation workers and building occupants exposed to large amounts of mold and mold spores as well as hazards such as dust and particulates generated during remediation work and biocidal solutions used during cleaning. Recommended personal protective equipment includes gloves, eye protection, protective clothing, and respiratory protection.
- 3 Occupational health professionals should encourage workers to seek health care if they experience any symptoms that may be linked to mold exposure.

age workers to don appropriate personal protective equipment when involved in mold cleanup in their homes or at their workplaces. Workers should be encouraged to seek health care if they are experiencing any symptoms that may be linked to mold exposure.

The author thanks Mary Ann Latko, CIH, CSP, QEP, Director, Scientific and Technical Initiative, American Industrial Hygiene Association, for contributing to this article.

REFERENCES

- Bush, R. K., Portnoy, J. M., Saxon, A., Terr, A. I., & Wood, R. A. (2006). The medical effects of mold exposure. *Journal of Allergy and Clinical Immunology*, 117(2), 326-333.
- Centers for Disease Control and Prevention. (2000). Morbidity and mortality associated with Hurricane Floyd: North Carolina, September-October 1999. *MMWR*, 49(17), 369-372.
- Centers for Disease Control and Prevention. (2006a). Health concerns associated with mold in water-damaged homes after Hurricanes Katrina and Rita: New Orleans area, Louisiana, October 2005. *MMWR*, 55(2), 41-44.
- Centers for Disease Control and Prevention. (2006b). Mold prevention strategies and possible health effects in the aftermath of hurricanes and major floods. *MMWR*, 55(RR-8), 1-27.

- Chew, G., Wilson, J., Rabito, F., Grimsley, F., Iqbal, S., Reponen, T., et al. (2006). Mold and endotoxin levels in the aftermath of Hurricane Katrina: A pilot project of homes in New Orleans undergoing renovation. *Environmental Health Perspectives*, 114(12), 1883-1889.
- Cummings, K. J., Cox-Ganser, J., Riggs, M. A., Edwards, N., & Kreiss, K. (2007). Respirator donning in post-hurricane New Orleans. *Emerging Infectious Diseases*, 13(5), 700-707.
- Environmental Protection Agency. (2001). *Mold remediation in schools and commercial buildings* (Publication No. EPA 402-K-01-001). Retrieved November 29, 2007, from www.epa.gov/mold/mold_remediation.html
- Environmental Protection Agency. (2002). *A brief guide to mold, moisture, and your home* (Publication No. EPA-402-K-02-003). Retrieved November 29, 2007, from www.epa.gov/mold/moldguide.html
- Gots, D. E., Layton, N. J., & Pirages, S. W. (2003). Indoor health: Background levels of fungi. *AIHA Journal*, 64(4), 427-438.
- National Institute for Occupational Safety and Health. (2005). *NIOSH hazard based interim guidelines: Protective equipment for workers in hurricane flood response*. Retrieved November 29, 2007, from www.cdc.gov/niosh/topics/flood/pe-workers.html
- Pearce, M., Huelman, P. H., Janni, K. A., Olsen, W., Seavey, R. T., & Velsey, D. (1995). Long-term monitoring of mold contamination in flooded homes. *Journal of Environmental Health*, 58(3), 6-11.
- Rao, C. Y., Riggs, M. A., Chew, G. L., Muilenberg, M. L., Thorne, P. S., Sickel, D. V., et al. (2007). Characterization of airborne molds, endotoxins and glucans in homes in New Orleans after Hurricanes Katrina and Rita. *Applied and Environmental Microbiology*, 73(5), 1630-1634.
- Schwab, K. J., Gibson, K. E., Williams, D. L., Kulbicki, K. M., Lo, C. P., Mihalic, J. N., et al. (2007). Microbial and chemical assessment of regions within New Orleans, LA impacted by Hurricane Katrina. *Environmental Science & Technology*, 41(7), 2401-2406.
- Solomon, G. M., Hjelmroos-Koski, M., Rotkin-Ellman, M., & Hammond, S. K. (2006). Airborne mold and endotoxin concentrations in New Orleans, Louisiana, after flooding, October through November 2005. *Environmental Health Perspectives*, 114(9), 1381-1386.
- Storey, E., Dangman, K. H., Schenck, P., DeBernardo, R. L., Yang, C. S., Bracker, A., et al. (2004). *Guidance for clinicians on the recognition and management of health effects related to mold exposure and moisture indoors*. Retrieved November 29, 2007, from www.oehc.uchc.edu/clinser/MOLD%20GUIDE.pdf

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.