

Mold Prevention Strategies and Possible Health Effects in the Aftermath of Hurricanes and Major Floods*

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Introduction

On August 29 and September 24, 2005, Hurricanes Katrina and Rita, respectively, made landfall along the Gulf Coast. After both storms, levees were breached, leading to massive flooding in New Orleans and surrounding parishes.

The duration of flooding, the extent of flooding, and the number of structures flooded in New Orleans as a result of these hurricanes made massive mold contamination a certainty. Many structures remained flooded for weeks after the hurricane and became saturated with water. An assessment of homes in New Orleans (Orleans Parish) and the surrounding parishes of St. Bernard, East Jefferson, and West Jefferson (excluding the 9th Ward) identified an estimated 46 percent (>100,000 homes) with some mold contamination; approximately 17 percent (40,000 homes) had heavy mold contamination.¹

Recent parallels to the kind of flooding observed in New Orleans as a result of Hurricanes Katrina and Rita occurred in 1997 in Grand Forks, North Dakota, and in 1999 in North Carolina after Hurricane Floyd.² The

number of structures affected was much smaller in North Dakota than in New Orleans, and the population affected in North Carolina was much more dispersed than that affected in New Orleans. In North Carolina a reported increase in persons presenting with asthma symptoms was postulated to be caused by exposure to mold.² In 2001 flooding and subsequent mold growth on the Turtle Mountain reservation in Belcourt, North Dakota, was associated with self-reports of rhinitis, rash, headaches, and asthma exacerbation.³

Methods

This document was initially prepared by the Centers for Disease Control and Prevention (CDC) as a guide for public health officials and the general public in response to the massive flooding and the anticipated mold contamination of homes and other structures along the U.S. Gulf Coast associated with Hurricanes Katrina and Rita.⁴ A workgroup was convened of CDC staff with expertise in relevant subject areas. This included medical epidemiologists, environmental epidemiologists and occupational epidemiologists, industrial hygienists, infectious disease physicians, and mycologists. The framework for the document was decided by consensus discussions, and workgroup members were assigned to research and write different sections. The members produced individual written summaries, which formed the basis of the report. Wherever possible, recommendations were based on existing recommendations or guidelines. Where adequate guidelines did not exist, the guidelines were based on CDC experience and expertise.

The revised version appearing in this chapter is intended to more broadly address public health concerns related to limiting exposure to mold and identifying, preventing, and managing mold-related health effects following any natural disaster or other occurrences that result in flooding or major water intrusion. Published guidelines, established standards, and the peer-reviewed literature were reviewed to ensure the accuracy and consistency of the recommendations. In addition, the document was sent for stakeholder review and external peer review by experts in the areas of worker protection; general public health; medical, environmental, and occupational epidemiology; allergy; industrial hygiene; mycology; and pulmonology.

Mold: A Definition

Molds, mushrooms, mildews, and yeasts are all classified as fungi, a kingdom of organisms distinct from plants and animals. Fungi differ from plants and animals in several respects. Unlike animals, fungi have cell walls. However, unlike plants, which also have cell walls, fungal cell walls are made up mostly of chitin and glucan. Fungi cannot produce their own nutrients as plants do through photosynthesis. Fungi secrete enzymes that digest the material in which the fungi are embedded and absorb the released nutrients. Multicellular fungi do not differentiate into different organs or functional components the way plants and animals do.⁵

Approximately 100,000 species of fungi exist; fewer than 500 fungal species have been described as human pathogens that can cause infections.⁵ Visible growth of multicellular fungi consisting of branching filamentous structures (mycelia) are known popularly as molds⁵ and are referred to by that term in this chapter.

Molds are ubiquitous in nature and grow almost anywhere indoors or outdoors. The overall diversity of fungi is considerable. For example, the genus *Aspergillus* has at least 185 known species.⁶ Molds spread and reproduce by making spores, which are small and lightweight, able to travel through air; capable of resisting dry, adverse environmental conditions; and capable of surviving a long time. The filamentous parts of mold (hyphae) form a network called mycelium, which is observed when a mold is growing on a nutrient source. Although these mycelia are usually firmly attached to whatever the mold is growing on, they can break off, and people can be exposed to fungal fragments. Some microorganisms, including molds, also produce characteristic volatile organic compounds (VOCs) or microbial VOCs (mVOCs). Molds also contain substances known as beta glucans; mVOCs and beta glucans might be useful as markers of exposure to molds.⁷

Some molds are capable of producing toxins (sometimes called mycotoxins) under specific environmental conditions, such as competition from other organisms or changes in the moisture or available nutrient supply. Molds capable of producing toxins are popularly known as toxigenic molds; however, use of this term is discouraged because even molds known to produce toxins can grow without producing them.⁶ Many fungi are capable of toxin production, and different fungi can produce the same toxin.⁶

Factors That Produce Mold Growth

Although molds can be found almost anywhere, they need moisture and nutrients to grow. The exact specifications for optimal mold growth vary by the species of mold. However, mold grows best in damp, warm environments. The availability of nutrients in indoor environments rarely limits mold growth, because wood, wallboard, wallpaper, upholstery, and dust can be nutrient sources. Similarly, the temperature of indoor environments, above freezing and below the temperature for denaturing proteins, can support mold growth, even if the actual temperature is not optimal.⁸

The primary factor that limits the growth of mold indoors is lack of moisture. Substantial indoor mold growth is virtually synonymous with the presence of moisture inside the building envelope. This intrusion of moisture might be from rainwater leaking through faulty gutters or a roof in disrepair, from a foundation leak, from condensation at an interface (e.g., windows or pipes), or between a cold and a warm environment. Water also can come from leaks in the plumbing or sewage system inside the structure. Studies of mold growth on building materials, such as plywood, have found that mold grows on materials that remain wet for forty-eight to seventy-two hours.⁸ Flooding, particularly when floodwaters remain for days or weeks, provides an almost optimal opportunity for mold growth.

How People Are Exposed to Mold

Mold exposure can produce disease in several ways. Inhalation is usually presumed to be the most important mechanism of exposure to viable (live) or nonviable (dead) fungi, fungal fragments or components, and other dampness-related microbial agents in indoor environments. The majority of fungal spores have aerodynamic diameters of 2–10 μm , which are in the size range that allows particles to be deposited in the upper and lower respiratory tract.⁵ Inhalation exposure to a fungal spore requires that the spore be initially aerosolized at the site of growth. Aerosolization can happen in many ways, ranging from disturbance of contaminated materials by human activity to dispersal of fungi from contaminated surfaces in heating,

ventilating, and air-conditioning (HVAC) systems. Fungal spores also can be transported indoors from outdoors. Overall, the process of fungal-spore aerosolization and related issues (e.g., transport, deposition, resuspension, and tracking of fungi to other areas) are poorly understood.

People can be exposed to mold through skin contact, inhalation, or ingestion. Because of the ubiquity of mold in the environment, some level of exposure is inevitable. People may be exposed to mold through contact with airborne spores or with mycelial fragments. Exposure to high airborne concentrations of mold spores could occur when they come into contact with a large mass of mold, such as might occur in a building that has been flooded for a long time. Exposure to mycelial fragments could occur when someone encounters a nutrient source for mold that has become disrupted, such as during removal of mold-contaminated building material. Skin contact or exposure by inhalation to either spores or mycelial fragments also could occur in a dusty environment, if the components of dust include these fungal elements.

For the majority of adverse health outcomes related to mold exposure, a higher level of exposure to living molds or a higher concentration of allergens on spores and mycelia results in a greater likelihood of illness. However, no standardized method exists to measure the magnitude of exposure to molds. In addition, data are limited about the relation between the level of exposure to mold and how that causes adverse health effects and how this relation is affected by the interaction between molds and other microorganisms and chemicals in the environment. For this reason, it is not possible to sample an environment, measure the mold level in that sample, and make a determination about whether the level is low enough to be safe or high enough to be associated with adverse health effects.

People affected by major hurricanes or floods probably will be exposed to a wide variety of hazardous substances distributed by or contained within the floodwater. This chapter does not provide a comprehensive discussion of all such potential hazards; such situations will of necessity require case by case evaluation and assessment. Guidance has been provided by the CDC for such issues in a number of documents, including *NIOSH Hazard Based Interim Guidelines: Protective Equipment for Workers in Hurricane Flood Response*⁹ and *Protect Yourself from Chemicals Released during a Natural Disaster*.¹⁰

Factors That Cause Disease from Mold

Numerous species of mold cause infection through respiratory exposure. In general, persons who are immunosuppressed are at increased risk for infection from mold.¹¹ Immunosuppression can result from immunosuppressive medication, from medical conditions and diseases that cause it, or from therapy for cancer that causes transient immunosuppression. Although certain species of mold cause infection,^{5, 8, 11} many mold species do not. Infections from mold might be localized to a specific organ or disseminated throughout the body.

Many of the major noninfectious health effects of mold exposure have an immunologic (i.e., allergic) basis.⁶ Exposure to mold can sensitize persons, who then might experience symptoms when re-exposed to the same mold species. For sensitized people, hay fever symptoms and asthma exacerbations are prominent manifestations of mold allergy.⁶ Although different mold species might have different propensities to cause allergy, available data do not permit a relative ranking of species by risk for creating or exacerbating allergies. In addition, exposure to beta glucans might have an inflammatory effect on the respiratory system.¹²

Prolonged exposure to high levels of mold (and some bacterial species) can produce an immune-mediated disease known as hypersensitivity pneumonitis.¹³ Clinically, hypersensitivity pneumonitis is known by the variety of exposures that can cause this disorder (e.g., farmer's lung, woodworker's lung, and malt worker's lung).

Ingesting toxins that molds produce can cause disease. Long-term ingestion of aflatoxins (produced by *Aspergillus* species) has been associated with hepatocellular cancer.¹⁴ In addition, ingestion of high doses of aflatoxin in contaminated food causes aflatoxicosis and can result in hepatic failure.¹¹ Whether concentrations of airborne mold toxins are high enough to cause human disease through inhalation is unknown, and no health effects from airborne exposure to mold-related toxins have been proven.

General Guidelines

Assessing Exposure to Mold

Exposure assessment. Any structure flooded after hurricanes or major floods should be presumed to contain materials contaminated with mold

if those materials were not thoroughly dried within forty-eight hours.^{15, 16} In such cases, immediate steps to reduce the risk for exposure to mold are likely to be of greater importance than the further exposure assessment steps presented below.

Assessing the level of human exposure to mold in flooded buildings where mold contamination is not obvious is often a central and ongoing activity in recovery related to hurricanes and floods. Understanding the strengths and limitations of the approaches that are available to assess such exposures is important. Buildings that were not flooded could also have mold. For example, buildings with leaking roofs or pipes, which allow water to penetrate into biodegradable building materials, or excessive humidity, particularly those built with biodegradable materials, are susceptible to mold growth.²

Visual inspection and moisture assessment. A visual inspection is the most important step in identifying possible mold contamination.^{17, 18} The extent of any water damage and mold growth should be visually assessed. This is particularly important in determining remedial strategies and the need for personal protective equipment (PPE) for people in the contaminated area. Ceiling tiles, gypsum wallboard (sheetrockTM), cardboard, paper, and other cellulosic surfaces should be given careful attention during a visual inspection. Not all mold contamination is visible;^{9, 16} with a flood, contamination in the interior wall cavities or ceiling is common. A common means of assessing the mold contamination of a building is to estimate the total square feet of contaminated building materials.^{9, 18, 19} However, professional judgment will necessarily play an important role in the visual inspection, because less quantifiable factors (e.g., location of the mold, building use, and function) and exposure pathways are also important in assessing potential human exposure and health risks.

Ventilation systems also should be visually checked, particularly for damp filters, damp conditions elsewhere in the system, and overall cleanliness. To avoid spreading microorganisms throughout the building, HVAC systems known or suspected to be contaminated with mold should not be run. Guidelines from the U.S. Environmental Protection Agency (EPA) and CDC^{20, 21} provide useful information on this topic. Various algorithms for assessing and remediating mold-contaminated buildings are available. Examples of such algorithms are available from the U.S. Army,²² the New

York City Department of Health,¹⁸ and the Occupational Safety and Health Administration (OSHA).²³

Moisture meters provide qualitative moisture levels in building materials and might be helpful for measuring the moisture content in a variety of building materials (e.g., carpet, wallboard, wood, brick, and concrete) following water damage.^{9, 17} Meters also can be used to monitor progress in drying wet materials. Damaged materials should be removed and discarded. Moisture meters are available from contractor tool and supply outlets. Humidity meters can be used to monitor indoor humidity. Inexpensive (< \$50) models that monitor both temperature and humidity are available.

A borescope is a handheld tool that allows users to see hidden mold problems inside walls, ceiling plenums, crawl spaces, and other tight areas.^{6, 18} No major drilling or cutting of dry wall is required.

Sampling for mold. Sampling for mold is not part of a routine building assessment.^{9, 16, 18, 19} In most cases, appropriate decisions about remediation and the need for PPE can be made solely on the basis of visual inspection. If visible mold is present, then it should be remediated regardless of what types of microorganisms are present, what species of mold is present, and whether samples are taken. Other than in a controlled, limited research setting, sampling for biological agents in the environment cannot be meaningfully interpreted and would not substantially affect relevant decisions about remediation, reoccupancy, handling or disposal of waste and debris, worker protection or safety, or public health. If sampling is being considered, a clear purpose should exist, such as the following:

- To help evaluate a source of mold contamination. For example, testing the types of mold and mold concentrations indoors versus outdoors can be used to identify an indoor source of mold contamination that might not be obvious on visual inspection.
- To help guide mold remediation. For example, if mold is being removed and it is unclear how far the colonization extends, then surface or bulk sampling in combination with moisture readings might be useful.

Types of samples used to assess the presence of mold and the potential for human exposure to mold in a water-damaged building include air samples, surface samples, bulk samples, and water samples from condensate drain pans or cooling towers. Detailed descriptions of sampling and analysis techniques have been published.^{6, 17}

Among the types of samples, airborne sampling might be a good indicator of exposure from a theoretical point of view, particularly for assessing acute short-term exposures. However, in practice many problems (e.g., detection problems and high variability over time) limit the usefulness of these types of samples for most biological agents. If air sampling is conducted, personal measurements best represent the current exposure, although practical constraints might make personal sampling difficult. Therefore, area sampling is the most commonly performed type of air sampling used to assess bioaerosol exposure despite resultant uncertainty about how accurately the measurements reflect actual personal exposure.

One type of surface sampling is the sampling of settled dust. A theoretical advantage of settled-dust sampling is the presumed correlation of concentrations of fungi in the settled dust with chronic exposure to those fungi.¹⁷ However, surface sampling is a crude measure and will yield a poor surrogate for airborne concentrations.^{6, 17} Results of surface sampling as a measure of exposure should be interpreted with caution. Bulk samples can provide information about possible sources of biological agents in buildings and the general composition and relative concentrations of those agents.

Assessment of microorganisms. Two distinct approaches are used for evaluating the presence of specific microbes: culture-based and nonculture-based. The strengths and limitations of these approaches have been published.⁶

Instead of measuring culturable or nonculturable fungi or fungal components, constituents or metabolites of microorganisms can be measured as a surrogate of microbial exposure. Examples of such techniques include polymerase chain reaction (PCR) technologies and immunoassays.^{6, 17} Methods for measuring microbial constituents (with some exceptions) are in an experimental phase and have not yet been routinely applied in clinical assessments, risk assessments, or epidemiological studies.

No health-based standards (e.g., OSHA or EPA standards) or exposure limits (e.g., National Institute for Occupational Safety and Health [NIOSH]-recommended exposure limits) for indoor biological agents (airborne concentrations of mold or mold spores) exist. Differences in season; climatic and meteorological conditions; type, construction, age, and use of the building and ventilation systems; and differences in measurement protocols used in various studies (e.g., viable versus nonviable

microorganism sampling, sampler type, and analysis) make it difficult to interpret sampling data relative to information from the medical literature.^{6, 17} If sampling is performed, exposure data can be evaluated (either quantitatively or qualitatively) by comparing them with background data, indoor environments with outdoor environments, or problem areas with nonproblem areas. A quantitative evaluation involves comparing exposures, whereas a qualitative evaluation could involve comparing species or genera of microorganisms in different environments. Specifically, in buildings without mold problems the qualitative diversity of airborne fungi indoors and outdoors should be similar. Conversely, the dominating presence of one or two kinds of fungi indoors and the absence of the same kind outdoors might indicate a moisture problem and degraded air quality. In addition, the consistent presence of fungi such as *Stachybotrys chartarum*, *Aspergillus versicolor*, or various *Penicillium* species over and beyond background concentrations might indicate a moisture problem that should be addressed.¹⁷ Indoor and outdoor mold types should be similar, and indoor levels should be no greater than levels outdoors or in noncompliant areas.¹⁷ Analytical results from bulk material or dust samples also might be compared with results of similar samples collected from reasonable comparison areas.

Other Issues

Biomarkers. For biological agents, few biomarkers of exposure or dose have been identified, and their validity for exposure assessment in the indoor environment is often unknown. Testing to determine the presence of immunoglobulin E (IgE) to specific fungi might be a useful component of a complete clinical evaluation in the diagnosis of illnesses (e.g., rhinitis and asthma) that can be caused by immediate hypersensitivity.^{17, 24} Testing is usually done by in vitro tests for serum specific IgE or by skin prick or puncture tests. Detection of immunoglobulin G (IgG) to specific fungi has been used as a marker of exposure to agents that might cause illnesses such as hypersensitivity pneumonitis.^{17, 24} However, the ubiquitous nature of many fungi and the lack of specificity of fungal antigens limit the usefulness of these types of tests in evaluating possible building-related illness and fungal exposure.^{17, 24} Specific serologic tests (e.g., for cryptococcal antigen, coccidioidal antibody, and *Histoplasma* antigen) are useful in the

diagnosis of some fungal infections, but these are the exception. The routine clinical use of immunoassays as a primary means of assessing environmental fungal exposure or health effects related to fungal exposure is not recommended. Healthcare providers whose patients express concern about the relation between symptoms and possible exposure to fungi are advised to use immunoassay results with care and only in combination with other clinical information, including history, physical findings, and other laboratory results.²⁴

Mycotoxins. In recent years increased concern has arisen about exposure to specific molds that produce substances called mycotoxins. Health effects related to mycotoxins are generally caused by ingestion of large quantities of fungal-contaminated material.¹⁷ No conclusive evidence exists of a link between indoor exposure to airborne mycotoxins and human illness.^{6, 25} Many molds can potentially produce toxins, given the right conditions.^{6, 11, 17} Some molds that produce mycotoxins are commonly found in moisture-damaged buildings; research related to the importance of these findings is ongoing. Although the potential for health problems is an important reason to prevent or minimize indoor mold growth and to remediate any indoor mold contamination, evidence is inadequate to support recommendations for greater urgency of remediation in cases where mycotoxin-producing fungi have been isolated.

Summary

The interpretation of environmental sampling data generally requires professional judgment, and medical conclusions cannot be made based solely on the results of analysis of environmental sampling. In the context of mold growth following a major hurricane or flood, mold growth itself and the extent of growth based on a thorough visual inspection is sufficient to categorize a building as moldy or not moldy. This should provide sufficient information for action, and no additional characterization is needed.

Cleanup and Prevention

The most effective way to eliminate mold growth is to remove it from materials that can be cleaned and to discard materials that cannot be cleaned or are physically damaged beyond use.^{9, 18, 19, 26–30} People with

respiratory conditions, allergies, asthma, or weakened immune systems should avoid mold cleanup if possible or seek the advice of their doctor and determine what type of personal protective equipment is appropriate. Appropriate PPE (e.g., tight-fitting NIOSH-approved N-95 respirator, gloves to limit contact of mold and cleaning solutions with skin, and goggles)^{13, 26–30} should be used when performing cleanup or other activities in mold-contaminated homes or buildings after a flood.

Cleanup. Removing mold problems requires a series of actions.^{6, 9, 16} The order of these actions is sometimes important,⁶ but might vary on a case-by-case basis. Typically the following actions are taken regardless of whether a problem is small and simple or large and complex:

- Take emergency action to stop water intrusion, if needed.
- Determine the extent of water damage and mold contamination.
- Plan and implement remediation activities.
 - ◊ If needed, establish containment and protection for workers and occupants.
 - ◊ Eliminate or limit water or moisture sources.
 - ◊ Decontaminate or remove damaged materials, as appropriate.
 - ◊ Dry any wet materials, if possible.
 - ◊ Evaluate whether space has been successfully remediated.
 - ◊ Reassemble the space to prevent or limit the possibility of recurrence by controlling sources of moisture.

For small, simple problems, the entire list of tasks can be done by one person. Large, complex problems might require many people from different professions and trades. For circumstances that fall between those extremes, some combination of occupant action and professional intervention will be appropriate. In general, no single discipline brings together all the required knowledge for successful assessment and remediation.

Returning to mold-contaminated homes or buildings after a flood. When people return to homes or buildings after a flood, they should take the following steps:^{6, 9, 16, 26–30}

- Clean up and dry out the building quickly. Open doors and windows and use fans or dehumidifiers to dry out the building.

- Remove all porous items that have been wet for more than forty-eight hours and that cannot be thoroughly cleaned and dried. These items can remain a source of mold growth and should be removed from the home or building. Porous, noncleanable items include carpeting and carpet padding, upholstery, wallpaper, drywall, ceiling tiles, insulation material, some clothing, leather, paper, some wood and wood products, and food. Removal and cleaning are important because even dead mold can cause allergic reactions.
- Clean wet items and surfaces with detergent and water to prevent mold growth.
- Temporarily store damaged or discarded items outside the home or building until insurance claims can be processed.

Removing and cleaning up mold in a building. To clean mold covering less than ten square feet in an area flooded by clean water, detergent and water might be adequate.^{9, 16} However, after hurricanes and major floods, floodwater is likely to be contaminated, and in this setting, mold can be removed with a bleach solution of one cup chlorine bleach per one gallon of water.^{26–30} Never mix bleach or bleach-containing products with ammonia or ammonia-containing products. If water damage is substantial or mold growth covers more than ten square feet, consult the EPA guide, *Mold Remediation in Schools and Commercial Buildings*.¹⁵

Some companies specialize in water damage restoration and can assess the issues involved in cleaning up homes after a flood. Two professional trade groups that might be able to help locate such an expert are the Association of Specialists in Cleaning and Restoration (<http://www.ascr.org>) and the Institute of Inspection, Cleaning, and Restoration Certification (<http://www.iicrc.org>).

Contractors used for remediation should have experience in cleaning mold. Check references and ask the contractor to follow the recommendations in the guidelines of the American Conference of Governmental Industrial Hygienists (ACGIH) or other guidelines from professional organizations or state agencies. Contact your state health department's Web site for information about state licensing requirements for contractors in your state. Examples of Web sites from states that have recently dealt with natural disasters include <http://www.tdh.state.tx.us/beh/mold> (Texas) and <http://www.lslbc.louisiana.gov> (Louisiana).

Cleaning clothes, textiles, or stuffed animals. Ensure that laundry is washed in safe water. Use only water that is properly disinfected or that the authorities have stated is safe. Take the appropriate steps to make sure that use of gas or electric appliances is safe.

Before using a washing machine that was in a flooded building, run the machine through one full cycle before washing clothes. Use hot water and a disinfectant or sanitizer. Take clothes and linens outdoors and shake off any dried mud or dirt before washing them. Hose off muddy items to remove all dirt before putting them in the washer.

If the items are only wet, they may be laundered normally. Check the labels on clothes and linens and wash them in detergent and warm water if possible, or take them to a professional cleaner. Adding chlorine bleach to the wash cycle will remove most mildew and will sanitize the clothing. However, bleach might fade some fabrics and damage others. If the label reads “dry clean only,” shake out loose dirt and take the item to a professional cleaner.

Consult a remediation professional for advice on whether heavily mold-contaminated items made of leather, suede, or a similar material are salvageable or should be discarded. Do not burn or bury textiles that cannot be cleaned. Put them into properly sealed plastic bags and dispose of them as you would normal household garbage in your area.

Salvaging household items. When assessing or remediating mold contamination to a house, homeowners or cleanup personnel might decide to repair or clean household items (e.g., housewares or kitchen items) damaged or contaminated by floodwaters. As with clothing and other textiles, make sure the water being used is safe. Use only water that is properly disinfected or that the authorities have stated is safe.

Nonporous items (e.g., dishes, pots, glass items, and hard plastic items) can be salvaged. However, because floodwaters are contaminated, nonporous items should be washed by hand in a disinfectant and then air-dried. Do not use a dish towel. Porous items (e.g., cloth, some wood and wood products, and soft plastic) must be discarded because they probably absorbed whatever contaminants were in the floodwaters.

Before using the dishwasher, clean and disinfect it. Then use a hot setting to wash your pots, pans, dishes, and utensils. Do not use the energy-saving setting. Throw away canned foods that are bulging, opened, or damaged.

Food containers with screw-caps, snap-lids, crimped caps (soda pop bottles), twist caps, flip tops, snap-open, and home-canned foods should be discarded if they have come into contact with floodwater, because they cannot be disinfected. If intact cans have come in contact with floodwater or storm water, remove the labels, wash the cans, and dip them in a solution of one cup of bleach in five gallons of water. Relabel the cans with a marker.

Cleaning a heating, ventilating, and air-conditioning system. All surfaces of an HVAC system and all its components that were submerged during a flood are potential reservoirs for dirt, debris, and microorganisms, including bacteria and mold. In addition, moisture can collect in areas of HVAC system components that were not submerged (e.g., air supply ducts above the water line), and this also can lead to the growth of microorganisms. Therefore, all floodwater-contaminated and moisture-laden components of the HVAC system should be thoroughly inspected, cleaned of dirt and debris, and disinfected by a qualified professional. The CDC has prepared recommendations for professionals to help ensure that floodwater-contaminated HVAC system components are properly cleaned and remediated.²¹ If HVAC systems are not properly cleaned and disinfected to prevent the dissemination of mold and other debris throughout a building, bioaerosols of mold and other microorganisms might be present and can cause a variety of adverse health effects in the building's occupants. Ensure that the HVAC system is shut down before any remedial activities take place.

Prevention after the flood. Limited scientific information exists on the efficacy and impact of prevention strategies. In addition, little of the practical knowledge acquired and applied by design, construction, and maintenance professionals has been subject to thorough validation.⁶ No generally accepted health-based standards exist for remediation.⁶

If property owners decide to make extensive repairs or completely rebuild after a flood, they might consider designing and building in a way that will limit the potential for future mold growth.^{6, 30} The key to prevention of mold is to eliminate or limit the conditions that foster microbial growth by limiting water intrusion and the nutrients that allow mold to grow.^{6, 9, 16, 30} The two basic approaches are to keep moisture-sensitive materials dry and to use materials that are not easily biodegradable or that offer a poor substrate for mold growth.

Notes

*This chapter has been adapted and reprinted from Centers for Disease Control and Prevention, Mold prevention strategies and possible health effects in the aftermath of hurricanes and major floods, *Morbidity and Mortality Weekly Report* 55 (RR-8) (2006): 1–27.

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