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REVIEW

Review of health hazards and prevention measures for response and recovery workers and volunteers after natural disasters, flooding, and water damage: mold and dampness

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Abstract Health problems and illnesses encountered by unprotected workers, first-responders, home-owners, and volunteers in recovery and restoration of moldy indoor environments after hurricanes, typhoons, tropical storms, and flooding damage are a growing concern for healthcare providers and disaster medicine throughout the world. Damp building materials, particularly cellulose-containing substrates, are prone to fungal (mold) and bacterial infestation. During remediation and demolition work, the airborne concentrations of such microbes and their by-products can rise significantly and result in an exposure risk. Symptoms reported by unprotected workers and volunteers may relate to reactions of the airways, skin, mucous membranes, or internal organs. Dampness-related fungi are primarily associated with allergies, respiratory symptoms or diseases such as dermatitis, rhinosinusitis, bronchitis, and asthma, as well as changes of the immunological system. Also, cognitive, endocrine, or rheumatological changes have been reported. Based on the consensus among experts at a recent scientific conference and a literature review, it is generally recommended to avoid and minimize unnecessary fungal exposure and use appropriate personal protective equipment (PPE) in disaster response and recovery work. Mycologists recommend addressing any moisture or water intrusion rapidly, since significant mold growth can occur within 48 h. Systematic source removal, cleaning with "soap and water," and "bulk removal" followed by high-efficiency particulate air vacuuming is recommended in most cases; use of "biocides" should be avoided in occupied areas. Public health agencies recommend use of adequate respiratory, skin, and eye protection. Workers can be protected against these diseases by use of dust control measures and appropriate personal protective equipment. At a minimum, a facial dust mask such as the National Institute for Occupational Safety and Health (NIOSH)-approved N95 respirator should be used for mold remediation jobs. For any large-scale projects, trained remediation workers who have medical clearance and use proper personal protection (PPE) should be employed.

Keywords Health · Prevention · Dampness · Mold · Microbials · Allergens · Toxins · Respiratory health

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Introduction

There is growing concern among public and occupational health experts regarding adverse health reactions and illnesses encountered in restoration and occupancy of moldy indoor environments after hurricanes, typhoons, tropical storms followed by flooding damage, and chronic dampness. In particular, cleaning and restoration of water-

damaged and damp homes, businesses, and mold-contaminated personal items may result in exposure of unprotected workers, first-responders, home-owners, and volunteers. In response to the destructive hurricane Sandy (a category 3 hurricane on October 25, 2012 along the northeastern coast of North America), on March 13–15, 2013 the Fungal Research Group Foundation, Inc. (FRGF) [a 501(c)3 non-profit professional–academic organization in the USA that has held scientific meetings since 1994] gathered an international group of experts to present state-of-the-art knowledge and educate restoration and health specialists of the storm-ravaged areas (http://www.dampnessmold.com). During this meeting, testimony was heard from volunteers, workers, and their union representatives regarding troublesome industry practices, lack of training, and what would be deemed improper personal protective equipment (PPE) or unavailability of even simple respiratory protection (i.e., "paper masks"). Although some US governmental agencies now recommend use of a National Institute for Occupational Safety and Health (NIOSH)-approved "N95 paper mask" for respiratory protection, several occupational health experts expressed their unease regarding whether this would provide adequate and sufficient respiratory protection for the complex exposures of workers in storm- and mold-damaged buildings.

Evidence acquisition and materials

Critical appraisal of a recent specialty conference, testimony and presentations from an international group of experts ("Safe and Effective Flood and Mold Remediation—After the Super Storm Sandy and other Natural Disasters," held at Atlantic City, NJ, March 13–15, 2013 by the Fungal Research Group Foundation, Inc.; see also: http://www.dampnessmold.com), and a review of the relevant literature utilizing search engines such as PubMed.gov (http://www.ncbi.nlm.nih.gov/pubmed), ScienceDirect (http://www.sciencedirect.com), and DIMDI (www.dimdi.de) (search terms: fungi, mold, health, dampness, remediation, mycotoxin, asthma, hurricane, flood) resulted in the evidence summary, key findings, and recommendations presented below.

Evidence synthesis and results

Exposure sources: fungi and bacteria

Fungi, called "molds," are a heterogeneous group of organisms including true fungi, lichens, slime molds, and water molds. Fungi inhabit a wide range of niches and environments including plants, woods, food, feed, as well as paper and building materials. Although ordinarily beneficial in outdoor nature, most "naturally" occurring fungi when growing indoors or on building materials may be considered "a danger to health" of animals or humans depending on the concentration and exposure route. There may be from 150 species found indoors to over 600 different species in samples collected from water-damaged indoor environments. The fungi listed in environmental samples typically include *Penicillium* spp., *Aspergillus* spp., *Cladosporium* spp., *Rhizopus* spp., *Paecilomyces* spp., *Aureobasidium* spp., *Chaetomium* spp., *Stachybotrys* spp., and *Trichoderma* spp. Damp building materials, particularly cellulose-containing substrates, are prone to fungal infestation and subsequent mycotoxin production [1–3]. With fungal growth and development, their spores are released into the air, including mycotoxins becoming airborne [4–6]. Production of fungal toxins may also be influenced by interaction with and the presence of certain bacteria [7, 8].

General aspects of fungi and health

Workers may be exposed to fungi or their fragments and by-products (i.e., allergens, glucans, and mycotoxins) by inhalation or skin contact and to a lesser degree by ingestion. In general, the prevalence of skin contact and dermatitis in workers is as high as 10 %, and unprotected work is a concern [9]. Inhalation toxicity of mycotoxins appears to be increased by 20 to 40-fold compared with ingestion [10, 11]. Fungi have been associated in case reports, field investigations, and epidemiological studies with allergy and respiratory illnesses such as rhinosinusitis and asthma, but also with irritant or toxic effects, including skin irritation and other disorders. Mycotoxins are well known in veterinary medicine and food safety, and regulated in many countries regarding consumption and food content. These mycotoxins have also been explored as a possible risk factor in buildings with mold problems based on non-allergic clinical presentations of "sick-building-type" health complaints [12, 13]. Synergistic inhalation effects of fungal and bacterial by-products are believed to be potentially irritating, toxic, teratogenic, carcinogenic, and immunosuppressive [14]. Although in the "mold inspector" industry, "toxicity" is often inferred from the presence and finding of toxigenic fungi, i.e., *Stachybotrys chartarum*, there is no evidence that the detection and quantification of airborne fungi (by either viable or nonviable methods) are representative of actual mycotoxin concentrations. Such tests require highly specialized procedures and laboratories that are not available to general investigators (e.g., certified industrial hygienists). Nevertheless, in studies of molds, endotoxins, and glucans in homes in New Orleans after Hurricanes Katrina and Rita or the Cedar

River floods, levels of airborne concentrations that had been associated with adverse health effects were detected [15, 16].

In medicine, fungi are principally known to be a cause of infections, allergies, and irritant–toxic disorders. Symptoms reported by patients are often nonspecific and may relate to reactions of the airways, skin, mucous membranes, or internal organs. Typical health complaints and symptoms of patients exposed to allergenic or toxigenic fungi are listed in Table 1.

Expert reviews of the scientific literature concluded that dampness-related fungi are highly associated with allergies, respiratory symptoms, or diseases such as asthma as well as changes of the immunological system [14, 17–19]. There are clinical studies and case reports of adverse health reactions that include non-allergic adverse effects to the lungs [sarcoidosis, bleeding in infants; allergic alveolitis (hypersensitivity pneumonitis)], neurological system (headaches and cognitive dysfunction), and endocrine and reproductive organs (thyroid hormonal changes and menstrual disorders in women), as well as psychiatric (depression) and rheumatological disorders (joint pain). An increased risk of cancer from fungal indoor exposure has been explored, but there seems to be little evidence for this at this time. Some fungi (maybe in combination with bacteria) produce chemicals that are known genotoxins and carcinogens [20–27]. Fungi and their byproducts, such as 1,3-β-D-glucan, mycotoxins, and microbial volatile organic compounds (MVOCs), have been implicated in these adverse health reactions and diseases. However, these case studies are difficult to document and confirm in epidemiological or experimental studies and have therefore been considered debatable; further research on these hypotheses is necessary. Medical conditions associated with fungal and bacterial exposure during unusual indoor exposure are listed in Table 2.

Table 1 Health complaints and symptoms reported by patients with exposure to excessive allergenic or toxigenic fungi

Headaches
Runny nose, sinus or nasal congestion
Burning sensation and watery eyes
Sore throat and hoarseness
Cough, chest tightness, shortness of breath, and wheezing; "burning" sensation in the chest
Skin and mucous membrane irritation (occasionally hair loss, "sunburn-like rash")
Severe fatigue and exhaustion (physical and/or mental)
Nausea (vomiting) and gastrointestinal problems (loose stools, stomach aches)
Feverish feeling ("flu-like" reactions)
Joint and muscle ache
Cognitive dysfunction (i.e., concentration and memory problems)
Unusual nosebleeds and coughing up of blood (rare)

Besides encountering large areas of visible mold conditions in situations such as Hurricanes Sandy, Rita (1997), Floyd (1999), and Katrina (2005), typically in damp and wet indoor environments, microbial contaminants are often at higher levels than they are in the ambient air. Characteristic health complaints of people living in moldy indoor environments or workers coming into contact with excessive fungal exposure are described in the literature as: burning sensation of the skin or mucous membranes, irritation and watery eyes, sinus congestion or rhinorrhea, sore throat and hoarseness, headaches, nausea and vomiting, severe fatigue and exhaustion, sneezing or cough, chest tightness, wheezing, chest pain and burning, epistaxis and hemoptysis, dyspnea, hair loss, and even dizziness, concentration, and memory problems or feverish/flu-like reactions [14, 28]. In most cases, the adverse health reactions are normally of short duration and reversible, provided the exposure has been stopped. However, in some cases the adverse health consequences may be more serious or may be irreversible [29]. Mold-exposure-related medical conditions may be diagnosed as atopic dermatitis, urticaria,

Table 2 Medical conditions associated with fungal and bacterial exposure during unusual indoor exposure

Organ system/pathway	Clinical effect	Exposure/agents
Upper airways: nose, sinuses, throat	Rhinitis, sinusitis, laryngitis	Fungi, allergens, irritants, MVOCs, particles
Lower airways: lung with bronchial system and alveoli	Bronchitis, asthma, bronchiolitis, allergic bronchopulmonary aspergillosis (ABPA), allergic extrinsic alveolitis (also known as hypersensitivity pneumonitis), toxic alveolitis, pneumonitis	Fungi, allergens, fungal by-products, fine particles
Combined upper and lower airway	Aspergillosis; fungal rhino-sinusitis	Fungi, fine particles, fungal irritants, allergens
Skin and mucous membranes	Urticaria, dermatitis (allergic or irritant type), conjunctivitis	Fungal irritants, allergens
Other organs: central nervous system, immune system, liver, kidney, endocrine system	Cognitive and psychiatric disorders; hepatitis, nephritis, thyroid, menses disorders (under investigation, anecdotal; commonly found in combination with other symptoms and disorders listed)	Fungi, organic dusts, microbial by-products, mycotoxins

rhinitis, sinusitis, bronchitis, asthma, extrinsic allergic alveolitis (hypersensitivity pneumonitis), organic dust toxic syndrome (ODTS), and toxic–irritant effects of the skin and respiratory organ. Although some have proposed "acceptable threshold levels" or "normal limits" for indoor mold, variations in sampling strategies and methodological limitations as well as the different health outcomes of concern make these very unreliable in practical settings. Therefore, the consensus among experts is to generally recommend avoidance or minimizing unnecessary fungal indoor exposure [30–32]. In addition, susceptible populations such as the very young and old, hospitalized, institutionalized (i.e., prisons), or immunocompromised people [acquired immunodeficiency syndrome (AIDS)/human immunodeficiency virus (HIV)], as well as highly allergic and susceptible individuals will require special care, protection, and consideration. These are individuals who should generally not be involved in water-damage and mold clean-up. During remediation and demolition work, the airborne concentrations of microbes and their by-products can rise significantly [33, 34]. In a recently published study of Hurricane Katrina restoration workers, 74 % of participants ($n = 791$) reported symptoms such as "transient fever/cough" (29 %), "sinus symptoms" (48 %), "pneumonia" (3.7 %), and "new-onset asthma" (4.5 %), and a moderate increase in respiratory dysfunction and toxic pneumonitis was observed [35].

Governmental agencies in the USA such as the New York City Department of Health, the Occupational Safety and Health Administration (OSHA), the Federal Emergency Management Agency (FEMA), the Environmental Protection Agency, and other public health agencies now recommend use of a facial dust mask such as the NIOSH-N95 respirator for mold remediation jobs as respiratory protection [36]. However, some have questioned the adequacy, effectiveness, and protective level of such a respirator to protect from complex exposure hazards during remediation work because of a lack of evidence and supporting data, and have suggested use of an even higher level of respiratory protection and personal protective equipment (PPE).

Specific health issues and concerns

(a) Infections

Infections caused by fungi are called mycoses and are categorized as endemic or opportunistic. Opportunistic fungal pathogens have public and occupational health importance, especially in subjects with an altered or weakened immune system, with human immunodeficiency virus (HIV), or on immunosuppressive medications. Chronic rhinosinusitis with eosinophilic inflammation of the airways has been linked to dampness-related fungi from indoor environments and may be related to the development of asthma [37–39].

(b) Allergy and respiratory diseases

Fungi are a known cause of allergic and respiratory disease and were identified as one of the major indoor allergens [40]. Long duration or intense indoor exposure to fungi can result in acute hypersensitivity reaction and chronic diseases. The reported percentages of populations allergic to molds may vary from 2 to 18 %. A high rate of asthmatics has been identified in damp buildings and is reported to be due to allergy to molds [39]. Notably, about a third of newly diagnosed asthma was attributable to workplace mold exposure [41]. Workplace-related asthma occurs in about 25 % of cases and is recognized in about 7 % of patients [42]. Patients can be tested for specific mold allergy using skin or serological tests to study immunological responses. However, due to the low sensitivity of some of the commercially available mold extract tests, false-negative results are not uncommon. Additionally, extracts that are generally available for allergy testing often correspond poorly with the fungi found in indoor surveys. Patients with an atopy are frequently allergic to multiple fungal species and manifest type I reactions. Allergic bronchopulmonary aspergillosis (ABPA) is a condition where the patient develops an allergy to the spores of *Aspergillus* molds [43]. Finally, children are particular susceptible to development of allergic complications from exposure to molds and their components [44].

(c) Hypersensitivity pneumonitis (HP) and organic dust toxic syndrome (ODTS)

Hypersensitivity pneumonitis (HP), also called extrinsic allergic alveolitis, is a well-recognized occupational disease, and fungi are one of the agents causing such interstitial lung disease. The clinical features, biochemistry, and pathophysiology of allergic or inflammatory–toxic reactions to airborne microbial exposure are difficult to separate. HP can be caused by fungal exposure at work and indoors [36, 45, 46]. Organic dust toxic syndrome (ODTS), also called toxic pneumonitis, is a nonallergic, noninfectious form of acute inflammatory lung reaction to high fungal dust exposure. The differences between HP and ODTS may be difficult to distinguish. Although ODTS is believed to be more likely to occur in settings such as agriculture and recovery facilities, it may also happen in office and domestic environments during flood remediation. Immunological blood changes (such as IgG antibody elevation) can be observed in waste-handling workers or other occupations with high fungal exposure [47].

Remediation and control

Currently in the USA and many other countries there are no specific laws or mandates in place that address assessment, cleaning, and restoration in water-damaged and moldy public buildings. Based on sentinel case investigations in the early 1990s in New York City [4, 48], guidelines now exist for the assessment and remediation of primarily "visible" mold indoors [49] based on an expert consensus document, which has now been widely adopted. However, much of what has become "industry standard" in the restoration industry is largely a combination based on professional experience, cost considerations, expert opinions, and practical necessities. In addition to visible mold, also, "hidden" mold and residual biomass should be investigated and removed. For certain populations, such as the very young and old, immunodeficient or impaired individuals or highly sensitized people, special precautions and clean-up procedures should be considered, since they are likely to be more susceptible and at higher risk for adverse health reactions. Many different remediation approaches have been applied with more or less success, but often also expose unprotected workers and building occupants to preventable harmful situations. In many cases, the questionable indoor use of a "biocide" is promoted by practitioners and commercial suppliers with insufficient evidence for its effectiveness and safety. This may contribute to workers' exposure to agents such as hydrogen peroxide, isopropyl alcohol, bleach, quaternary amines, or other proprietary products. However, hygiene experts have questioned the benefit and use of such products for health reasons [50]. Though fully completed remediation may result in improved fungal air counts, failure of air quality improvement may still be noted because residual non-viable and possibly toxic fungal by-products have not been addressed [51]. Mycologists recommend addressing any moisture or water intrusion immediately, since significant mold growth can occur within 48 h. Efforts to dry affected areas should be started as soon as possible. Systematic source removal, cleaning with "soap and water," and "bulk removal" followed by high-efficiency particulate air (HEPA) vacuuming is generally recommended in most cases. Workers can be protected against these microbial exposures and related diseases by use of dust control measures and appropriate personal protective equipment. For any larger-scale projects [defined by the New York City Department of Health (NYCDOH) guideline as "greater than 100 square feet in a contiguous area"] trained remediation workers should be medically cleared and use personal protective equipment (PPE) such as proper respiratory, skin, and eye protection. However, increased respiratory protection levels require medical clearance, respirator certification, and training, which contribute to additional costs and project management for contractors and employers. Mold remediation procedures for North American and Western European buildings have been summarized in recent publications [52, 53]. Several references are available online for guidance [54, 55, http://www.epa.gov/iedmold1/cleanupguidelines.html, IICRC (http://iicrc.org/standards/iicrc-s500/), and DHHS (NIOSH) publication number 2013-102]; however, industry compliance and documented effectiveness are mostly unknown.

References

1. Johanning E, Biagini R, Hull D, Morey P, Jarvis B, Landsbergis P. Health and immunology study following exposure to toxigenic fungi (*Stachybotrys chartarum*) in a water-damaged office environment. Int Arch Occup Environ Health. 1996;68:207–18.
2. Nielsen KF, Gravesen S, Nielsen PA, Andersen B, Thrane U, Frisvad JC. Production of mycotoxins on artificially and naturally infested building materials 2. Mycopathologia. 1999;145:43–56.
3. Gottschalk C, Bauer J, Meyer K. Determination of macrocyclic trichothecenes in mouldy indoor materials by LC–MS/MS. Mycotoxin Res. 2006;22:189–92.
4. Johanning E, Yang CS. Health problems related to fungal exposure—the example of toxigenic *Stachybotrys chartarum*. Eastern New York Occupational Health Program—CHP, 1994; p. 169–182.
5. Brasel TL, Douglas DR, Wilson SC, Straus DC. Detection of airborne *Stachybotrys chartarum* macrocyclic trichothecene mycotoxins on particulates smaller than conidia. Appl Environ Microbiol. 2005;71:114–22.
6. Gottschalk C, Bauer J, Meyer K. Detection of Satratoxin G and H in indoor air from a water-damaged building. Mycopathologia. 2008;166:103–7.
7. Taubel M, Sulyok M, Vishwanath V, Bloom E, Turunen M, Jarvi K, Kauhanen E, Krska R, Hyvarinen A, Larsson L, Nevalainen A. Co-occurrence of toxic bacterial and fungal secondary metabolites in moisture-damaged indoor environments. Indoor Air. 2011;21:368–75.
8. Peitzsch M, Sulyok M, Taubel M, Vishwanath V, Krop E, Borras-Santos A, Hyvarinen A, Nevalainen A, Krska R, Larsson L. Microbial secondary metabolites in school buildings inspected for moisture damage in Finland, The Netherlands and Spain. J Environ Monit. 2012;14:2044–53.
9. Luckhaupt SE, Dahlhamer JM, Ward BW. Prevalence of dermatitis in the working population, United States, 2010 National Health Interview Survey. Am J Ind Med. 2013;56:625–34.
10. Creasia DA, Thurman JD, Jones LJ III, Nealley ML, York CG, Wannemacher RW Jr, Bunner DL. Acute inhalation toxicity of T-2 mycotoxin in mice. Fundam Appl Toxicol. 1987;8:230–5.
11. Sorenson WG. Aerosolized mycotoxins, implications for occupational settings. 1994; p. 57–67.
12. Auger PL. Mycotoxins and neurotoxicity. In: Johanning E, Yang CS editors. Fungi and bacteria in indoor air environments—health effects, detection and remediation. Albany: Eastern New York Occupational Health Program; 1994. p. 161–167.
13. Johanning E, Biagini R, Hull D, Morey P, Jarvis B, Landsbergis P. Health and immunology study following exposure to toxigenic fungi (*Stachybotrys chartarum*) in a water-damaged office environment. Int Arch Occup Environ Health. 1996;68:207–18.

14. WHO et al. WHO guidelines for indoor air quality: dampness and mould. In: Hesseltine E, Rosen J DK-2100 Copenhagen O, Denmark, World Health Organization-Regional Office for Europe 2009; p. 1–248.
15. Rao CY, Riggs MA, Chew GL, Muilenberg ML, Thorne PS, Van SD, Dunn KH, Brown C. Characterization of airborne molds, endotoxins, and glucans in homes in New Orleans after Hurricanes Katrina and Rita. Appl Environ Microbiol. 2007;73: 1630–4.
16. Hoppe KA, Metwali N, Perry SS, Hart T, Kostle PA, Thorne PS. Assessment of airborne exposures and health in flooded homes undergoing renovation. Indoor Air. 2012;22:446–56.
17. Johanning E, Landsbergis P, Gareis M, Yang CS, Olmsted E. Clinical experience and results of a Sentinel Health Investigation related to indoor fungal exposure. Environ Health Perspect. 1999;107(Suppl 3):489–94.
18. Mendell MJ, Mirer AG, Cheung K, Tong M, Douwes J. Respiratory and allergic health effects of dampness, mold, and dampness-related agents: a review of the epidemiologic evidence. Environ Health Perspect. 2011;119:748–56.
19. Karvala K, Uitti J, Luukkonen R, Nordman H. Quality of life of patients with asthma related to damp and moldy work environments. Scand J Work Environ Health. 2013;39:96–105.
20. Koskinen O, Husman T, Meklin T, Nevalainen A. Adverse health effects in children associated with moisture and mold observations in houses. Int J Environ Health Res. 1999;9:143–56.
21. Olsen JH, Dragsted L, Autrup H. Cancer risk and occupational exposure to aflatoxins in Denmark. Br J Cancer. 1988;58:392–6.
22. Shenassa ED, Daskalakis C, Liebhaber A, Braubach M, Brown M. Dampness and mold in the home and depression: an examination of mold-related illness and perceived control of one's home as possible depression pathways. Am J Public Health. 2007;97:1893–9.
23. World Health Organization and National Agency for Research on Cancer (IARC), IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, World Health Organization (IARC), Lyon, France 1993.
24. Johanning E, Landsbergis P, Gareis M, Yang CS, Olmsted E. Clinical experience and results of a Sentinel Health Investigation related to indoor fungal exposure 6. Environ Health Perspect. 1999;107(Suppl 3):489–94.
25. Clark NM, Ammann HM, Brunekreef B, Eggleston P, Fisk WJ, Fullilove RE, Guernsey J, Nevalainen A, Von Essen SG, Brennan T, Douwes J. Damp indoor spaces and health (executive summary). Washington DC: The National Academies Press 2004.
26. Lorenz W, Sigrist G, Shakibaei M, Mobasheri A, Trautmann S. A hypothesis for the origin and pathogenesis of rheumatoid diseases. Rheumatol Int. 2006;26:641–54.
27. Ammann HM. IAQ and human toxicosis: empirical evidence and theory. In: Johanning E (ed). Bioaerosol, fungi and mycotoxins: health effects, assessment, prevention and control. Albany: Eastern New York Occupational and Environmental Health Center; 1999. p. 84–93.
28. Putus T. Health effects of moisture damage associated microbes. Albany: Fungal Research Group Foundation; 2005. p. 94–107.
29. Rylander R. Organic dusts and disease: a continuous research challenge. Am J Ind Med. 2004;46:323–6.
30. Macher J. Guidelines for the assessment of bioaerosols in the indoor environment. In: American Conference of Governmental Industrial Hygienist, Cincinnati, Ohio. 1999.
31. Ammann HM. IAQ and human toxicosis: empirical evidence and theory. In: Johanning E (ed). Bioaeorosols, fungi and mycotoxins: health effects, assessment, prevention and control. Albany: Eastern New York Occupational and Environmental Health Center; 1999. p. 84–93.
32. Baxi SN, Phipatanakul W. The role of allergen exposure and avoidance in asthma. Adolesc Med State Art Rev 2010; 21:57-ix.
33. Rautiala S, Reponen T, Nevalainen A, Husman T, Kalliokoski P. Control of exposure to airborne viable microorganisms during remediation of moldy buildings; report of three case studies. Am Ind Hyg Assoc J. 1998;59:455–60.
34. Rautiala S, Reponen T, Hyvarinen A, Nevalainen A, Husman T, Vehvilainen A, Kalliokoski P. Exposure to airborne microbes during the repair of moldy buildings. Am Ind Hyg Assoc J. 1996;57:279–84.
35. Rando RJ, Lefante JJ, Freyder LM, Jones RN. Respiratory health effects associated with restoration work in post-Hurricane Katrina New Orleans. J Environ Public Health. 2012;2012:462478.
36. NIOSH. Preventing Occupational Respiratory Disease from Exposure Caused by Dampness in Office Buildings, Schools, and Other Nonindustrial Buildings. DHHS (NIOSH) Publication No. 2013–102. 2012. Department of Health and Human Services Centers for Disease Control and Prevention National Institute for Occupational Safety and Health DHHS (NIOSH).
37. Ponikau JU, Sherris DA, Kern EB, Homburger HA, Frigas E, Gaffey TA, Roberts GD. The diagnosis and incidence of allergic fungal sinusitis. Mayo Clin Proc. 1999;74:877–84.
38. Kern EB, Ponikau JU, Sherris DA, Kita H. Fungi and chronic rhinosinusitis (CRS): cause and effect. In: Johanning E, Morey P, Auger P editors. Albany: Fungal Research Group Foundation. 2012; p. 89–100.
39. Park JH. Rhinosinusitis and mold as risk factors for asthma symptoms in occupants of a water-damaged building. In: Johanning E, Morey P, Auger P editors. Bioaerosols—the proceedings of the 6th international scientific conference on bioaerosols, fungi, bacteria, mycotoxins in indoor and outdoor environments and human health. Albany: Fungal Research Group Foundation, Inc., 2012.
40. Samson RA. Occurrence of moulds in modern living and working environments 302. Eur J Epidemiol. 1985;1:54–61.
41. Jaakkola MS, Nordman H, Piipari R, Uitti J, Laitinen J, Karjalainen A, Hahtola P, Jaakkola JJ. Indoor dampness and molds and development of adult-onset asthma: a population-based incident case–control study. Environ Health Perspect. 2002;110:543–7.
42. Mazurek JM, Filios M, Willis R, Rosenman KD, Reilly MJ, McGreevy K, Schill DP, Valiante D, Pechter E, Davis L, Flattery J, Harrison R. Work-related asthma in the educational services industry: California, Massachusetts, Michigan, and New Jersey, 1993–2000. Am J Ind Med. 2008;51:47–59.
43. Mazur LJ, Kim J. Spectrum of noninfectious health effects from molds. Pediatrics. 2006;118:e1909–26.
44. Tischer C, Chen CM, Heinrich J. Association between domestic mould and mould components, and asthma and allergy in children: a systematic review. Eur Respir J. 2011;38:812–24.
45. Fink JN, Ortega HG, Reynolds HY, Cormier YF, Fan LL, Franks TJ, Kreiss K, Kunkel S, Lynch D, Quirce S, Rose C, Schleimer RP, Schuyler MR, Selman M, Trout D, Yoshizawa Y. Needs and opportunities for research in hypersensitivity pneumonitis. Am J Respir Crit Care Med. 2005;171:792–8.
46. Jacobs RL, Andrews CP, Coalson JJ. Hypersensitivity pneumonitis: beyond classic occupational disease-changing concepts of diagnosis and management. Ann Allergy Asthma Immunol. 2005;95:115–28.
47. Bunger J, Antlauf-Lammers M, Westphal G, Muller M, Hallier E. Immunological reactions and health complaints in biological refuse personnel and composting by biological aerosol exposure. Schriftenr Ver Wasser Boden Lufthyg. 1999;104:141–8.
48. Johanning E, Morey P, Goldberg M. Remedial techniques and medical surveillance program for the handling of toxigenic *Stachybotrys atra*. In: Proceedings of Indoor Air '93, July 4–8, 1993. Helsinki, Finland, vol 4, 1993. p. 311–16.

49. Klitzman S, Morey P, Ahearn D, Crow S, Jarvis B, Light EN, Yang CS, Burge HA, Dearborn DG, Esswein E, Horn E, Schreiber J, Recer G, Llewellyn G, Price D, Pryce S, Chamorro A, d'Halewyn M-A, Favata E, Ammann HM, Allan TM. Guidelines on Assessment and Remediation of Fungi in Indoor Environments. 2002.
50. Kramer A, Below H, Assadian O. Health risk of surface disinfection in households with special consideration on quaternary ammonium compounds (QACS). In: Johanning E, Morey PR, Auger P editors. Bioaerosols, fungi, bacteria, mycotoxins in indoor and outdoor environments and human health. Albany: Fungal Research Group Foundation Inc.; 2012. p. 174–84.
51. Haverinen-Shaughnessy U, Hyvarinen A, Putus T, Nevalainen A. Monitoring success of remediation: seven case studies of moisture and mold damaged buildings. Sci Total Environ. 2008; 399:19–27.
52. Morey P. Mold remediation in North American buildings. In: Adan OCG, Samson RA editors. Wageningen: Wageningen Academic 2011. p. 383–411.
53. Warscheid T. Mold remediation in West-European buildings. In: Adan OCG, Samson RA editors. Fundamentals of mold growth in indoor environments and strategies for healthy living. Wageningen: Wageningen Academic; 2011. p. 413–33.
54. Guidelines for the protection and training of workers engaged in the maintenance and remediation work associated with mold. The national clearinghouse for worker safety and health training. MDB, Inc.: Washington DC; 2005. p. 1–39.
55. New York City Department of Health and Mental Hygiene. Guidelines on the Assessment and Remediation of Fungi in Indoor Environments. Internet. 2008. Environmental and Occupational Disease Epidemiology Unit of the New York City Department of Health and Mental Hygiene.