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Mold and Dampness in the Built Environment

White Paper

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MOLD AND HEALTH

Modest wetting and drying cycles in buildings and ventilation systems are considered normal and generally poses little risk to occupant health. Health-relevant signs of dampness and related mold growth include the presence of moldy or musty odors, visible mold growth or water staining or damage, standing water, and evidence of previous floods or leaks (Chew et al., 2016; Kanchongkittiphon et al., 2015; Mendell & Kumagai, 2017; Mendell et al., 2020).

The current position statement of ASHRAE (2021) on mold and dampness states, "Persistent indoor dampness is neither normal nor desirable and can lead to health risks for occupants in the short term and ultimately to structural risks."

The term *mold* is a colloquial term for a group of filamentous fungi that are common on food or wet materials. Most of these are Ascomycetes that produce a lot of spores. The molds that grow on damp building materials are normally found in the soil and are adapted to grow on a wide variety of materials. Outdoors, molds live in the soil, on plants, and on dead or decaying organic matter.

There are thousands of species of mold and they can be any color, ranging from black to red to white. Different mold species are adapted to different moisture conditions, ranging from just damp to saturated. In addition, different building materials contain different types and levels of nutrients, which affects the kinds of and distribution of fungi that can grow, and the secondary metabolites they can produce, on those materials (Hung et al., 2020).

Well-conducted epidemiology studies in several countries have consistently shown that exposures from house dampness and mold have been associated with increased risks for respiratory symptoms, asthma, hypersensitivity pneumonitis (HP), rhinosinusitis, bronchitis, and respiratory infections (Baxi et al., 2016; Mendell et al., 2011; Mendell et al., 2020; Miller 2023).

In studies conducted in nonindustrial workplaces, individuals with asthma or HP were found to be at risk for progression to more severe disease if the relationship between illness and exposure to the damp building was not recognized and exposures continued (Park & Cox-Ganser, 2011). People working in a moldy building for a long time have been shown to be more likely to become allergic to both indoor- and outdoor-derived allergens not associated with atopy (Cox-Ganser et al., 2005). This was consistent with the outcome of two large studies in the United States (n = 4,600 children) and Canada (n = 13,000 children) on the impact of residential mold and dampness on child respiratory health (Brunekreef et al., 1989; Dales et al., 1991). These studies found that children living in a moldy home had a significantly increased relative risk for both allergic and nonallergic respiratory disease.

Over the past 25 years, considerable research has been conducted to understand the mechanisms for the respiratory health effects of mold exposures with all fungi. The species that grow on damp building materials produce allergens. Characterized allergens have been identified from common damp-building associated fungi such as *Wallemia sebi, Penicillium rubens, Chaetomium globosum, Aspergillus versicolor,* and *A. glaucus,* as well as *Stachybotrys chartarum* (Miller, 2023; Miller, 2024).

One of the challenges faced by public health and industrial hygienists/occupational and environmental health and safety (IH/OEHS) practitioners is the belief that "mycotoxins" are part of the health story in damp indoor environments. The term "mycotoxin" refers specifically to low-molecular-weight secondary metabolites produced by fungi that are known to result in harm to human or animal health (Miller, 2023). In the United States and Canada, exposure to agriculturally important mycotoxins (i.e., aflatoxin, fumonisin, deoxynivalenol [DON], zearalenone, and ochratoxin) is mainly from cereals (Miller, 2023). However, studies have shown that none of the agriculturally important mycotoxins are produced by fungi that grow on water damaged building materials (Miller, 2024). Indeed, some of the fungi that produce these mycotoxins, including *Aspergillus flavus* and *Fusarium* species, do not even occur on damp building materials (Hung et al., 2020).

The U.S. Centers for Disease Control and Prevention (CDC), Health Canada, and Agriculture AgriFood Canada all have methodologies to measure exposures of the agricultural toxins in human serum or urine samples (Miller, 2024). However, the commercially available medical tests that claim to measure mycotoxins in serum or urine from people who have spent time in a damp and moldy buildings have not been validated (Kawamoto & Page, 2015; Nielsen & Frisvad, 2011; Williams et al., 2016). Additionally, no reference ranges for mycotoxins, or levels that are found in normal healthy individuals, as well as the levels at which adverse health effects are associated, have been established or accepted by the scientific community. Validated assays for toxins in serum and urine exist only for the foodborne mycotoxins at this time.

Mold fungi (i.e., anamorphic Trichocomaceae-related hyphomycetes) produce substances that are collectively termed *damage-associated molecular patterns* (DAMPS). These molecules stimulate innate immune responses in humans (Portnoy et al., 2016; Williams et al., 2016). Cell-wall constituents, particularly the form of glucan, (1,3)-ß-D-glucan mold glucan, found in fungi categorized as molds, are potent activators of a receptor located in lung cells. When activated, this receptor results in lung inflammatory effects. Other cell-wall constituents also affect lung biology, as do some fungal proteins (Miller, 2023; Miller, 2024). The forms of glucan in the fungi that are more common in outdoor air, such as *Cladosporium* spp. as well as mushroom spores, are chemically different than those found in water damaged buildings and do not bind effectively to the lung glucan receptor (Cherid et al., 2011; Miller, 2024).

High-quality systematic reviews of the available evidence concluded that the implementation of interventions that combine elimination of moisture intrusion and leaks with the removal of moldy materials and items helps to reduce mold exposure and respiratory symptoms and new-onset asthma (Baxi et al., 2016; Kreiger et al., 2010; Mendell et al., 2011). This position has also been taken up by NIOSH (2012), and Health Canada (2004, 2023), and internationally by the World Health Organization (2009). Based on this evidence, persistent dampness and mold damage in the nonindustrial workplace, including schools, office settings, and residential housing, requires prevention, management, and effective remediation. If visible mold growth is present indoors, it should be remediated, regardless of what species are present, and the underlying moisture condition that caused and supported the growth *must* be identified and corrected. Such actions are likely to reduce new-onset asthma, lead to savings in healthcare costs, and improve public health.

The following five principles describe key principles for indoor air quality professionals addressing mold and dampness in non-industrial workplaces and homes.

Therefore:

1. **The design, construction, and location of a building have the greatest impact on the onset of serious mold and moisture damage. However, the maintenance and effective management of moisture, mold, and dampness requires an ongoing strategy involving occupants, building owners and managers, ventilation experts, and occupational hygiene professionals** (ASHRAE, 2021; Hung et al., 2020; Lstiburek & Springston, 2024).

Owners and occupants should take action to detect and correct any and all leaks, condensation problems, and floods as soon as they are discovered. The potential for building structural damage, microbial growth, and increased adverse health effects can, and should, be reduced by limiting the buildup of indoor moisture. A formal water/moisture/mold prevention program, with clearly defined actions and responsibilities, is required for an effective response to signs of moisture (Hung et al., 2020).

Actions taken by building design and maintenance teams, as well as by owners and occupants of buildings, are critical to effective management of prolonged dampness in buildings. An effective prevention program is evidence of appropriate due diligence to protect both the health of occupants and visitors and to preserve the building structure. As new buildings are constructed, and older buildings undergo major renovations, consistent effort is needed on the part of the architects and engineers involved in the design and construction of the structure, cladding, roofing, and heating, ventilating, and air-conditioning (HVAC) system to make the building durable and dry (ASHRAE, 2021; Hung et al., 2020).

2. **The investigation and any subsequent remediation of moisture damage and the associated mold growth in buildings must be based on an informed visual and olfactory assessment, performed by a competent IH/OEHS professional, that may be augmented by the judicious use of existing sampling methods.**

Good industrial hygiene practices dictate that clients verify that the IH/OEHS professional has suitable training and project experience, as well as appropriate references (Hung et al., 2021). Almost all IHs have college degrees in engineering or in the natural sciences, such as biology, chemistry, biochemistry, or microbiology. Additionally, 42% have MSc degrees, and 12% have doctoral degrees.

Industrial hygienists also have specialized training in ventilation engineering, environmental health, toxicology, and microbiology. Unless the potential conflict of interest is waived by the client, the investigator performing the initial assessment and preparing the subsequent remediation protocol should be independent of the remediation contractor and testing laboratory associated with the project (Horner et al., 2008; Hung et al., 2021; Strode et al., 2024).

Basic competencies that all IH/OEHS professionals who conduct mold assessments should possess, and that should be verified by the client before hiring a professional, include the following: (a) knowledge and education in exposure characterization, microbiological assessment, and remediation, (b) knowledge of the ecology of fungi and bacteria associated with damp or flooded buildings, and (c) specific training in building sciences as well as the basics of ventilation, including potential problem areas in HVAC systems (e.g., cooling coils and drip pans).

If samples are collected, laboratory analytical staff should have specific training and experience in the identification of environmental mold and gram-negative bacteria (GNB) and should be able to demonstrate successful participation in an external laboratory proficiency testing program (Bouttenot & Havics, 2024; Canadian Construction Association, 2018; Hung, et al. 2020; Weekes, 2024).

Some states have certification requirements and other regulations regarding mold-related activities or remediation. Some Canadian municipalities have regulations that cover mold damage in residences that is due to illegal marijuana grow operations.

3. **It has long been recognized that, based on the application of existing methods to analyze air or dust samples, there are no widely recognized or accepted quantitative, health-based microbial exposure guidelines or thresholds** (Health Canada, 2023; NIOSH, 2012). **Samples should not be taken absent an informed inspection** (Hung et al., 2005; Hung et al., 2020; Weekes, 2024). **Indicators of dampness and mold (e.g., visual and olfactory inspection) are the best surrogates for determining whether a problem exists** (Mendell & Adams, 2022). **Observable indicators of dampness or mold consistently indicate the potential for increased health risks and the need for remediation, but microbiological measurements in buildings are not currently useful for estimating dampness or mold-related health risks** (Mendell & Adams 2022). **Sampling should only be performed if the results provide an answer to an unanswered question or hypothesis** (Weekes, 2024). **Any sampling data that may be produced during an investigation must be comprehensive and communicated in a form useful to physicians and allied professionals, building occupants, and decision-makers** (Barnes et al., 2016; Hung et al., 2020).

Since current analytical methods do not provide information on the health risks associated with mold exposures in the built environment, health assessment is primarily based on the nature and extent of the water or moisture damage and associated mold growth, as well as the types of potential reservoirs (e.g., carpets, soft or plush furniture) that may be present.

Semiquantitative estimates of the extent of visible mold or dampness are believed to be the best predictor of short- and long-term health outcomes (Dales et al., 2008; Health Canada, 2004: Mendell & Adams, 2019; Park et al., 2004). The investigator's report needs to present this information in a clear fashion according to methods discussed in the AIHA publications *Recognition, Evaluation, and Control of Indoor Mold, 2nd edition* (Hung et al., 2020) *and The IAQ Investigators Guide, 3rd edition* (Gunderson, 2016).

Any assessment and mold sampling that does occur must be performed by qualified and experienced investigators who are familiar with current guidelines and regulations. Some states require licensing of mold assessment and remediation professionals, so familiarization with any and all applicable local and state or provincial regulations is important.

Samples should not be collected without a clear purpose (e.g., testing a hypothesis) that has been determined ahead of time, and a sufficient number of samples must be taken to reliably assess the existing conditions (Hung et al., 2005; Weekes, 2024). Laboratories vary in experience and proficiency; using an AIHA-LAP, LLC EMLAP-accredited lab or ISO 17025 equivalent is recommended (AIHA, 2020).

Air and/or settled dust sampling can be used to defend hypotheses about the nature of the contamination, "hidden" sources of contamination, and whether or not the indoor air is similar to outdoor air (Barnes et al., 2016; Hung et al., 2005: Hung et al., 2020; Weekes, 2024). However, only qualified IH/OEHS professionals with expertise in mold and dampness, and who are familiar with the methods used to collect and analyze such samples (and their limitations), should perform such sampling. The data should be interpreted in the context of the visual inspection of the building (Havics et al., 2024). Methods involving various molecular tests, such as MSQPCR, need to be interpreted with caution (Hung et al., 2020).

There are several audiences for the report generated following a mold and moisture investigation. Regardless of the nature of the client (e.g., homeowner, insurance agent, property management company, government), the report must provide information that can (a) be translated into an action plan for repair and rehabilitation of the space, (b) provide a basis for protecting the health of occupants and remediation workers, and (c) be useful to the intended audience (Gunderson, 2016; Havics et al., 2024).

Investigators should provide clear and consistent field notes with sufficient detail to allow the fieldwork and sampling data, if any, to be interpreted, verified, and repeated. The report should include, at a minimum, appropriate documentation of sample collection handling and reporting results. Ideal documentation should be thorough, detailed, readable, and focused. Additionally, it should present sufficient information to allow the work to be verified and repeated, and it should describe all quality assurance/quality control procedures (Barnes et al., 2016; Hung et al., 2020).

Guidelines from the American Academy of Allergy, Asthma, and Immunology focus on factors that promote allergen and contaminant production ("facilitating factors" in this case, moisture) and reservoirs (Barnes et al., 2016; Chew et al., 2016). In this context, properly conducted building inspections, which depend on the training and experience of the investigator(s), are essential to physician evaluation.

Physicians reviewing such reports should find clearly described key elements and be able to judge the quality of a report. At a minimum, reports should include a statement of purpose and limitations, observations, results of any testing, conclusions, and recommendations. Such reports should not include any speculation or conclusions concerning medical causation (Barnes et al., 2016; Hung et al., 2020).

As noted, if mold growth is suspected but not apparent following a thorough visual inspection, then microbial air sampling conducted in accordance with guidance documents may be useful. If mold is being removed and there is a question about how far the colonization extends, then surface or bulk sampling, in combination with moisture measurements from affected building materials, may be useful. A general rule of thumb, however, is to simply remove affected porous materials 12–24 in. beyond where the visible water damage or mold growth ends.

Sampling for airborne mold spores can indicate whether the mix of indoor molds is "typical" of the outdoor mix above grade or, conversely, "atypical" or unusual, but such results are only representative of conditions at the time of sampling and cannot be generalized or compared in any meaningful way to other data or averages (Hung et al., 2005).

4. **It is not unusual for buildings to have a number of concurrent problems that affect IEQ or the perception of IEQ. In addition to possible mold growth, water and moisture damage can result in the**

release of gasses and volatile organic compounds (VOCs) from some building materials (NIOSH, 2012)**. Investigations of apparent or suspected mold-related health complaints must consider all possibilities. While mold damage comprises a large percentage of problem situations, studies of occupant complaints find that a high percentage of buildings have an insufficient outdoor air supply rate per ASHRAE Standard 62** (2022)**; inappropriate and inadequate temperature and humidity levels; inadequate control of contaminants from outdoor air (including ozone particulates and traffic pollutants); contaminants arising from equipment or activities within the building or house (including cooking activities); and poor air distribution** (Dales et al., 2008; Mendell et al., 2003)**.**

IH/OEHS practitioners should approach water intrusion, mold, and IEQ investigations in general with the same mindset they use when they approach all potential exposure investigations. The process includes three of the five key IH elements: anticipation, recognition, and evaluation. While the IH can reasonably anticipate that there will be mold exposures associated with water intrusion, mold may or may not be the primary cause of any health effects that may be experienced by the occupants. The IH should ensure that, while investigating mold-related complaints, whether apparent or reported, other possible, unrelated factors affecting the IEQ of the space are actively considered during the initial assessment (Cull, 2024).

In addition to mold-related exposures, contaminants that are both directly and indirectly associated with water-related damage may also be affecting the occupants. Other biological contaminants, such as endotoxin from GNB, can be important in damp buildings, as well as the allergens from house dust mites, cockroaches, and rodents (Chew, 2024; Portnoy et al., 2013a; Portnoy et al., 2013b; Thorne, 2024).

As noted, chemical contaminants that may also contribute to the adverse health effects observed in damp indoor environments, may include:

- particulate and gas/vapor contaminants, such as carbon monoxide, nitrogen, and sulfur compounds, soot and other fine particles, fuel vapors and other emissions associated with improper exhaust of combustion equipment (e.g., boilers) or improperly operating utilities, and
- VOCs, such as formaldehyde and other aldehydes, phenolics, and amines, from degradation or off-gassing of construction materials and finishes.

5. **The protection of workers and building occupants during remediation and renovations is essential** (Health Canada, 2004; Hung et al., 2020; Hung et al., 2021; Springston & Krause, 2024)**. In instances where occupants may have more serious preexisting respiratory conditions such as asthma, temporary relocation may be appropriate while work is being performed** (Health Canada, 2004; Iossifova et al., 2011).

It is the general consensus among governmental agencies, professional associates, and practitioners that, for all but small-scale (e.g., <10 s.f.) visible mold growth, containment procedures similar to those used to abate asbestos and other hazardous materials are required to safely remove contaminated materials and avoid contaminating adjacent spaces.

According to the New York City Department of Health and Mental Hygiene (2008), when possible, remediation work should be conducted while the building is unoccupied. For large-scale growth or contamination, an

IH/OEHS or other competent professional with experience performing microbial investigations or mold remediation projects should be consulted to develop the scope of work and to provide project oversight (Hung et al., 2021; Springston & Krause, 2024).

The use of proper personal protective equipment (PPE), particularly respiratory protection, is vital to worker protection. Because mold and other bioaerosols generally do not have occupational exposure levels, selection of respiratory protective equipment requires professional judgment and qualitative risk assessment methods beyond those typical for chemical hazards (Brosseau et al., 2024).

Many other potential contaminants may be present, along with mold damage, that can affect health or the safety of investigators, remediation workers, and occupants. For example, failure to recognize the possible presence of asbestos-containing materials or lead-based paint, particularly in older construction, could lead to their disturbance during investigative or remedial activities, unnecessarily creating a new hazard.

Finally, there is a need to recognize the possible hazards associated with some potential remediation strategies that may result in the introduction of pesticides, ozone, chlorine dioxide, or other chemicals as part of the remediation process. Unless used in accordance with manufacturer's instructions and federal EPA regulations, the application of such products could exacerbate existing health conditions or lead to new health issues in occupants.

SUMMARY

The previous white paper, *Mold and Dampness in the Built Environment*, was published in 2013. Since then, there have been important advances in our understanding of the health effects of mold and dampness exposure in nonindustrial workplaces including schools in the medical community (e.g., Baxi et al., 2016). This, along with new material in the second edition of the *AIHA Recognition, Evaluation, and Control of Indoor Mold* (Hung et al., 2020) as well as related material from *Bioaerosols: Assessment and Control, 2nd edition* (Marcham & Springston, 2024) provided the basis for this substantially revised AIHA white paper.

This white paper calls on certified industrial hygienists and IH/OEHS professionals who practice in this area to be informed about the importance of systematic building inspections and the strengths and weaknesses of sampling methods. It provides information on the common misapprehensions in the lay community about such issues as mycotoxins.

The harmful population health impact of mold and dampness in the United States and Canada remains an important issue in workplaces and homes. The white paper lays out general principles and provides authoritative references for investigators so they can be prepared with the best available information.

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