Mould Assessment in Indoor Environments - Review of Guidelines & Evidence

May 14, 2010

Prepared for:
National Collaborating Centre for Environmental Health
400 East Tower
555 W 12th Avenue
Vancouver, BC V5Z 3X7

Produced by:
Chrystal Palaty, PhD*
Metaphase Health Research Consulting, Inc
Vancouver BC, Canada
www.metaphase-consulting.com

Production of this document has been made possible through a financial contribution from the Public Health Agency of Canada through the National Collaborating Centre for Environmental Health. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the National Collaborating Centre for Environmental Health.

Key Recommendations

- Excessive dampness, and mould growth on building material surfaces and contents can pose health risks and should not be tolerated in indoor environments.
- A mould assessment determines if mould is present, but does not determine or estimate mould exposure.
- Health-based exposure limits for indoor mould in residential environments have not been established; removing sites of visible and hidden mould and repairing and controlling sources excessive moisture is the best approach to controlling health risks.
- Visual inspection is recommended as the primary tool for assessing indoor moisture and mould. Mould sampling is recommended only when the results of a visual inspection are ambiguous or when more detailed information is necessary.
- Awareness and ongoing prevention activities for mould and moisture are important strategies for building occupants and home owners.

1 Introduction & Scope

This report provides concepts on how to evaluate buildings, residences and other built environment for mould, in order to reduce the risk of exposure. The intended audiences for this report are Public Health Inspectors (PHIs) and Environmental Health Officers (EHOs) investigating homes for signs of moisture and visible mould growth. Although many of the mould assessment strategies contained in this report can be broadly applied, the investigation of large buildings may be complicated and will require additional skills and considerations[1,2,3]. In particular, mould growth in health care settings, such as clinics, hospitals and health care facilities require special attention and is beyond the scope of this report.

The information presented in this report is based on a survey of guidelines and peer-reviewed literature; due to the lack of scientific evidence in this area, most guidelines are based on practical experience and common sense or on risk management principles. The research process and a summary of documents reviewed are presented in the appendix.

While a recommended course of action is presented in this report, the author acknowledges that this is not the only acceptable approach, and individuals with sufficient training and experience may approach indoor mould assessments differently. This report does not cover accreditation requirements for inspectors, mould testing professionals or laboratories. This document is designed to be a companion article to *Mould Remediation in Indoor Environments - Review of Guidelines & Evidence*.

2 Principles of indoor mould growth

Mould is a common term for a subset of fungi, which are often microscopic, multi-cellular, spore-bearing organisms that grow as a mat of intertwined filaments or hyphae. Fungi are eukaryotic organisms existing in a separate classification from plants and animals. For the purposes of this document, "mould" refers to any of the following that are present in the air or on surfaces in indoor environments including: live growth on indoor surfaces, viable or nonviable mould spores, dead mould and structural components such as cell wall fragments and β -1,3-glucans, or mould metabolic byproducts including mycotoxins and microbial volatile organic compounds (mVOCs)[4]. Not all of these components are specific to mould alone, for example, β-1,3-glucans may result from other contaminants in the environment. Key mould and moisture principles that are widely accepted in the field and supported by research are presented below.

2.1 Mould is everywhere. The source of most indoor mould is outdoor air

Airborne mould spores are always present, and most indoor moulds come from the outside air, with spores and fragments entering through open windows, from foot traffic and drawn in through ventilation systems. In many indoor environments, the amount of airborne mould indoors is similar to or lower than the outdoor concentrations. Outdoor air concentrations of mould spores and fragments are highly variable depending on the season, climate, local vegetation and time of day, with levels ranging from < 100 - > 10^5 spores/m^3 [5]. Levels of outdoor mould are significantly elevated by activities such as lawn mowing, leaf blowing, street sweeping and construction work. As moulds are naturally occurring and widespread in the environment, it is not possible to eliminate exposures to all moulds, nor is it considered to be necessary from a health perspective.

2.2 Mould is associated with human health effects

Sufficient evidence exists to conclude that the exposure to specific types and concentrations of airborne mould in damp[*] indoor environments is associated with increased respiratory irritation in some individuals. Signs and symptoms may include coughing, wheezing, and nasal congestion. Under severe mould exposure conditions, hypersensitivity pneumonitis has been reported in susceptible persons[4,5]. Although a relationship between mould exposure and human health is not clearly defined, some of the occupants of damp or mouldy buildings have a greater risk of respiratory symptoms and asthma[5].

2.3 Moisture is the key determinant of indoor mould growth

The surfaces of most indoor environments provide appropriate temperature conditions and ample nutrients for moulds to grow, the only additional element required for growth is water. Moisture on surfaces does not automatically result in mould growth; liquid moisture must persist on a building material surface for a sufficient period of time before moulds will grow. Mould has been shown to grow on materials that remain wet for 48 -72 hours[6].

[*] The World Health Organization defines dampness as: "*any visible, measurable or perceived outcome of excess moisture that causes problems in buildings, such as mould, leaks or material degradation, mould odour or directly measured excess moisture (in terms of relative humidity or moisture content) or microbial growth*". WHO guidelines for indoor air quality: dampness and mould. 2009. p.2.

2.4 The amount of mould in an environment does not directly relate to exposure levels or to the severity of health effects

Exposure is defined as: "*an event during which people come into contact with a pollutant at a certain concentration during a certain length of time*".[*] A dose-response relationship between the amount of mould in an indoor environment, exposure levels and health effects is not defined and is unlikely to be defined in the future[4]. Reasons for this include:

- **Mould may not be the only thing contributing to a health effect.** Damp indoor environments encourage the presence and growth of many types of microorganisms such as yeasts, dust mites, and insects such as cockroaches, that can release allergens[4,5,7,8]. In addition, dampness initiates chemical or biological degradation of materials, all of which may individually or synergistically contribute to health symptoms[5,8].

- **Mould is a mixture of live and dead organisms, and both could be harmful.** Both live and dead mould contribute mycotoxins, mould structural fragments, allergens, mVOCs and other chemicals to the environment.[4] Recent evidence has shown that mould colonies remain viable long after a water source has vanished and mycotoxins and other mould products can be dispersed through a building and remain toxic over extended periods of time.[9] For this reason, indoor mould growth must always be removed.

- **Individual species of moulds and other biological agents responsible for health effects cannot always be identified and measured**[4,5]. The mix of organisms in indoor environments can be variable and complex.

- **Exposure is determined by more than just the quantity of mould present.** In order for mould to reach an occupant, a clear exposure pathway must be present[4,10,11]. An assumption is that most indoor mould exposure occurs through inhalation, which is supported by the fact that most health effects from indoor exposure affect the airways and the upper respiratory tract. Therefore, exposure also depends on the resuspension of mould, which is in turn influenced by size, nature and interaction of the particles.

- **Individuals are exposed to different species and quantities of moulds in many different environments: outside, at home and at work.** Exposure in different environments and for variable durations makes the accurate determination of exposure challenging.

- **Individual susceptibility plays an important role in the response to mould exposure**. Some individuals will experience negative health effects in response to very low amounts of mould because of individual susceptibility or the existence of preexisting health problems.

[*] World Health Organization. Damp and Mould - Health risks, prevention and remedial actions. 2009. p.20.

2.5 There are no recommended health-based exposure limits for mould

Numerical standards for acceptable quantities of mould in indoor environments are often requested as a guide for when to conduct remediation activities or to determine if mould remediation activities have been successful. Mould concentration limits have been published previously[12], however, many were retracted as they cannot be scientifically justified with the information available[1]. Most professional organizations, including the Institute of Inspection, Cleaning and Remediation (IICRC), American Industrial Hygiene Association (AIHA), and the American Conference of Governmental Industrial Hygienists (ACGIH), have not agreed upon, nor supported numerical limits for mould due to a lack of scientific data.

Researchers have tried to establish acceptable indoor limits based on the amounts of mould measured, including specific criteria for genus or species of moulds present[13,14]. Variability in mould concentrations and differences in measurement protocols have made this a challenge[15]. As an alternative, some guidelines and papers suggest that a more meaningful measure is a comparison of the indoor and outdoor airborne mould spores[16,17]. In theory, the amount of mould indoors should be less than the amount of mould measured outdoors[14], and the distribution of mould types indoors as compared to outdoors should be similar. Some publications caution that these relationships are often more complex than expected, and species identification is required for comparison[11,14,17,18]. The current approach, endorsed by most of the guidelines, is that **the visible growth of mould indoors, regardless of the species or the amount, is inappropriate and needs to be removed.**

2.6 Determining mould exposure is complex

Currently, there are no scientifically validated methods to measure mould exposure, although various methods and sampling devices are in development[19,20]. Personal monitoring can be used to measure the airborne mould in a person's breathing zone, however this provides at best, a snapshot of mould exposure, and does not take into account the variability of mould, the long-term exposure experienced by the individual, or exposure from different environments[21]. While biological response monitoring tests can confirm that exposure has occurred, they do not indicate a relationship between exposure and health effects, and do not prove when or where the exposure occurred[22].

Many studies have examined the validity of monitoring fungi in dust or air to assess occupant exposure with variable results[23,24]. More recently, scientists have tried to quantify exposure through the measurement of fungal components or byproducts such as ergosterols[25,26] or microbial volatile organic compounds (mVOCs)[27]. All of these approaches can provide evidence of environmental contamination, or the lack thereof, but do not provide evidence of a received dose[4,11,22].

In order for occupants to be exposed to mould, a clear exposure pathway needs to exist. Part of an assessment may include identifying possible sources of direct exposure for the building occupants to mould spores or fragments indoors. Possible sources of mould exposure for the occupants of mould-impacted buildings include: (1) visible mould development on surfaces in the indoor environment, such as on walls, ceilings, floors, and/or other materials indoors[4]; (2) mould growing in heating ventilation and air conditioning (HVAC) systems, where mould spores and fragments could be delivered to the indoor environment[4]; (3) mould spores and fragments in carpets and floor dust, which could become airborne when disturbed by the building occupants or after using inefficient non-HEPA vacuum cleaners[4]. Hidden mould development in wall cavities and enclosed spaces within the building structure could present an exposure and health concern for the building occupants **only** if there is an appreciable air exchange or an identified pathway for material transfer between the site of hidden mould development and the indoor environment.

In conclusion, there is no point in developing personal monitoring methods or estimating the amount of exposure, given the absence of recommended health-based exposure limits for mould. **While mould assessment determines if mould is present, it does not determine or estimate mould exposure**.

Extreme situations: marijuana grow operations (MGOs)

MGOs are extreme mould and moisture situations, "*operated with little or no regard to the immediate or future safety of the occupants or neighbors*" [13]. MGOs present significant health and safety hazards such as structural problems, electrical tampering, chemical contamination, increased levels of combustion gases, tampering with HVAC and hot water, and build up of combustion byproducts. A description of associated hazards and proposed remediation strategies are described in the NCCEH document *Recommendations for Safe Re-occupancy of Marijuana Grow Operations*.

3 Mould assessment: determining the presence, location and amount of indoor moisture and mould.

The purpose of mould assessment is to (1) determine the presence, location and extent of past and current mould growth in buildings; (2) identify the source, cause and extent of water ingress, condensation or dampness indoors; (3) determine if there are plausible and significant indoor mould exposure pathways for occupants and; (4) use this information to make a mould exposure risk management decision[1,28]. The scope of the assessment varies with the size and nature of the building. The challenge for Public Health Inspectors and Environmental Health Officers is to reduce the risks of illness and damage using available information, with the caveat that in any situation there may be unknown factors such as hidden mould or environmental characteristics which may positively or negatively influence the risk[1].

All major guidelines reviewed agree regarding standard mould assessment strategies[1,4,11,28,29]. Each guideline approaches assessment in a systematic manner and follows defined processes, while emphasizing the need to accommodate any limitations that are present and to adapt to individual building characteristics. The general recommendations are summarized in the flowchart, Figure 1.

The first two steps in the process, **Step 1: Information Gathering & Planning**, and **Step 2: Visual Inspection of Premises,** are normally conducted by PHIs or EHOs. If additional analysis is necessary to determine the presence/absence of mould, the building owner or occupant is encouraged to hire a qualified Environmental Specialist/Consultant to further the assessment by conducting **Step 3: Mould Sampling**, and if necessary, **Step 4: Investigate Suspect Hidden Areas**.

The mould assessment process begins with a suspicion of mould. This can be a complaint from the occupant about health effects, an odour, the presence of visible mould or moisture damage, excess humidity, or a specific incident such as a leak or flood.

3.1 Step 1: Information gathering and planning

The first step in a mould assessment is to gather as much information as possible about the situation and to create an assessment plan. Factors to be considered include resource availability, documentation requirements, occupant interviews and inspector qualifications. The assessment plan can range from an informal plan to a formal, comprehensive written plan. The magnitude of the observed on anticipated problem often dictates the extent of the planning phase.

3.1.1 Resource considerations

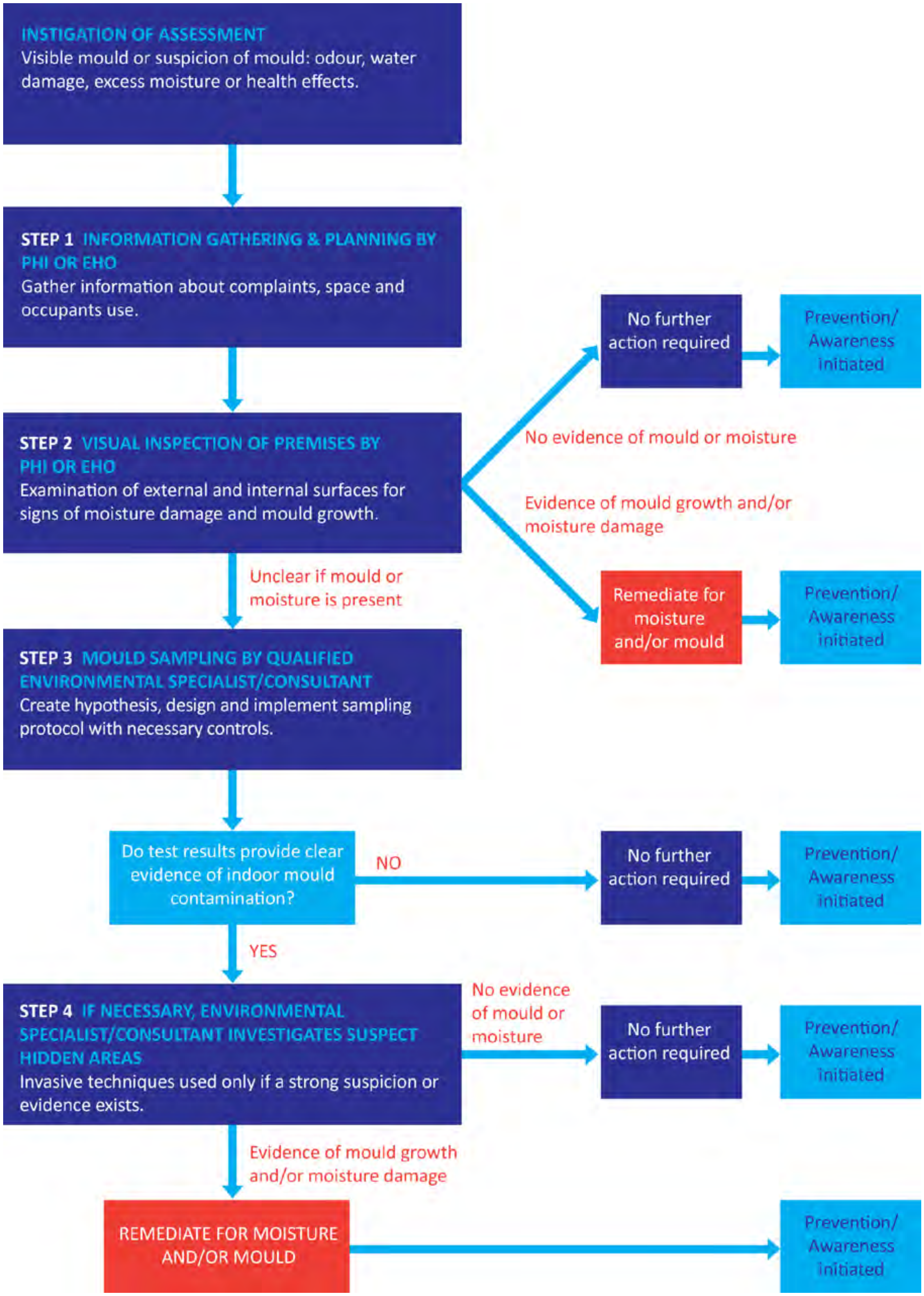
Resource availability is an important consideration in mould assessment and remediation. When it comes to indoor mould, the need for an effective and reasonably thorough assessment should be balanced with the costs for conducting an effective remediation.

3.1.2 Documentation requirements

Thorough documentation is required to: (1) record the inspection and the scope of the mould and/or moisture problem; (2) describe the stages of a destructive inspection, if conducted; (3) support and assist risk management and remediation decisions; and (4) to record the remediation actions taken and the final state after remediation. Assessment documentation should include checklists, written notes, and a full set of photographs of the visible damage, taken before, during and after remediation.

Documentation may also include occupant questionnaires and interviews. The documentation should be of sufficient detail so that an individual who has not been involved with a particular project can review the materials and have a clear understanding of what was found, and the basis of the recommended remediation steps. Excellent examples and templates are provided in the American Industrial Hygiene Association's *Recognition, Evaluation, and Control of Indoor Mold*[1].

Figure 1: Mould assessment decision flowchart



3.1.3 Inspector qualifications

Visual inspections can be conducted by occupants; however, evidence supports the use of a trained inspector to determine if mould is present[5,30,31]. Guidelines recommend that a trained field inspector conducts inspections in the following situations: (1) where the house is very damp, where there are signs of water stains on walls or reports of chronically wet areas within the occupied spaces, signs of active plumbing leaks, or other evidence such as measured high concentrations of atmospheric humidity; (2) when there are signs of visible mould in locations where it should not be present ; (3) when the occupant experiences health symptoms coupled with other evidence strongly suggesting that mould may be present; or (4) when mould returns after repeated cleaning[1,32]. Inspectors need to have good observational skills as well as some understanding about moisture dynamics, basics of building construction and knowledge of the usual locations for moisture and mould. A list of qualifications, training and experience required for Indoor Environmental Professionals is described in several guidelines[1,2]; depending on the scope of contamination, a variety of experts may need to be involved in an inspection.

3.1.4 Occupant interviews or questionnaires

Occupant interviews or questionnaires may be used to obtain information about the building that cannot be obtained in an inspection alone. This can include information about previous water damage or leaking, sources of periodic or seasonal moisture which may not be present at the time of the inspection, the presence of musty or mouldy odours, the history and use of the building; previous renovations, duration of moisture damage, and specific locations of problems. Caution needs to be exercised as information from occupant interviews and questionnaires is not always accurate[5,30,31]. Interviews can be conducted prior to or during the site inspection, but should never replace an inspection. If occupants are concerned about health risks or issues, they need to be appropriately referred to physicians, as they alone are qualified to diagnose and address occupant health effects[1,10,29,33,34].

3.2 Step 2: Visual inspection of premises

All guidelines agree that a detailed visual inspection coupled with the history of building conditions is the best method to identify the cause, location and extent of mould within the occupiable spaces of a structure[1,3,4,5,6]. Building characteristics such as architecture, construction quality, age and materials, history of prior water issues, maintenance, and the condition and repair of the building need to be considered. Many guidelines provide detailed instructions and checklists for examining buildings[1,28,35].

3.2.1 Inspector safety and PPE during inspections

Personal protective equipment (PPE) is not usually required by inspectors during a visual inspection. In invasive or destructive inspections (discussed in more detail later), precautions are necessary to protect both inspectors and occupants from mould exposure.

3.2.2 Identify sources of water damage and evidence of mould

Indicators of present or past water damage, or mould include visible mould growth, an earthy or musty odour, any evidence of leaks or flooding such as water stains, wet areas, decayed wood, peeling paint, wrinkled wallpaper, cracks in plaster, warped wood such as cupped hardwood flooring planks, or white powdery salt crystals on the surface of walls, brick or masonry. In addition, signs of water intrusion or chronic condensation, structural damage, previous repairs and renovations, as well as structural defects need to be identified. All observations and readings obtained during the inspection need to be documented in notes or photographs.

3.2.2.1 Review of the building exterior

The inspector needs to check the building exterior for any obvious signs of building deficiencies, obvious locations for water intrusion, failed materials or surfaces, including missing drainage elements or staining. . The area surrounding the building should also be inspected for potential sources of aerosolized mould, including water sources, landscaping and digging activities.

3.2.2.2 Review of the building interior

The inspection includes a walk-through of all occupiable areas as well other areas (if applicable and appropriate) such as attics, basements, crawl spaces and storage spaces. The number of occupants, living activities, characteristics and contents of the building need to be considered. Condensation observed on windows and pipes needs to be documented. Surfaces around plumbing, such as baths, showers, under sinks, around dishwashers, refrigerators, and hot water heaters needs to be inspected. Rooms with running water, especially bathrooms and kitchens, are the most likely rooms where mould growth is observed[4,11,14,28]. Surfaces under and adjacent to windows, doors and other penetrations through the building's exterior should be examined.

During the course of inspection, the inspector may encounter confined spaces[*]. Entry into confined spaces requires specific training as well as appropriate protective clothing and breathing equipment. In some jurisdictions, a Confined Space Entry Procedure is required for inspectors to enter into a crawl space or attic to assess the presence or absence of moulds. For this reason, inspection of the confined spaces may not always be conducted during an initial building inspection, but may be more appropriate for more intrusive inspections (Step 4).

3.2.2.3 Inspection of Heating, Ventilation and Air Conditioning (HVAC) systems

When properly managed, heating, ventilation and air conditioning (HVAC) systems can help minimize mould problems in a building; if contaminated, HVAC systems can introduce or distribute mould. This contamination occurs primarily in systems equipped with air conditioning, as moisture condensation occurs. While HVAC inspection may be simple and straightforward in some structures, larger or more complex systems may need to be evaluated by specially trained and experienced individuals[29]. Even residential air handling units can be challenging to evaluate since access to interior components is often difficult. At a minimum, the furnace, heating, air conditioning and humidification systems need to be examined.

---

[*] Confined spaces are defined as (1) spaces large enough and configured so that an employee can enter and perform assigned work; (2) have limited or restricted means for entry or exit; (3) are not designed for continuous employee occupancy. Institute of Inspection, Cleaning, and Restoration Certification (IICRC): *IICRC S520 Standard and Reference Guide for Professional Mold Remediation*. 2008. Vancouver, Wash. p. 29.

3.2.2.4 Identify the source and extent of moisture

Inspectors need to be aware that water/moisture moves through buildings dynamically, so the conditions and wetted areas will likely change[1,4,29]. For example, moisture entering near the top of the building may flow down through many floors and may penetrate many different materials. Slow, hidden, chronic leaks from plumbing or ingress associated with problems with the building's envelope can be insidious problems, since often the mould growth occurs out of sight, and once it is recognized the problem may be much more extensive than what is visible. Important sources of moisture include: (1) rainwater and ground water leading into building; (2) water entering the building from failures or problems with the building's envelope, such as failures of roofs, walls, windows; (3) plumbing leaks and spills[1,5]; (4) inadequate thermal insulation within the building envelope (e.g., exterior walls, attics, crawl spaces) which can lead to condensation, high indoor air humidity, low temperature of walls and surfaces[1,33]; (5) water vapour released as part of occupant activities such as exhalation, bathing, cleaning, food preparation and humidification resulting in condensation related mould issues[1]; (6) residual water contained in building material surfaces, such as concrete[1].

While it is easy to identify ongoing moisture damage such as leaks, it is more difficult to identify periodic or seasonal moisture sources as they may not exist at the time of inspection[1], or those that occur within hidden areas, such as in wall cavities from slow leaks of plumbing, showers and tubs. Once the water source is identified, the type of water needs to be determined, as this will have an impact on the occupant and the remediation strategy: contaminated water containing soil, sewage or pathogens may harm occupants regardless of mould[1].

Moisture measurements can be used to locate or estimate the extent of concealed or non-visible mould contamination, and can include relative humidity (RH) measurements as well as surface moisture measurement of building materials. Several guidelines recommend the use of hygrometers and moisture meters to measure the RH of buildings and to identify moisture that may not be obvious[1,5,11,28], however studies disagreed as to whether or not RH predicts indoor mould[24,36]. Guidelines vary in their recommendations for acceptable levels of atmospheric moisture in an environment, however, Health Canada recommends an acceptable range of 30% to 80% relative humidity in the summer, and 30% to 55% relative humidity in the winter[37].

3.2.2.5 Determine the presence, amount and location of indoor mould

The presence, amount and location of indoor mould identified in an inspection needs to be documented. If there is uncertainty about whether a growth is mould, easy and inexpensive tests can be conducted to determine this, such as collecting a tape lift using transparent tape that is placed in a sealable plastic bag and analyzed by a mould laboratory. Although often requested as part of an assessment, mould sampling is unnecessary if visible mould is not in dispute, as sampling does not influence the remediation actions that follow[4,35]. It is important, as part of the inspection process, to estimate the size of the visible fungal growth, since the size of the affected area will dictate the types of procedures used during mold remediation. The most common thresholds for mould remediation are $1m^2$ or less of visible mould growth for small scale projects, 10 m^2 for moderate projects, and greater than $10m^2$ for large scale remediation projects[35].

3.2.2.6 Suspicion of hidden mould

Hidden mould is defined as "*concealed visible colonizing growth of filamentous fungi on building materials or contents that is within the building enclosure but concealed from view during a normal walk-through inspection*"[*]. Hidden moulds are beyond the scope of a visual inspection as performed by the PHIs/EHOs, and are usually investigated by environmental health professionals from the consulting industry, with the reports submitted to public health agencies for review. Investigations for hidden moulds are covered in Section 3.4.

Examining the evidence: Do housing characteristics help to predict mould problems?

Many studies conducted over the last few decades have tried to determine if specific housing characteristics were predictive of mould problems. Results between different studies vary greatly, likely due to different methods being used and variability of interiors being examined[4,38].

Although results vary, some characteristics that were significantly associated with increased concentrations of airborne moulds include: living on the ground floor, lack of ventilation systems, and electric heating[30]. Another study determined that older houses, flat-roofed houses built in the 1960s and 1970s, and houses with a concrete slab on the ground that were built before 1983 were all associated with one or more of the dampness indicators[39]. Moreover, tenancy and earlier renovation due to mould or moisture problems was strongly associated with dampness[39]. Floor covering seems to make a difference, and rooms with carpets have more mould spores than rooms with other floor[40]. In contrast, other studies examining housing characteristics did not specify housing characteristics that correlated to mould growth[41].

3.2.3 Outcomes of visual inspections

Visual inspections can lead to three possible outcomes:

(1) No evidence of mould growth or moisture damage. In this case, no remediation action is required, and no further action is required by the PHI/EHO. Prevention and awareness activities should be initiated so that occupants become aware of how their activities can contribute to indoor mould.

(2) Evidence of mould growth or moisture damage. In this case, remediation actions need to be initiated to remove the mould and to address the underlying cause of the moisture; please see accompanying paper, *Mould Remediation in Indoor Environments - Review of Guidelines & Evidence* for recommendations. Prevention and awareness activities should be initiated so that occupants become aware of how their activities can contribute to indoor mould.

(3) Unclear if mould or moisture is present. In this case, an environmental consultant/inspector needs to be engaged to proceed with Step 3: Mould Sampling.

[*] American Industrial Hygiene Association (AIHA). Recognition, Evaluation and Control of Indoor Mold. 2008. p.211.

3.3 Step 3: Mould sampling - collection, analysis and interpretation

Mould sampling should be done only when a visual inspection reveals issues or characteristics indicating that unusual mould growth may present, but the presence cannot be confirmed by visual inspection. Mould sampling needs to be conducted in order to prove or disprove a clear and testable hypothesis. Sampling may be appropriate when: (1) the presence of hidden mould is suspected and intrusive or destructive sampling may be required to locate it[1,2]; (2) there are surface stains but it is uncertain if the staining is mould; (3) to judge the effectiveness of remediation or as part of a quality assurance strategy to ensure that there are no additional sources of contamination outside of the remediation area[1,2,3].

Proper planning reduces the possibility of unclear or ambiguous results. The sample plan should consider why sampling is required and what agents are being tested, with the sample types, sample numbers, testing times, locations and controls planned in advance[11]. A sample plan is often a compromise between what is ideal and what is feasible. The types of sampling and assessment methods selected are based on availability and resources, as well as the type of information required. As part of indoor air quality investigations, current and/or historical sampling for the presence of airborne moulds indoors and the referent values outdoors should be documented and kept on file for future reference.

3.3.1 Limitations of mould sampling

Mould sampling has many significant limitations and sampling results are often ambiguous and difficult to interpret. Sampling can be time consuming and expensive when resources are better used for remediation[28]. Sampling does not identify sources of moisture or why a problem has occurred, nor will results likely influence decisions about which remediation procedures are appropriate. None of the sampling methods are able to determine the duration of mould growth, or provide information about the level of exposure hazard. Disturbing mould growth to obtain samples may increase the health risk for occupants. Testing and analysis methods are not well validated or standardized, and are often unavailable commercially. Some tests detect specific fungal components but not others. Air sampling may only capture a small window, when in fact there is a large temporal and special variability in fungi.

3.3.2 Mould collection methods

The sampling method selected depends on resources available, method availability and information required. There are a wide variety of mould collection methods used to collect mould from air, surfaces and from settled dust. There is no standardized collection protocol, and protocols vary widely between different guidelines and papers. Points of controversy between different papers and guidelines include the numbers and locations of samples, timing for when duplicates are taken, amounts of household activity and operation of HVAC systems during testing. For these reasons, mould sampling is best conducted by qualified environmental professionals who are knowledgeable and experienced regarding the use of controls, as well as calibrating, maintaining, cleaning and decontaminating equipment.

Controversy: speciation and indicator fungi

Guidelines disagree about the importance of determining the species of mould present. Speciation is expensive and often unnecessary as remediation methods do not usually vary with species[28,29]. Speciation does allow comparison of the biodiversity of indoor and outdoor air, with the presence of unique species indoors indicating a potential contamination problem[1,2,11].

Many papers and guidelines describe the use of mould species which act as "water damage indicators", and can only grow in conditions of moist or wet building materials that have been wet for extended periods of time. Evidence varies about the utility of this approach, with some studies correlating the presence of indicator fungi with indoor moisture[36,42], while other studies identified indicator fungi in homes without any water damage or mould growth[23].

An evolving strategy being developed to estimate a home's mould and water damage uses mold specific quantitative polymerase chain reaction (MSQPCR) analysis, to determine the species and types of mould present; 29 indicator species and 10 other species are measured[43]. This group also found that the presence of two species (*Aspergillus niger and Aspergillus unguis*) were associated with asthma in children[44]. This technique, developed by U.S. EPA scientists, is considered by EPA to be a prototype and unproven technique. Until research confirms the accuracy of this approach, its use should be limited to research applications.

3.3.3 Mould sample analysis

Three main mould sample analysis methods include (1) culture-based assays, (2) non-culture based analysis (microscopy and spore counting), and (3) molecular analysis. Some mould collection methods allow analysis by a combination of methods. Each of these analytical methods have specific strengths and weaknesses that must be considered before determining which method to use. A full description of the analytical methods is found in the American Industrial Hygiene Association's *Recognition, Evaluation and Control of Indoor Mold*[1].

Sample analysis must be conducted by a certified environmental laboratory; in Canada, the laboratory regulatory body is the Canadian Association for Laboratory Accreditation (www.cala.ca). Laboratories should demonstrate successful performance in the AIHA Environmental Microbiology Proficiency Analytical Testing (EMPAT) program, be accredited by the Standards Council of Canada (SCC), or have ISO ISO/IEC 17025 or Good Laboratory Practice (GLP) certification[2].

Some of the newer analytical methods were developed with the intention of detecting hidden mould in indoor environments[42,45], or as ways to better determine exposure[46]. In the absence of specific airborne mould exposure guideline levels, the use or importance of these methods for indoor mould risk assessment is quite limited. Results demonstrated that the compound of interest may be below the analytical detection limit for conventional indoor air analysis[45], and the compound measured may not correlate with the amount of mould present[27,47,48,49]. As well, the indoor environment may contain other organisms (such as bacteria) which also produce the compound being measured[27].

Sampling versus visual inspection

The expense and ambiguity of mould sampling point towards visual inspection as the cheapest, most practical way to assess mould. Many studies have compared the effectiveness of visual inspection with sampling. Overall, these results do not conclusively support one method over another; visual inspection and sampling can both be effective methods to determine if mould growth is present.

Studies have found that visible mould growth and signs of dampness are correlated with increased numbers of mould spores and species in the air[30,31,36,41]. The correlation between visible inspection and high indoor mould levels was accurate in 80 percent of cases; in the remaining 20% of cases, high concentrations of mould were not identified by visual inspection, implying that they were due to hidden mould, behind walls or under carpets[30].

Studies correlating the Environmental Relative Moldiness Index (ERMI) with visual inspection found some correlation between the ERMI designation of a mouldy home with at least one of the following: visible mould, visible water damage, mould odour or water damage history. In contrast, homes determined to be non-mouldy by ERMI had none of the water damage indicators[43].

One study used the "Tools for schools" air quality checklist and compared it to air sampling. In this instance, air sampling was deemed more effective at revealing the presence of hidden mold in areas where mold was not visible. The study did not mention how this correlated with the presence of water damage[50].

3.3.4 Mould Sample Interpretation

One of the biggest challenges in mould sampling is in interpretation of the results. Due to a lack of standardization and objectivity, results can be highly variable, ambiguous and difficult to interpret. This can lead to inconsistent conclusions, even among professionals[51].

This and similar problems can be avoided by using the same method/instrument/technique in collecting airborne mould samples from the indoor and the surrounding outdoor environment for reference and comparison. A comprehensive airborne mould assessment involving a reasonable number of samples collected from both indoor and outdoor environments within the same day could be quite practical, cost-effective and helpful in addressing mould related issues in water/moisture damaged buildings. Normally, indoor airborne mould spores are present at the same or lower concentrations as compared to what is present outdoors, with the same types of moulds dominating.

3.3.5 Outcomes of mould sampling

Results of mould sampling will ideally point to one of two possible outcomes:

(1) No evidence of mould contamination. In this case, no remediation action is required, and no further action is required by the environmental consultant. Prevention and awareness activities should be initiated so that occupants become aware of how their activities can contribute to indoor mould.

(2) Clear evidence of mould contamination. In this case further investigative actions need to be initiated to identify the source and amount of mould present. In this case, an Environmental Specialist/Consultant needs to be engaged to proceed with ***Step 4: Investigate suspect hidden areas***.

3.4 Step 4: Investigate suspect hidden areas

Hidden mould can grow anywhere there is leaking or condensation. If a strong suspicion of hidden mould is supported by mould sampling results, more invasive techniques may be employed to determine the location. Before invasive or destructive measures are to be taken to find hidden mould, air sampling is strongly recommended.

Qualified industrial hygienists and other building health professionals do not fully agree on the potential impact of hidden mould growth on indoor air quality, as the potential for exposure to microbial contaminants in spaces such as attics, crawl spaces, exterior sheathing, and garages is poorly understood[1,4,52].

There is a growing consensus that visible indoor growth – regardless of the area - should be removed to reduce structural damage and long term health risks[1]. When making a decision to remediate hidden mould, many things need to be considered including potential exposure pathways, effect of the mould on the structural integrity of the building and the susceptibility or health status of building occupants. The viability and species of mould do not factor in this decision[1].

3.4.1 Invasive inspection for hidden mould

Hidden mould can be expensive and difficult to identify, and relies on an inspector's experience combined with results of the visual inspection, knowledge of moisture migration and dynamics, knowledge of mould growth conditions, and appropriate use of instruments and testing[1,28]. Because of the complexity as well as additional risks, investigations for hidden mould must be conducted by a qualified environmental professional.

Identifying mould in hidden areas may require small scale destructive openings of walls or other surfaces, lifting carpets or vinyl sheet flooring and removing wallpaper, drywall or paneling for investigational purposes[13]. Signs of possible hidden mold include stains at the base of walls, including stains on tack strip under carpet, commonly under possible leak locations, such as windows. Testing along the base of walls using surface moisture meters, can be useful in identifying hidden moisture. More sophisticated methods, such as using hand-held infrared cameras, can also be used to identify locations where unusual moisture may be present. Training is needed since these devices are prone to give false positive and false negative readings to the inexperienced operator.

It is important to note that moulds in wall cavities and enclosed spaces do not present a health risk for the building occupants if there are no possible or reasonably predictable pathways of appreciable exposure indoors. Therefore, hidden moulds should not be considered to have the same importance as extensive visible mould development in the indoor environments where the building occupants could be exposed through both direct physical contact and inhalation of viable/nonviable mould spores and disturbed mould fragments.

If there is a strong suspicion of uncovering visible mould growth, personal protective equipment should be worn as a precaution for inspectors conducting invasive inspections, as spores and dust may be released into residential or occupational areas. Sensitive individuals need to be removed from the premises before invasive or destructive inspection is conducted. If mould is disturbed, immediate containment and other engineering controls such as HEPA filtration or negative pressure should be employed.

This invasive inspection may involve entry into confined spaces (discussed in section 3.2.2.2), which may contain hazards other than mould. Bird, bat or rodent droppings identified in contained areas such as attics or crawl spaces, are a cause for special concern, as they can be associated with pathogens which are harmful to humans. Fungal/bacterial pathogens that are potentially associated with bird/bat/rodent droppings include *Histoplasma capsulatum* and *Cryptococcus neoformans* (fungi) and *Chlamydia psittaci* (bacteria) [53,54,55]. Special precautions are necessary to protect inspectors and occupants, particularly for immune compromised individuals[11,14]. Occupants need to be referred to professional pest control and remediation companies to prevent continued infestation and to remove accumulated droppings and nesting materials.

3.4.2 Destructive inspection for hidden mould

'Destructive inspection involves the removal of building material surfaces to permit visual inspection of typically hidden areas[*], and is limited to situations where there is no other method to locate hidden mould and moisture. Because destructive inspections may involve the dismantling of building structures and can compromise the integrity of building materials, cooperation and collaboration with other professions is required. Special caution is needed for destructive inspection, as there are exposure hazards with regards to lead paint and asbestos. If a wall needs to be opened, the area needs to be contained with plastic sheets and cleaned with a HEPA vacuum to prevent the dispersal of particulate matter and to protect occupants and inspectors against dust and other particles.

4 Decisions and recommendations

A mould assessment needs to be conducted in a stepwise process, moving from planning and information gathering to visual inspection. Mould sampling (Step 3) should only be initiated if the results of visual inspection (Step 2) are unclear. An investigation for hidden mould (Step 4) is conducted only if there is a strong suspicion of hidden mould, based on the inspection and sampling results and if there is a reasonable pathway for the suspected hidden mould to enter the indoor environment and become an important source of mould exposure for the building occupants. A mould assessment concludes with a decision about the presence of mould and moisture. Discovery of either mould or moisture means that additional investigation and possibly remediation needs to follow.

At the end of this process, an indoor occupied space is considered to be acceptable for mould and moisture if there is no visible mould growth on building surfaces (excluding naturally damp areas such as

[*] American Industrial Hygiene Association (AIHA). Recognition, Evaluation and Control of Indoor Mold. 2008. p. 131.

bathroom tiles and window sills), no indications of hidden mould, nor any unusual moisture sources identified such as ongoing leaks, moisture infiltration or excessive condensation. Prevention and awareness activities should be initiated; occupants need to be aware of how their activities can contribute to indoor mould and try to reduce the sources of moisture that can be controlled. Regular indoor environmental maintenance activities such as the use of HEPA vacuum cleaners, being vigilant about mould growth and moisture infiltration, and cleaning up moisture immediately can all contribute to better indoor environments.

5 Research Gaps

The mould assessment field has many points of controversy, mostly due to a lack of objective data and the potential risk presented by mould in the built environment. Future exposure assessment studies need to consider outdoor exposures and include appropriate controls.
Areas for future research include:

- Determining the impact of mould exposure outdoors, and how this compares to mould exposure indoors;
- Development of better exposure assessment methods, so that the health risks of mould exposure can be determined, and a risk-relevant exposure metrics can be developed;
- Development and validation of sampling and analytical methods to identify and accurately measure all microbial agents in indoor environments.

6 Appendix 1: Research process for mould assessment paper

Described below is the approach used to identify and evaluate guidelines and papers reviewed in NCCEH's *Mould Assessment in Indoor Environments*. This report does not intend to compare and contrast different guidelines, but to distill and present evidence-based or experience-based consensus recommendations about how to approach mould assessment. Guidelines and papers reviewed in the document are included in the tables at the end of this report.

6.1 Identifying and selecting relevant literature

To identify sources of information for this article, standard literature review processes were used. Recently published guidelines by the World Health Organization (WHO)[5], American Industrial Hygiene Association (AIHA)[1],the Institute of Inspection, Cleaning and Restoration (IICRC)[29], and the Institute of Medicine (IOM)[4], are considered benchmarks in the field and were used to identify the main issues and key words for literature searches. Guidelines used in the preparation of this article are listed in Table 1.

Scientific literature searches to identify relevant research papers were conducted using PubMed. The most relevant abstracts were selected based on the title of publication, and the most relevant papers were selected based on the abstract. As with any scientific literature review, additional references were identified while reading the research papers. Only those papers that were judged to be directly relevant to these documents were referenced in the paper or included in Table 2.

Most studies used in the preparation of these documents were from the peer-reviewed scientific literature. Although many technical studies exist, they were not referenced in the scientific literature and were difficult to locate.

6.2 Reviewing Mould Guidelines

Most of the mould guidelines are intended for one of the following audiences: policy makers[4,5], homeowners/residents[28,56], or remediation professionals[1,29]. Perspectives varied between the different guidelines; those written for remediation professionals were more specific and detailed and covered a wider scope of situations than the ones for policy makers or home owners.

There is not a clear method to evaluate guidelines. The Canadian Mortgage and Housing Corporation's *Clean-up Procedures for Mold in Homes*[28], included evaluation criteria, including (1) the credibility of the organization, (2) support or sanctioning by experts (3) how current is the information. The most recent guidelines were given the most emphasis because the field is evolving with regards to scientific and medical knowledge, new technologies, and new attitudes towards risk management. Only the most updated version from each organization was reviewed. Some older guidelines were consistently referenced in the newer publications, so were included for that reason[11,14,57].

With few exceptions, most guidelines reviewed were consistent in terms of the recommendations provided. While the guidelines suggested different processes and approaches to remediation, (for example some had a strong emphasis on documentation or QA/QC), the actual recommended activities for remediation were very similar from one guideline to another.

6.3 Challenges in evaluating the evidence

An effort was first made to evaluate the quality of the evidence presented in the scientific literature by adapting the approach used Downs and Black[58] to evaluate clinical trials research. Unfortunately, this approach was met with mixed success; the variability in situation, study design, intervention and evaluation methods made it difficult to compare mould studies. In the end, the method was simplified and the evaluation limited to the following there points: (1) Scientific strength (*Is the work scientifically valid? Does research take limitations into account? Are appropriate controls used?):* (2) Quality of evidence (*Do the results support the conclusion?*); (3) Appropriateness of study (*Is the situation representative of a typical mould or moisture situation encountered in homes? Is the intervention typical or applicable to a normal home?*). The approach taken was subjective and only papers that were applicable or relevant were included in the table. Literature reviews are included with the guidelines.

Table 1 Mould Guidelines Reviewed (arranged chronologically)

Guideline/ Author	Title	Year	Objectives	Type of publication/ endorsement
Yukon Health & Social Services, Environmental Health Services[59]	Interim Strategy for Responding to Mould in Rental Accommodations	2009	Framework for responding to complaints of mould in rental accommodations for Public Health Officers (PHOs) and Environmental Health Officers (EHOs). Intended for rental situations only.	Draft Guideline endorsed by Yukon Health & Social Services, Environmental Health Services
World Health Organization (WHO)[33]	Damp and Mould - Health risks, prevention and remedial actions	2009	Summarizes key messages that the general public needs to know in order to prevent and reduce the exposure to dampness and mould, and to remove potential mould once it occurs	Brochure/guideline developed in collaboration with WHO and the Health and Environment Alliance (HEAL), co-funded by the European Commission
World Health Organization (WHO)[5]	WHO guidelines for indoor air quality: dampness and mould	2009	Provides comprehensive review of the scientific evidence on health problems associated with building moisture and biological agents for public health and other authorities. Summarizes the available information on the conditions that determine the presence of mould and measures to control their growth indoors. Anticipated to remain valid until 2018.	Guidelines based on a scientific review of literature, developed by the WHO Regional Office for Europe in collaboration with WHO headquarters as part of the WHO programme on indoor air pollution.
National Collaborating Centre for Environmental Health (NCCEH)[60]	Recommendations for Safe Re-occupancy of Marijuana Grow Operations	2009	Practical approach to achieving safe re-occupancy of former marijuana grow-operations and a review of possible exposure hazards. Written for public health and municipal staff.	Recommendations by the National Collaborating Centre for Environmental Health
New York City Department of Health and Mental Hygiene[35]	Guidelines on Assessment and Remediation of Fungi in Indoor Environments	2008	Provides an approach to address potential and observed mold growth on structural materials in commercial, school, and residential buildings, for building owners and managers, environmental contractors and environmental consultants.	Guideline endorsed by the Environmental and Occupational Disease Epidemiology Unit of the New York City Department of Health and Mental Hygiene

Approved American National Standard (ANSI)/Institute of Inspection, Cleaning and Restoration Certification (IICRC)[29]	IICRC S520 Standard and Reference Guide for Professional Mold Remediation	2008	Defines criteria and methodology to be used by mould remediation professionals for inspecting mould contamination and establishing remediation procedures and safety plans.	Voluntary standard and reference guide. Institute of Inspection, Cleaning and Restoration Certification Standard, and Approved American National Standard.
American Industrial Hygiene Association (AIHA)[1]	Recognition, Evaluation and Control of Indoor Mold	2008	Comprehensive guidance for industrial hygienists on the topic of mould assessment. Detailed sampling protocols and techniques. Also covers remediation project management, communication and QA/QC. Deals with hidden mould.	Guidance by AIHA
World Health Organization (WHO)[61]	Interventions and actions against damp and mould - Report on a WHO working group meeting	2008	A review of practical interventions and their effectiveness in reducing exposure. Case studies on actions and interventions against damp and mould in indoor settings were reviewed and discussed by international experts during a review meeting.	Working group report, by WHO's panel of international experts
Health Canada[62]	Residential Indoor Air Quality Guidelines	2007	States a position on mould health and provides top recommendations for assessment and remediation.	Position statement by Health Canada
Calgary Health Region[63]	Fungal Air Testing, Investigation and Reporting Requirements for Marihuana Grow Operations (MGOs)	2007	Fungal air testing, investigation and reporting requirements for home owners.	Policy by Calgary Health Region
Calgary Health Region[13]	MGO Remediation Guidelines	2007	Describes the Calgary Health Region's current requirements to have an Unfit for Human Habitation Order and Notice of Health Hazard removed from a remediated MGO property. Written for public health inspectors.	Guideline by Calgary Health Region
US Dept of Labour, Occupational Safety and Health Administration (OSHA)[32]	Preventing Mold- Related Problems in the Indoor Workplace. A Guide for Building Owners, Managers and Occupants	2006	Guide helps owners, managers, and occupants understand and prevent building-related illnesses associated with mold problems in offices and other indoor workplaces. Focus was directed toward preventive measures to reduce potential environments for mold growth at the source.	Guideline by the US Department of Labour

Brandt M *et al.*[6]	Mold Prevention Strategies and Possible Health Effects in the Aftermath of Hurricanes and Major Floods	2006	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	Recommendations by United States Centre For Disease Control (CDC).
Scott, JA[28]	Clean-up procedures for mold in houses	2005	Purpose is to help homeowners (with little or no experience) to identify and correct straight forward problems. Builds on the Health Canada publications, 1993, 1995 and 2004.	Guideline by the Canadian Mortgage and Housing Corporation
Institute of Medicine (IOM) of the National Academies[4]	Damp Indoor Spaces and Health	2004	Examines health impacts of damp indoor environments and offers recommendations for public health interventions. Intended for a wide ranging audience of science, health, engineering and building professionals, government officials and members of the public.	Review by the IOM, supported by most other organizations.
Storey, *et al.*[34]	Guidance for Clinicians on the Recognition and Management of Health Effects Related to Mold Exposure and Moisture Indoors	2004	This guidance is designed to help the healthcare provider address patients with illnesses related to mold in the indoor environment by providing background understanding of how mold may be affecting patients.	Guidance supported by the US Environmental Protection Agency (EPA) and the University of Connecticut Health Centre
Health Canada[2]	Fungal Contamination in Public Buildings: Health Effects and Investigation Methods	2004	The purpose of this document is to assist front-line public health workers in the management of potential health risks associated with fungal contamination in public buildings.	Guideline by Health Canada
US Department of Labour, Occupational Safety and Health Administration (OSHA)[64]	A Brief Guide to Mold in the Workplace	2003	Provides recommendations for the prevention of mold growth and describes measures designed to protect the health of building occupants and workers involved in mold cleanup and prevention. Aimed at building managers, custodians, and others who are responsible for buildings.	Advisory Bulletin by the US Department of Labour

Horner, WE[65]	Assessment of the indoor environment: evaluation of mold growth indoors	2003	Review article focuses on assessment of mold in homes, intended for scientific audience (allergists and investigators).	Review article
Rogers, CA[22]	Indoor fungal exposure	2003	Review article focuses on current state of knowledge about assessment of indoor environments for fungal exposure. Intended for scientific audience.	Review article
US Environmental Protection Agency (EPA)[66]	A brief guide to mold, moisture, and your home.	2002	This guide provides information and guidance for homeowners and renters on how to clean up residential mold problems and how to prevent mold growth	Guideline by the US Environmental Protection Agency.
Canadian Mortgage and Housing Corporation (First Nations)[56]	Mold in Housing: An information kit for first nations communities	2002	Purpose is to help a broad spectrum audience respond to an existing mould situation and prevent future situations. Book is divided into sections for occupants and for specialists	Guideline - joint publication by the CMHC, Indian and Northern Affairs Canada, Assembly of First Nations Housing Secretariat, and Health Canada
US Environmental Protection Agency (EPA)[3]	Mold Remediation in schools and public buildings	2001	Guidelines for the remediation/cleanup of mold and moisture problems in schools and commercial buildings; includes measures designed to protect the health of building occupants and remediators. Targeted for building managers, custodians, and others who are responsible for commercial building and school maintenance.	Guidelines by the US Environmental Protection Agency.
Macher, J (ed): [11]	Bioaerosols - Assessment and Control	1999	Focuses on the identification and control of bioaerosols in non-manufacturing workplaces, empahsizing the evaluation of actual or potential bioaerosol exposure in office environments. Targeted at Industrial or occupational hygienists.	Guideline/text book by American Conference of Governmental Industrial Hygienists (ACGIH)
Flannigan, B and Morey, PR [57]	Task Force Report: TFI-1996 Control of Moisture Problems Affecting Biological Indoor Air Quality	1996	Guidelines for the control of moisture-related problems, with its focus being largely on the problems of the growth on fungi and bacteria and multiplication of mites.	Guideline by the International Society of Indoor Air Quality and Climate (ISIAQ)

Health Canada[14]	Fungal contamination in Public buildings: A guide to recognition and management	1995	Assists in the recognition and management of fungal contamination problems in public buildings. It also strives to further the understanding of the health significance of fungi detected in the course of building investigations. This guide applies to indoor air in all public buildings, excluding hospitals and industrial settings.	Guideline by Health Canada

Table 2 – Assessment evidence papers reviewed (sorted alphabetically)

Author	Title	Key conclusion	What they did, exactly
Baudisch, *et al.* 2009[42]	Concentrations of the genera *Aspergillus*, *Eurotium* and *Penicillium* in 63-µm house dust fraction as a method to predict hidden moisture damage in homes	Developed a method to evaluate hidden moisture damage by examining fungal indicators in house dust.	Tried to develop a method for assessing the mould load in houses, based on mould measurements taken from house dust and indoor air.
Betancourt, *et al.* 2007[67]	Method for evaluating mold growth on ceiling tile	The masticator method was demonstrated as efficient for bulk sampling of ceiling tiles.	Statistical analysis comparing results obtained by masticator extraction and the swab method was performed.
Charpin-Kadouch, *et al.*2006[47]	Mycotoxin identification in moldy dwellings	Evidence for mycotoxins (MCT) on walls and floors in moldy dwellings, but not in air samples. MCT levels were not correlated with the moldy surface areas.	Collected floor, wall and air samples from an index group comprising 15 flooded dwellings contaminated by *Stachybotrys chartarum* or *Chaetomium* and a control group of nine dwellings without molds on visual inspection and mold sampling.
Chew, *et al.* 2003[24]	Dustborne and airborne fungal propagules represent a different spectrum of fungi with differing relations to home characteristics.	Data do not indicate a strong relationship between culturable fungi in dust and indoor air. Essential to collect both air and dust samples, as well as information on housing characteristics, as indicators for fungal exposure.	Sequential duplicate 45-l air samples were collected in bedrooms of 496 homes. After air sampling, bedroom floors were sampled with a vacuum cleaner that was modified to collect dust in a cellulose extraction thimble.

Cho, *et al.* 2006[68]	The effect of home characteristics on dust antigen concentrations and loads in homes	*Alternaria* antigen level in house dust was not associated with visual mold or water damage.	On-site home visits, consisting of a home inspection, dust sampling, and questionnaires were conducted in 777 homes belonging to an ongoing birth cohort study in Cincinnati, Ohio.
Codina, *et al.* 2008[16]	Typical Levels of Airborne Fungal Spores in Houses Without Obvious Moisture Problems During a Rainy Season in Florida, USA	Airborne fungal spores are present in average homes without obvious moisture problems, at levels that are lower than those found outdoors. Suggests that indoor/outdoor ratios of airborne fungal spores should be evaluated in conjunction with other factors.	Eighteen single-family homes were selected based on protocol questionnaire and cursory inspection, which revealed no obvious moisture or visible fungal growth. Non-cultured spores were collected with Air-O-Cell cassette and analyzed by optical microscopy.
Dassonville, *et al.* 2008[36]	Assessment and predictors determination of indoor airborne fungal concentrations in Paris newborn babies' homes	Outdoor levels and season largely contributed to the variability of indoor total airborne fungal concentrations, which also depended on aeration and signs of dampness.	Sequential duplicate air samples were collected twice a year in the newborn's bedroom and outside the building.
Godish, *et al.* 2008[69]	Total Airborne Mold Particle Sampling: Evaluation of Sample Collection, Preparation and Counting Procedures, and Collection Devices	Count differences between samplers were relatively small compared with the large differences observed among three count magnifications.	Compared performance of three commercially available total mold spore sampling devices.
Haas, *et al.* 2007[41]	Assessment of indoor air in Austrian apartments with and without visible mold growth	Extent of visible mold growth is significantly correlated with concentrations of fungal spores in indoor air; the median of total spore concentration in the air of apartments with visible mold growth was 10 times higher than in the apartments without visible mold growth.	Collected fungal spore concentrations in air samples from 66 households, along with outdoor air as reference value. The size of the visible mold growth was categorized in order to correlate the extent of mold growth with the concentration of airborne spores as well as the fungal genera.
Haatainen, *et al.* 2010[70]	The Suitability of the IOM Foam Sampler for Bioaerosol Sampling in Occupational Environments	The IOM (Institute of Occupational Medicine (Scotland)) foam sampler performs well for collecting inhalable fungi and actinobacteria. However, the Andersen sampler provides better information on fungal genera.	Concurrent samples were collected with Andersen and IOM foam samplers to determine whether if the IOM foam sampler can be applied to collect culturable microorganisms.
Hagerhed-Engman, *et al.* 2009[71]	Low home ventilation rate in combination with moldy odour from the building structure increase the risk for allergic symptoms in children,	Association was found between moldy odour along skirting board and allergic symptoms. No associations found between allergic symptoms and discoloured stains, floor dampness or a general mold odour in the room. Furthermore, low ventilation rate increased risk.	In a nested case-control study of 400 Swedish children, observations and measurements were performed in their homes by inspectors, and the children were examined by physicians for diagnoses of asthma, eczema, and rhinitis.
Hagerhed-Engman, *et al.* 2009[39]	Building characteristics associated with moisture related problems in 8,918 Swedish dwellings.	Single-family houses, older houses, flat-roofed houses built in the 1960s and 1970s, houses with a concrete slab on the ground that were built before 1983 are associated with one or more of the dampness indicators (visible dampness, condensation, mould odour, floor moisture, dry air). Moreover, tenancy and earlier renovation due to mould or moisture problems was strongly associated with dampness.	A questionnaire study about home environment with a focus on dampness problems and health was conducted in one county of Sweden (8,918 homes, response rate 79%).

Hicks, *et al.* 2005[23]	Air samples and Fungal Types and Concentrations from Settled Dust in Normal Residences	Disputes the use of numerical limits as definitive evidence that a residential surface is contaminated with unusual amounts of culturable fungi. Settled dust sampling is appropriate for determining the fungal status of a localized area, or as a gross screening tool, but using settled dust results alone to establish the presence of unusual fungal types or concentrations within a structure is not recommended.	Collection and analysis of surface dust from 26 residential environments with no mould or moisture damage.
Horner, *et al.* 2004[72]	Air- and Dustborne Mycoflora in Houses Free of Water Damage and Fungal Growth	Established baseline levels for mould in non-moisture damaged homes. Did not find any indicator species in these homes.	Each home was visually examined, and samples of indoor and outdoor air and of indoor settled dust were taken in winter and summer.
Hyvärinen, *et al.* 2006[38]	Characterizing Microbial Exposure With Ergosterol, 3-Hydroxy Fatty Acids, and Viable Microbes in House Dust: Determinants and Association With Childhood Asthma	The variation of microbial levels in dust could be explained relatively well by home characteristics. Ergosterol was associated with livestock and cleaning rugs outside; viable fungi was associated with the material used in the building frame, visible mold, and the practice of cleaning rugs outside.	Measured building characteristics are related it to other factors measured.
Iossifova *et al.* 2008[46]	Use of (1-3)-b-D-glucan concentrations in dust as a surrogate method for estimating specific fungal exposures	It is not practical to measure all fungal species found indoors, no matter what analytical system is used. The (1-3)-b-D-glucan content of different fungal species varies widely. (1-3)-b-D-glucan concentration in field samples as a surrogate for total fungal exposure should be used with caution.	Used quantitative PCR (QPCR) method to analyze 36 indoor fungal species in 297 indoor dust samples. These samples were also simultaneously analyzed for (1-3)-b-D-glucan concentration using the endpoint chromogenic Limulus Amebocyte lysate assay
Johnson, *et al.* 2008[51]	Professional Judgment and the Interpretation of Viable Mold Air Sampling Data	Professional judgment in the evaluation of airborne mold sampling data leads to inconsistent conclusions regarding the presence of an indoor mold source.	A survey containing 30 sets of viable mold (Andersen N6) air sampling results from indoor air quality studies was mailed to 40 indoor air quality practitioners. Recipients had no information about occupant health symptoms, building history, investigator observations, or other data that might influence their decisions.
Kaarakainen, *et al*. 2009[15]	Microbial content of house dust samples determined with qPCR	Microbial concentrations varied significantly between different seasons, within the home and between different homes.	Two types of vacuumed house dust samples, rug dust and vacuum cleaner bag dust, were collected in 5 normal urban homes in four different seasons
Krstic, G. 2003[52]	Airborne Mould Concentrations in the Indoor Environment of "Mouldy Buildings"	In the absence of visible mould development on the interior surfaces of water-damaged buildings, mould in enclosed spaces of building structure do not necessarily lead to elevated concentrations of airborne mould spores in the indoor environment.	Measured airborne spore counts in 31 water-damaged buildings and compared to outdoor concentrations.

Lee, *et al.* 2004[73]	A field comparison of four samplers for enumerating fungal aerosols I. Sampling characteristics	These results indicate that fungal airborne concentration data are dependent on the methods used for assessment, and introduce additional variability in exposure assessment studies. There were differences between the samplers in detection limits, reproducibility, and overall yield.	Study compared three culturable sampling devices and one particulate sampling device, in offices and public areas in a variety of buildings, under conditions of forced air or natural ventilation.
Macher, *et al.* 2008[19]	Chamber Evaluation of a Personal, Bioaerosol Cyclone Sampler	These chamber tests have shown that the cyclone is suitable for collection of airborne fungal spores over a wide concentration range and time period and for analysis by microscopy, culture, and polymerase chain reaction (PCR).	To test personal cyclone sampler (cyclone), side by side with a 25-mm filter sampler (filter) and either a slit impactor (Air-O-Cell) or a single-stage, multiple-hole, agar impactor (N6), with fungal spore aerosols.
Macher, *et al.* 2008[20]	Field Evaluation of a Personal, Bioaerosol Cyclone Sampler	The personal cyclone may be considered for collection of and outdoor airborne spores and for analysis by traditional and advanced assay methods.	The suitability of the personal cyclone for collection of ambient, naturally generated fungal spores was examined through simultaneous, side-by-side comparisons with the previously tested filter sampler and two devices widely used in aerobiological research that were too large to evaluate in the chamber study.
Meklin, *et al.* 2007[17]	Comparison of mold concentrations quantified by MSQPCR in indoor and outdoor air sampled simultaneously	Authors concluded that an evaluation of the mold burden indoors by a simple genus level comparison to the outdoors may be misleading, and interpretation of the meaning of short-term (<48 h) mold measurements in indoor and outdoor air samples must be made with caution. Conclusion may be biased.	Mold specific quantitative polymerase chain reaction (MSQPCR) was used to measure the concentrations of the 36 mold species in indoor and outdoor air samples that were taken simultaneously for 48 h in and around 17 homes.
Niemeier, *et al*. 2006[74]	Assessment of Fungal Contamination in Moldy Homes: Comparison of Different Methods	These findings confirm that reliance on one sampling or enumeration method for characterization of an indoor mold source might not provide an accurate estimate of fungal contamination of a microenvironment.	Four methods were used to quantify mold contamination in 13 homes with visible mold: swab and settled dust, fungal spore source strength tester (FSSST), and air sampling. Relationships between the data obtained with the four different sampling methods were examined using correlation analysis.
Park, *et al.* 2004[31]	Building-related respiratory symptoms can be predicted with semi-quantitative indices of exposure to dampness and mold	Conditions suggestive of indoor mold exposure at work were associated with building-related respiratory symptoms. Suggests that observational semi-quantitative indices of exposure to dampness and mold can support action to prevent building-related respiratory diseases.	Collected data on upper and lower respiratory symptoms and their building relatedness, and time spent in specific rooms with a self-administered questionnaires.

Park, *et al.* 2008[25]	Hydrophilic Fungi and Ergosterol Associated with Respiratory Illness	Among employees in a building with a long history of water damage, respiratory symptoms and post-occupancy asthma were strongly associated with fungi in a linear exposure–response manner, especially the levels of hydrophilic fungi (including yeasts) in dust.	Analyzed dust samples collected from floors and chairs of 323 cases and comparisons for culturable fungi, ergosterol, endotoxin, and cat and dog allergens. They examined associations of total fungi, hydrophilic fungi (requiring water activity ≥ 0.9), and ergosterol with the health outcomes using logistic regression models.
Petronella, *et al.* 2005[50]	Clearing the Air: A Model for Investigating Indoor Air Quality in Texas Schools	In general, Tools for Schools provides an excellent foundation for a school indoor air quality program, although the authors did find it necessary to streamline data collection and did find that mold with the potential for adverse health effects was present, albeit not visible in some areas.	The overall goal was to determine if use of Tools/or Schools was sufficient to identify conditions with the potential to cause adverse health effects.
Pietarinen, *et al*. 2008[75]	Quantitative PCR analysis of fungi and bacteria in building materials and comparison to culture-based analysis	In general, the results of the two methods did not correlate well, since concentrations of fungi and streptomycetes were higher and their occurrence more prevalent when determined by qPCR compared to culture-based results. However, with increasing concentrations, the correlation generally increased.	Quantitative PCR (qPCR) used for the detection of selected fungal and bacterial groups in 184 building materials of different types and compared the results with culture-based analysis.
Polizzi, *et al.* 2009[48]	Fungi, mycotoxins and microbial volatile organic compounds in mouldy interiors from water-damaged buildings	In general, the fungi identified matched well with the mycotoxins detected. Did not get a good correlation between mould and mVOC.	The presence of fungi, 20 mycotoxins and mVOC was investigated in 99 samples (air, dust, wallpaper, mycelium or silicone) collected in the mouldy interiors of seven water-damaged buildings.
Portnoy, *et al.* 2004[10]	Sampling for Fungi	Standardized approaches for performing and reporting assessments of indoor fungi are essential if our understanding of this complex field is to improve. This paper strongly supported sampling.	Reviewed the medical literature and described a hypothesis-driven approach to planning, sampling, and interpreting the results of indoor assessments for fungi. Discusses many different sampling methods including those for mVOCs.
Reboux, *et al.* 2009[76]	Indoor mold concentration in Eastern France	Fungal species did not correlate with health risk. Rest of conclusions vague.	Prospective case–control study of 118 dwellings, examined fungal contamination in 32 homes with visible mold contamination and adverse health outcomes reported by the occupants, 27 dwellings occupied by allergic patients (with medical diagnostic and positive prick-tests for molds) and 59 matched control dwellings.
Roussel, *et al.* 2008[30]	Characteristics of dwellings contaminated by moulds	If the occupant is sick, if the source of fungal contamination is not clear, or if the presence of moulds is strongly suspected without odour or visible spots, air samples must be taken.	Studied 128 dwellings: 69 dwellings with problems of moulds and humidity health symptoms, and 59 dwellings with healthy occupants.
Schleibinger, *et al.* 2008[49]	Microbial volatile organic compounds in the air of moldy and mold-free indoor environments	The results show no significant association between most of the analyzed MVOC and the mold status.	Air sampling for MVOC was performed in 40 dwellings with evident mold damage and in 44 dwellings where mold damage was excluded after a thorough investigation.

Schuchardt and Kruse, 2009[45]	Quantitative volatile metabolite profiling of common indoor fungi: relevancy for indoor air analysis	Most of the microbial-produced VOC concentrations were below the analytical detection limit for conventional indoor air analysis. Indoor air analysis in mold homes confirmed these findings. The present findings raise doubts about the utility of indicator VOC for the detection of hidden mold growth in indoor environments.	Examined 14 typical indoor fungal strains for their growth rates and their capability to produce volatile organic compounds (VOC) on standard clinical media and on agar medium made from building materials.
Sen and Asan, 2009[77]	Fungal flora in indoor and outdoor air of different residential houses in Tekirdag City (Turkey): Seasonal distribution and relationship with climatic factors	Correlations between the presence of *Aspergillus,* temperature, relative humidity, duration of sunny periods and agents of air pollution were statistically significant. No significant correlations found between other fungal genera and environmental variables.	Six homes were tested, both indoors and outdoors. Samples were collected by exposing petri plates 1.4 meters above the ground.
Sordillo, *et al.* 2009[26]	Development of a new isotopically labeled internal standard for ergosterol measurement by GC/MS	Developed a new internal standard for an existing GC/MS assay for ergosterol measurement in environmental samples.	We developed an isotopically labelled internal standard for ergosterol quantification by GC/MS/MS, to eliminate bias due to sample matrix effects and selective losses during preparation.
Toivola and Nevalainen, 2004[21]	Personal exposures to particles and microbes in relation to micro-environmental concentrations	While the concentrations of viable fungi were related between personal and home concentrations, the time weighted micro-environmental model underestimated the personal exposures of viable fungi and total fungi.	Determined particle mass concentration, black smoke (BS) concentration and concentrations of viable and total microorganisms on the sampled filters were determined using personal exposure sampling and micro-environmental measurements in homes and workplaces.
Vesper, *et al.* 2009[78]	Screening Tools to Estimate Mold Burdens in Homes	Two screening tools were developed for estimating the mold burden in homes. The full ERMI analysis provides a more precise estimate of the mold burden, application of the reduced ARMI scale and VB dust may be useful as screening tools.	Two possible screening methods were considered for mold analysis: use of vacuum cleaner bag dust rather than the standard protocol dust samples and reducing the number of molds needed to be quantified resulting in the creation of an alternative mold burden scale.
Vesper, *et al.* 2009[43]	Correlation between ERMI Values and Other Moisture and Mold Assessments of Homes in the American Healthy Homes Survey	Some correlation between inspection and ERMI. The ERMI analysis of dust from homes may be useful in finding hidden mold problems.	Evaluate the correlation between the Environmental Relative Moldiness Index (ERMI) values and the inspector's "walkthrough" assessment of visual or olfactory evidence of mold combined with occupant's answers to a questionnaire about mold odours and moisture.
Vesper, *et al.* 2008[44]	Higher Environmental Relative Moldiness Index (ERMI) values measured in Detroit homes of severely asthmatic children	The ERMI values in the homes of severely asthmatic children were significantly greater compared to the nonasthmatics. *Aspergillus niger* and *Aspergillus unguis* were the primary mold species that distinguished severely asthmatic children's homes and nonasthmatic children's homes.	Used the ERMI to correlate mouldiness with children's asthma.

Vesper, *et al.* 2007[79]	Relative moldiness index as predictor of childhood respiratory illness	The binary classification of homes as either moldy or non-moldy by on-site visual home inspection was not predictive of the development of respiratory illness, however a method based on the RMI index fit to a logistic function, can be used to predict the occurrence of illness in homes and allows stake-holders the choice among various levels of risk.	The purpose of this study is to examine the predictive value of the RMI compared to the traditional mold inspection and wheezing and/or rhinitis in infants.
Vesper, *et al.* 2007[80]	Development of an Environmental Relative Moldiness Index for US Homes	The Environmental Relative Moldiness Index scale may be useful for home mold-burden estimates in epidemiological studies.	The objective of this study was to establish a national relative moldiness index for homes in the United States.
Vesper, *et al.* 2005[81]	Comparison of populations of mould species in homes in the UK and USA using mould-specific quantitative PCR	MSQPCR analysis of dust samples can provide an objective measure of indoor moulds which could lead to better management of their health effects.	Compared mould species from dust in British and US homes - analysed species and did a statistical comparison of common species.
Vishwanath, *et al.* 2009[82]	Simultaneous determination of 186 fungal and bacterial metabolites in indoor matrices by liquid chromatography/tandem mass spectrometry	The method is a valuable tool for obtaining a comprehensive picture of the range of potentially toxic metabolites produced by various fungal and bacterial genera occurring in damp indoor environments, as demonstrated in case of the 20 different analytes identified in the investigated real-world samples.	Tried to develop a quantitative analysis of a wide variety of fungal metabolites from dust and other indoor materials. Applied method to indoor damp homes.

7 Acknowledgements

The author gratefully acknowledges Goran Krstic, Mona Shum, Jeff Hicks, Del Malzahn and Keith Smith for their input and review of the manuscript.

8 References: Papers and Guidelines Reviewed

1. American Industrial Hygiene Association (AIHA). Recognition, Evaluation and Control of Indoor Mold. 2008.

2. Health Canada. Fungal Contamination in Public Buildings: Health Effects and Investigation Methods. 2004. Available at: http://www.hc-sc.gc.ca/ewh-semt/pubs/air/fungal-fongique/index-eng.php (Accessed March 4, 2010).

3. Environmental Protection Agency. Mold Remediation in Schools and Commercial Buildings. 2001. Available at http://www.epa.gov/mold/mold remediation.html (Accessed March 4, 2010).

4. Institute of Medicine. Damp Indoor Spaces and Health. Washington, DC: National Academies Press, 2004.

5. World Health Organization. WHO guidelines for indoor air quality: dampness and mould. 2009. Available at: http://www.euro.who.int/document/E92645.pdf (Accessed March 4, 2010).

6. Brandt M et al. Mold Prevention Strategies and Possible Health Effects in the Aftermath of Hurricanes and Major Floods Morbidity and Mortality Weekly Report, Morbidity and Mortality Weekly Report. Recommendations and Reports June 9, 2006. Vol. 55; No. RR-8.

7. Wu F, Takaro TK. Childhood asthma and environmental interventions. Environ Health Perspect. 2007. Jun;115(6):971-5. Review.

8. Kovesi T, Creery D, Gilbert NL, Dales R, Fugler D, Thompson B, Randhawa N, Miller JD. Indoor air quality risk factors for severe lower respiratory tract infections in Inuit infants in Baffin Region, Nunavut: a pilot study. Indoor Air. 2006. Aug;16(4):266-75.

9. Straus DC. Molds, mycotoxins, and sick building syndrome. Toxicology and Industrial Health. 2009. Oct-Nov;25(9-10):617-35. Review.

10. Portnoy JM, Barnes CS, Kennedy K. Sampling for indoor fungi. J Allergy Clin Immunol. 2004. Feb;113(2):189-98; quiz 199. Review.

11. Macher, J. (ed): *Bioaerosols: Assessment and Control*. Cincinnati, Ohio: American Conference of Governmental Hygienists (ACGIH). 1999.

12. Rao CY and Burge HA. Review of quantitative standards and guidelines for fungi in indoor air. J Air Waste Manag Assoc. 1996. Sep;46(9):899-908.

13. Calgary Health Region. Marihuana Grow Operation Remediation Guidelines. 2007. Available at: http://www.calgaryhealthregion.ca/publichealth/envhealth/program_areas/illegal_drug_operations/documents/MARIHUANA_GROW_OPERATION_REMEDIATION_November_07.pdf (Accessed April 13, 2010).

14. Health Canada, Federal-Provincial Committee on Environmental and Occupational Health. Fungal Contamination in Public Buildings: A Guide to Recognition and Management. June 1995. Available at: http://individual.utoronto.ca/jscott/fpwgmaqpb001.pdf (Accessed March 4, 2010).

15. Kaarakainen P, Rintala H, Vepsäläinen A, Hyvärinen A, Nevalainen A, Meklin T. Microbial content of house dust samples determined with qPCR. Sci Total Environ. 2009 Aug 1;407(16):4673-80.

16. Codina R, Fox RW, Lockey RF, DeMarco P, Bagg A. Typical levels of airborne fungal spores in houses without obvious moisture problems during a rainy season in Florida, USA. J Investig Allergol Clin Immunol. 2008. 18(3):156-62.

17. Meklin T, Reponen T, McKinstry C, Cho SH, Grinshpun SA, Nevalainen A, Vepsäläinen A, Haugland RA, Lemasters G, Vesper SJ. Comparison of mold concentrations quantified by MSQPCR in indoor and outdoor air sampled simultaneously. Sci Total Environ. 2007. Aug 15;382(1):130-4.

18. Franck U, Tuch T, Manjarrez M, Wiedensohler A, Herbarth O. Indoor and Outdoor Submicrometer Particles: Exposure and Epidemiologic Relevance (''The 3 Indoor Ls''). Environ Toxicol. 2006. Dec;21(6):606-13.

19. Macher J, Chen B, Rao C. Chamber evaluation of a personal, bioaerosol cyclone sampler. J Occup Environ Hyg. 2008. Nov;5(11):702-12.

20. Macher J, Chen B, Rao C. Field evaluation of a personal, bioaerosol cyclone sampler. J Occup Environ Hyg. 2008b Nov;5(11):724-34.

21. Toivola M, Nevalainen A, Alm S. Personal exposures to particles and microbes in relation to microenvironmental concentrations. Indoor Air. 2004. Oct;14(5):351-9.

22. Rogers, CA Indoor fungal exposure. Immunol Allergy Clin N Am. 2003. 23:501–518.

23. Hicks JB, Lu ET, De Guzman R, Weingart M. Fungal types and concentrations from settled dust in normal residences. J Occup Environ Hyg. 2005. Oct;2(10):481-92.

24. Chew GL, Rogers C, Burge HA, Muilenberg ML, Gold DR. Dustborne and airborne fungal propagules represent a different spectrum of fungi with differing relations to home characteristics. Allergy. 2003. Jan;58(1):13-20.

25. Park JH, Cox-Ganser JM, Kreiss K, White SK, Rao CY. Hydrophilic fungi and ergosterol associated with respiratory illness in a water-damaged building. Environ Health Perspect. 2008. Jan;116(1):45-50.

26. Sordillo J, Vespa D, Haggerty L, Youngs F, Gold D, Milton D. Development of a new isotopically labeled internal standard for ergosterol measurement by GC/MS. J Environ Monit. 2009. Aug;11(8):1513-7.

27. Korpi A, Jarnberg J, Pasanen A. Microbial Volatile Organic Compounds. Critical Reviews in Toxicology. 2009. 39:139–193.

28. Scott JA. Clean-up Procedures for Mold in Houses. 2005 Ottawa: Canada Mortgage and Housing Corporation Press, 90 pp. ISBN: 0-660-19227-6.

29. Institute of Inspection, Cleaning, and Restoration Certification (IICRC): IICRC S520 Standard and Reference Guide for Professional Mold Remediation. 2008. Vancouver, Wash.

30. Roussel S, Reboux G, Bellanger AP, Sornin S, Grenouillet F, Dalphin JC, Piarroux R, Millon L. Characteristics of dwellings contaminated by moulds. J Environ Monit. 2008. Jun;10(6):724-9.

31. Park JH, Schleiff PL, Attfield MD, Cox-Ganser JM, Kreiss K. Building-related respiratory symptoms can be predicted with semi-quantitative indices of exposure to dampness and mold. Indoor Air. 2004. Dec;14(6):425-33.

32. Occupational Safety and Health Administration (OSHA). Preventing Mold-Related Problems in the Indoor Workplace. 2006. OSHA 3304-04N Available at: http://www.osha.gov/Publications/preventing_mold.pdf (Accessed March 5, 2010).

33. World Health Organization. Damp and Mould - Health risks, prevention and remedial actions. 2009. Available at: http://www.euro.who.int/document/hoh/damp_mould_brochure.pdf (Accessed March 4, 2010).

34. Storey E, et al. Guidance for clinicians on the recognition and management of health effects related to mold exposure and moisture indoors. 2004. Available at: http://oehc.uchc.edu/images/PDFs/MOLD%20GUIDE.pdf (Accessed March 4, 2010).

35. New York City Department of Health and Mental Hygiene. Guidelines on Assessment and Remediation of Fungi in Indoor Environments. 2008. Available at: http://www.nyc.gov/html/doh/downloads/pdf/epi/epi-mold-guidelines.pdf (Accessed March 4, 2010).

36. Dassonville C, Demattei C, Vacquier B, Bex-Capelle V, Seta N, Momas I. Indoor airborne endotoxin assessment in homes of Paris newborn babies. Indoor Air. 2008. Dec;18(6):480-7.

37. Health Canada. Exposure Guidelines for Residential Indoor Air Quality; A Report of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1995. Available at: http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/air/exposure-exposition/exposure-exposition-eng.pdf (Accessed March 4, 2010).

38. Hyvärinen A, Sebastian A, Pekkanen J, Larsson L, Korppi M, Putus T, Nevalainen A. Characterizing microbial exposure with ergosterol, 3-hydroxy fatty acids, and viable microbes in house dust: determinants and association with childhood asthma. Arch Environ Occup Health. 2006. Jul-Aug;61(4):149-57.

39. Hägerhed-Engman L, Bornehag CG, Sundell J. Building characteristics associated with moisture related problems in 8,918 Swedish dwellings. Int J Environ Health Res. 2009. Jun 19:1-15.

40. Tranter DC, Wobbema AT, Norlien K, Dorschner DF. Indoor allergens in Minnesota schools and child care centers. J Occup Environ Hyg. 2009. Sep;6(9):582-91.

41. Haas D, Habib J, Galler H, Buzina W, Schlacher R , Marth E , Reinthaler F F. Atmospheric environment Assessment of indoor air in Austrian apartments with and without visible mold growth. Indoor Air. 2005. International Conference on Indoor Air Quality and Climate No10, Beijing , China. 2007, vol. 41:25 (112 p.), pp. 5192-5201.

42. Baudisch C, Assadian O, Kramer A. Concentration of the genera *Aspergillus, Eurotium* and *Penicillium* in 63-microm house dust fraction as a method to predict hidden moisture damage in homes. BMC Public Health. 2009. Jul 17;9:247.

43. Vesper S, McKinstry C, Cox D, Dewalt G. Correlation between ERMI Values and Other Moisture and Mold Assessments of Homes in the American Healthy Homes Survey. J Urban Health. 2009. Nov;86(6):850-60.

44. Vesper S, McKinstry C, Haugland R, Neas L, Hudgens E, Heidenfelder B, Gallagher J. Higher Environmental Relative Moldiness Index (ERMI^{sm}) values measured in Detroit homes of severely asthmatic children. Sci Total Environ. 2008. May 1;394(1):192-6.

45. Schuchardt S, Kruse H. Quantitative volatile metabolite profiling of common indoor fungi: relevancy for indoor air analysis. J Basic Microbiol. 2009. Aug;49(4):350-62.

46. Iossifova Y, Reponen T, Sucharew H, Succop P, Vesper S. Use of (1-3)-beta-d-glucan concentrations in dust as a surrogate method for estimating specific fungal exposures. Indoor Air. 2008. Jun;18(3):225-32.

47. Charpin-Kadouch C, Maurel G, Felipo R, Queralt J, Ramadour M, Dumon H, Garans M, Botta A, Charpin D. Mycotoxin identification in moldy dwellings. J Appl Toxicol. 2006. Nov-Dec;26(6):475-9.

48. Polizzi V, Delmulle B, Adams A, Moretti A, Susca A, Picco AM, Rosseel Y, Kindt R, Van Bocxlaer J, De Kimpe N, Van Peteghem C, De Saeger S. JEM Spotlight: Fungi, mycotoxins and microbial volatile organic compounds in mouldy interiors from water-damaged buildings. J Environ Monit. 2009 Oct;11(10):1849-58.

49. Schleibinger H, Laussmann D, Bornehag CG, Eis D, Rueden H. Microbial volatile organic compounds in the air of moldy and mold-free indoor environments. Indoor Air. 2008. Apr;18(2):113-24.

50. Petronella SA, Thomas R, Stone JA, Goldblum RM, Brooks EG. Clearing the air: a model for investigating indoor air quality in Texas schools. J Environ Health. 2005. Jun;67(10):35-42.

51. Johnson D, Thompson D, Clinkenbeard R, Redus J. Professional judgment and the interpretation of viable mold air sampling data. J Occup Environ Hyg. 2008. Oct;5(10):656-63.

52. Krstic G. Airborne Mould Concentrations in the Indoor Environment of "Mouldy Buildings". Proceedings of the 9th Canadian Conference on Building Science and Technology. February 2003. Vancouver, British Columbia.

53. Kauffman CA. Histoplasmosis: a clinical and laboratory update. Clin Microbiol Rev. 2007 Jan;20(1):115-32.

54. Pfaller MA, Diekema DJ. Epidemiology of invasive mycoses in North America. Crit Rev Microbiol. 2010;36(1):1-53.

55. Harkinezhad T, Geens T, Vanrompay D. Chlamydophila psittaci infections in birds: a review with emphasis on zoonotic consequences. Vet Microbiol. 2009. Mar 16;135(1-2):68-77. Epub 2008. Sep 16.

56. Health Canada, Indian and Northern Affairs Canada, Assembly of First Nations and Canadian Mortgage and Housing Corporation. Mold in Housing: An Information Kit for First Nations Communities. 2002. Publication 62245.

57. Flannigan B and Morey PR. ISIAQ Task Force Report: TFI-1996 Control of Moisture Problems Affecting Biological Indoor Air Quality. International Society of Indoor Air Quality and Climate (ISIAQ). 1996.

58. Downs SH and Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. Epidemiol Community Health. 1998. 52:377-384.

59. Yukon Health & Social Services, Environmental Health Services. Interim Strategy for Responding to Mould in Rental Accommodations. 2009. (Used with permission of Yukon Health & Social Services).

60. National Collaborating Centre for Environmental Health (NCCEH). Recommendations for Safe Re-occupancy of Marijuana Grow Operations. 2009. Available at: http://www.ncceh.ca/files/Marijuana_Grow_Operations_Mar_2009.pdf (Accessed March 4, 2010).

61. World Health Organization. Interventions and actions against damp and mould - Report on a WHO working group meeting. 2008. Available at: http://www.euro.who.int/Document/E91664.pdf (Accessed March 4, 2010).

62. Health Canada. Residential Indoor Air Quality Guidelines - Moulds. 2007. Available at: http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/air/mould-moisissures-eng.pdf (Accessed March 4, 2010).

63. Calgary Health Region. Fungal Air Testing, Investigation and Reporting Requirements for Marihuana Grow Operations. 2007. Available at: http://www.calgaryhealthregion.ca/publichealth/envhealth/program_areas/illegal_drug_operations/documents/AirSamplingProtocol.pdf (Accessed April 13, 2010).

64. U.S. Department of Labor. Occupational Safety and Health Administration (OSHA). A Brief Guide to Mold in the Workplace. Safety and Health Information Bulletin (SHIB 03-10-10). 2003. Available at: http://www.osha.gov/dts/shib/shib101003.html (Accessed March 4, 2010).

65. Horner WE. Assessment of the indoor environment: evaluation of mold growth indoors. Immunol Allergy Clin North Am. 200.3 Aug;23(3):519-31. Review.

66. US Environmental Protection Agency. A Brief Guide to Mold, Moisture and your Home (EPA 402-K-02-003). Available at: http://www.epa.gov/mold/pdfs/moldguide.pdf (Accessed May 11, 2010).

67. Betancourt DA, Dean TR, Menetrez MY. Method for evaluating mold growth on ceiling tile. J Microbiol Methods. 2005. Jun;61(3):343-7.

68. Cho SH, Reponen T, Bernstein DI, Olds R, Levin L, Liu X, Wilson K, Lemasters G. The effect of home characteristics on dust antigen concentrations and loads in homes. Sci Total Environ. 2006. Dec 1;371(1-3):31-43.

69. Godish D, Godish T. Total airborne mold particle sampling: evaluation of sample collection, preparation and counting procedures, and collection devices. J Occup Environ Hyg. 2008. Feb;5(2):100-6.

70. Haatainen S, Laitinen J, Linnainmaa M, Reponen T, Kalliokoski P. The suitability of the IOM foam sampler for bioaerosol sampling in Occupational Environments. J Occup Environ Hyg. 2010. Jan;7(1):1-6.

71. Hägerhed-Engman L, Sigsgaard T, Samuelson I, Sundell J, Janson S, Bornehag CG. Low home ventilation rate in combination with moldy odor from the building structure increase the risk for allergic symptoms in children. Indoor Air. 2009. Jun;19(3):184-92.

72. Horner WE, Worthan AG, Morey PR. Air- and dustborne mycoflora in houses free of water damage and fungal growth. Appl Environ Microbiol. 2004. Nov;70(11):6394-400.

73. Lee KS, Bartlett KH, Brauer M, Stephens GM, Black WA, Teschke K. A field comparison of four samplers for enumerating fungal aerosols I. Sampling characteristics. Indoor Air. 2004. Oct;14(5):360-6.

74. Niemeier RT, Sivasubramani SK, Reponen T, Grinshpun SA. Assessment of fungal contamination in moldy homes: comparison of different methods. J Occup Environ Hyg. 2006. May;3(5):262-73.

75. Pietarinen VM, Rintala H, Hyvärinen A, Lignell U, Kärkkäinen P, Nevalainen A. Quantitative PCR analysis of fungi and bacteria in building materials and comparison to culture-based analysis. J Environ Monit. 2008. May;10(5):655-63.

76. Reboux G, Bellanger AP, Roussel S, Grenouillet F, Sornin S, Piarroux R, Dalphin JC, Millon L. Indoor mold concentration in Eastern France. Indoor Air. 2009. Dec;19(6):446-53. Epub 2009. Feb 13.

77. Sen B, Asan A. Fungal flora in indoor and outdoor air of different residential houses in Tekirdag City (Turkey): seasonal distribution and relationship with climatic factors. Environ Monit Assess. 2009. Apr;151(1-4):209-19.

78. Vesper S, McKinstry C, Bradham K, Ashley P, Cox D, Dewalt G, Lin KT. Screening tools to estimate mold burdens in homes. J Occup Environ Med. 2009. Jan;51(1):80-6.

79. Vesper SJ, McKinstry C, Haugland RA, Iossifova Y, Lemasters G, Levin L, Khurana Hershey GK, Villareal M, Bernstein DI, Lockey J, Reponen T. Relative moldiness index as predictor of childhood respiratory illness. J Expo Sci Environ Epidemiol. 2007. Jan;17(1):88-94. Epub 2006. Oct 11.

80. Vesper S, McKinstry C, Haugland R, Wymer L, Bradham K, Ashley P, Cox D, Dewalt G, Friedman W. Development of an Environmental Relative Moldiness index for US homes. J Occup Environ Med. 2007. Aug;49(8):829-33.

81. Vesper SJ, Wymer LJ, Meklin T, Varma M, Stott R, Richardson M, Haugland RA. Comparison of populations of mould species in homes in the UK and USA using mould-specific quantitative PCR. Lett Appl Microbiol. 2005. 41(4):367-73.

82. Vishwanath V, Sulyok M, Labuda R, Bicker W, Krska R. Simultaneous determination of 186 fungal and bacterial metabolites in indoor matrices by liquid chromatography/tandem mass spectrometry. Anal Bioanal Chem. 2009. Nov;395(5):1355-72.