Mould Remediation in Indoor Environments –

Review of Guidelines & Evidence

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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.
- The main goal of remediation is to reduce the risk of exposure to mould and to prevent structural damage; the underlying cause of dampness must be identified and eliminated, or mould will reappear.
- Effective mould remediation requires the physical removal of mould growth and spores. Even dead mould can cause negative health effects.
- Strategies must be employed to reduce the risk to workers and occupants during remediation.
- Ongoing prevention is the most important concept in mould intervention; keep all surfaces in the home as clean and as dry as possible to prevent mould from growing.

1 Introduction & Scope

This report provides mould remediation recommendations to Public Health Inspectors (PHIs) and Environmental Health Officers (EHOs) with the intention of making living conditions in homes better for the occupants. The mould remediation recommendations are based on available evidence from current research papers and mould assessment guidelines. Due to the lack of scientific evidence in this area, most guidelines are based on practical experience and common sense or on risk evaluation and mitigation principles. As stated by the Institute of Inspection, Cleaning and Restoration Certification (IICRC), "*The mold remediation procedures ... are based on generally accepted industrial hygiene practices, and safety and health principles*"[*]. With few exceptions, most guidelines reviewed were consistent in terms of the recommendations provided.

This document focuses specifically on mould in indoor environments, but acknowledges that damp[**] indoor spaces also encourage the presence or growth of other agents influencing air quality and health, such as bacteria, dust mites, pet allergens, and gases from building deterioration[1]. The recommendations provided in this report are primarily intended for homes. While general mould

[*] Institute of Inspection, Cleaning, and Restoration Certification (IICRC): IICRC S520 Standard and Reference Guide for Professional Mold Remediation. 2008. Vancouver, Wash. p.162

[**] 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.

remediation principles apply to schools, workplaces, public and commercial buildings affected by indoor dampness and mould, remediation of larger buildings needs to take the activities and safety of a larger number of people into consideration[2,3,4,5]. This report addresses only the situations where mould remediation is technically and economically feasible. This document does not discuss or assign roles and responsibilities for assessment or remediation, nor does it cover accreditation requirements for remediation professionals.

Background information on mould and a review of current mould assessment guidelines are included in the companion article, *Mould Assessment in Indoor Environments - Reviewing Guidelines & Evidence*. A list of resources that can be provided to occupants and building owners is provided at the end of this document.

1.1 Purpose of mould remediation

The purpose of mould remediation is to: "*correct the moisture problem and to remove moldy and contaminated materials to prevent human exposure and further damage to building materials and furnishings*" [*]. Mould remediation involves the clean-up of both moisture and mould, with the goal of returning the structure and contents as closely to the pre-damaged condition as possible. The scope of remediation activities depends on the extent of water damage and mould contamination, ranging from surface mould removal by an occupant, to an extensive structural renovation requiring a team of skilled professionals. Although health authorities and environmental professionals would like to have numerical limits for acceptable levels of mould in the air or on surfaces, these limits do not yet exist as the relationship between indoor dampness, levels of mould exposure and health effects is not easily quantifiable[1,2,5]. All guidelines agree that mould growth on building material surfaces and contents, and excessive dampness should not be tolerated in indoor environments.

2 Remediation decisions

In the absence of health-based limits, there are several accepted ways to determine the scope of mould remediation. Using the area of visible mould as a decision criterion is the most popular decision method[6], however other mould decision paradigms have been recently introduced, based on the contamination conditions[7], or the amount of water damage present[2].

2.1 Mould remediation decisions based on area of visible contamination

Basing remediation decisions on the amount of visible mould contamination is a concept that was first recommended by the New York City Department of Health in 1994. This approach is widely accepted in the field and has been adopted by almost all guidelines, with some variation in the size classifications of visible mould (Table 1). The most common thresholds for mould remediation are 1 m^2 or less of visible growth for small scale remediation projects, up to 10 m^2 of visible growth for moderate remediation projects, and greater than 10 m^2 of visible growth for large scale remediation.

[*] 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, p.3.

Some experts disagree with this method because the health risks associated with different amounts/sizes of mould growth are not known[8]. This recommendation is founded on practical considerations and while there has been little evidence to prove that this method is appropriate or effective[2,6,8], recent evidence has shown that the area of mould is correlated to the number of mould spores present[9]. Many of the guidelines recommend expert assessment to determine if professional remediation is necessary.

Table 1: Generalized guidelines for area of visible mould.

Supported by the New York City Department of Health (NYCDOH)[6], US Environmental Protection Agency (EPA)[4], Canadian Mortgage and Housing Corporation (CMHC)[10] and others[11,12,13]. For a more thorough explanation of the different classifications, the reader should consult the references.

Classification	Description	Remediation decision.
Small /Area 1	Total area: 1 m^2 of visible mould growth or less.	• Most guidelines recommend that occupants can clean up areas less than 1 m^2. No special training is required. • Recommended PPE: N-95 mask and rubber gloves as a minimum. • Guidelines disagree about whether containment is required for this size of growth[7,11,12]. At a minimum, source containment needs to be used.
Moderate/ Area II	Total area: between 1 -4 m^2 of visible mould.	• Most guidelines recommend that occupants can clean up moderate areas if they have received some training and are using proper procedures. • Recommended PPE: N-95 mask, goggles and rubber gloves. • Minimal containment is required, including air filtration and barriers.
Large/Area III	Total area: 4 - 10 m^2 of visible mould.	• Professional remediation only. Full PPE recommended. • Some guidelines recommend that project oversight is provided by environmental health and safety professionals[11]. • Full containment including air filtration required.
Extensive contamination/ Area IV	Contiguous visible mould growth larger than 10 m^2 in an area.	• Professional remediation only. • Full PPE and full containment including air filtration required. Note: only guidelines from the US Department of Labour[11] and the NYCDOH [6] include extensive areas of mould growth.

2.2.1 Who is qualified to remediate?

Most guidelines state that no special training is required to clean up areas less than 1 m^2 of mould, and occupants or building owners can safely clean up small amounts of visible mould on surfaces[14]. For larger areas, more specialized mould remediation training is required, commensurate with the scope of work to be performed. Remediation qualifications, licensing requirements, training and certification for remediation professionals is described in publications by the American Industrial Hygiene Association (AIHA) or the National Institute of Environmental Health Sciences (NIEHS)[2,8].

2.2 Mould remediation decisions based on condition - IICRC S520

The Institute of Inspection, Cleaning and Restoration Certification (IICRC) Consensus Body Standard Committee states that their "*collective experience involving hundreds of actual remediation jobs and reviews of sampling test results, has determined that using square footage of visible mould, alone, while helpful, is not feasible as an action level decision criterion*"[*]. Unlike the other professional bodies, the IICRC does not support the area of visible contamination as a decision criterion, but instead classifies indoor areas into several conditions. Their rationale includes the fact that evaluating the area of visible mould does not factor in hidden mould, nor does it take into consideration any contamination from settled spores that have dispersed from areas of active mould growth. This approach takes into consideration the location of visible mould growth, the cause of the mould contamination, the building use and occupant type, the existence of known or concealed mould contamination, and the likelihood of suspected or concealed mould contamination.

Condition 1 (normal fungal ecology): an indoor environment that may have settled spores, mould fragments or traces of actual growth whose identity, location and quantity are reflective of a normal fungal ecology for a similar indoor environment. No remediation is required for Condition 1 environments[7].

Condition 2 (settled spores): an indoor environment that is primarily contaminated with settled spores and which may have traces of actual growth. Although the IICRC assumes that the settled spores are dispersed directly or indirectly from a Condition 3 area, they may also come from surrounding ambient air or dust brought indoors from outdoors and accumulated over time with poor cleaning practices. Remediation/cleaning may be required for Condition 2 environments if it is established that the identified settled spores originate directly or indirectly from a Condition 3 area as described below.

Condition 3 (actual growth): an indoor environment contaminated with the presence of actual mold growth and associated spores. Actual growth includes growth that is active or dormant, visible or hidden. Remediation is required for all Condition 3 environments where a significant risk of exposure for the building occupants to the identified source of mould growth has been established by a skilled and recognized environmental assessment professional. By these definitions, condition 3 includes all areas of visible mould growth (small, medium, large) described in Table 1.

As the IICRC S520 standard is an industry document, it assumes that all evaluation and cleaning of Condition 2 and Condition 3 spaces are to be conducted by professionals. In a real life situation, this may not be feasible. The main point emphasized by the IICRC S520 standard, is that mould growth and spores need to be removed from indoor environments.

2.3 Mould remediation decisions based on area of water damage

The American Industrial Hygiene Association (AIHA) recommends using multiple factors to determine remediation procedures, including dampness/moisture damage observations and the location of the

[*] Institute of Inspection, Cleaning, and Restoration Certification (IICRC): IICRC S520 Standard and Reference Guide for Professional Mold Remediation. 2008. Vancouver, Wash. P. 150.

mould relative to the occupant[2]. The remediation decision is based on practical considerations, classifies the severity of moisture damage as "low", "medium" and "high", and has a remediation matrix based on the severity of moisture damage[*].

A low severity situation includes minor water damage, no hidden damage suspected, no odors, and can be cleaned by the occupant. On the other end of the spectrum is a high severity situation, which involves massive water intrusion, the possibility of hidden damage, and odorous materials. Industrial hygienists or indoor environmental professionals need to be involved to provide oversight for remediation, full PPE and full containment are required.

2.4 Other remediation decision methods in development

In the last several years, the US EPA has supported the development of an algorithm based on mould-specific quantitative polymerase chain reaction (MSQPCR) to estimate the mould burden on a home. The Environmental Relative Moldiness Index (ERMI) has been designed to estimate the mould burden of a home, based on the identification and quantification of DNA of 26 mould species associated with water damage, and 10 that are not[15]. EPA considers the method to be a research method that is under development and is not yet validated, thus it normally should not be used except under special circumstances.

3 Reducing the risks to occupants and workers during remediation

Remediation disturbs mould, releasing both mould and mould byproducts into the air. Steps need to be taken to prevent contamination of clean areas and to protect both occupants and remediation workers. Risk mitigation strategies include project planning, the use of personal protective equipment, removing occupants, the use of containment and engineering controls and Quality Assurance/Quality Control measures. These risk mitigation principles must be applied to large and small projects alike.

3.1 Reducing risk through proper planning

A documented remediation plan is recommended for even small remediation projects. At its most basic, a remediation plan includes: (1) a strategy for addressing the moisture conditions causing mould growth; (2) a thorough and systematic approach to cleaning; and (3) a way to safely remove all mould damaged materials from the site.

More formal documentation is required for larger remediation projects, and needs to include specific descriptions of the conditions, the work conducted in all stages of the process, as well as results of pre and post remediation assessment. The professional guidelines produced by the AIHA[2] or IICRC[7] clearly define components of work plans, including scope, project specifications, type of specifications, remediation roles and risk communication.

[*] American Industrial Hygiene Association (AIHA). Recognition, Evaluation and Control of Indoor Mold. 2008. pp 196-199.

In cases where other risks may be present, including asbestos, lead-based paint or bird or animal droppings, remediation professionals may need to be consulted to conduct a hazardous materials audit and to ensure additional precautions are taken to protect both occupants and workers during remediation.

3.2 Reducing risk by removing vulnerable persons from work area

Recent evidence is clear that personal susceptibility plays a large role in how individuals respond to mould[16,17,18]. All guidelines recommended removing susceptible or sensitive persons from the work area for the duration of remediation. These individuals include infants under 12 months, pregnant women, those recovering from surgery, immune suppressed persons, or persons with any kind of chronic respiratory ailment such as allergies or asthma.

3.3 Reducing risk by using Personal Protective Equipment (PPE)

All guidelines recommend that during remediation, gloves, eye protection and respirators must be worn to protect against mould and mould particulate, biocides and antimicrobials (if used), as well as any other hazards such as lead-based paint or asbestos. The selection of gloves depend on whether dry or wet work is being conducted[8]. Most guidelines recommend half face N-95 respirators. The mask must be worn properly, with the respirator correctly oriented on the face, held in position with both straps, and with the nose clip tightened to prevent gaps[19,20]. Eye protection can include either safety glasses or vented goggles[8]. Larger scale jobs require additional protection, such as a full face mask and contamination suits, including foot and head coverings[3,6,7,8,11].

3.4 Reducing risk through containment

Containment is defined as any method to minimize the aerosolization of mould during remediation, and/or to reduce the distribution of mould and particulates to surrounding areas[7]. The type, extent and location of containment should be guided by the amount, location and distribution of mould, the types of materials affected, the extent of building or material degradation, the type of building and occupants, the remediation strategy or application, as well as other hazards present[2]. General containment strategies supported by most guidelines include the following.

- **Limiting access** to the area.
- **Prevention** - remediation work should be conducted in a manner that limits aerosolization and spore dispersal[2,7].
- **Isolation** - the use of tape and plastic sheeting to prevent the movement of dust and particulate matter[2,3,4,7]. Drop clothes for the floor are also recommended.
- **Ventilation control** - closing windows, turning off fans and air conditioners and sealing off any ventilation points leading to or from the contaminated area[2,3,7].
- **Dust suppression** - ongoing cleaning and use of a High-Efficiency Particulate Air (HEPA) vacuum cleaner in work areas.[7] Although some guidelines mention the use of misting to reduce dust[6,11], the IICRC states that spraying, wetting or misting are not recommended, as they can release or disperse mould spores.

- **Negative pressure** - vent contaminated air outside to prevent further indoor spore dispersion and contamination[2,3,4,5,7]. This is most appropriate for large scale projects.

Containment strategies for mould are modeled on those from the asbestos industry, and are based on professional experience and risk prevention concepts[2,6]. While it is tempting to adapt containment guidelines from other fields, these guidelines may not always be appropriate, and are sometimes unnecessarily rigorous and expensive. Although many guidelines discuss containment strategies for public buildings, they are less clear about the containment requirements for home remediation[2,3,4,7,12].

Containment recommendations from the US Environmental Protection Agency (EPA)[4] and Health Canada[3] recommend limited containment for areas between 1 - 10 m^2 of mould growth, and full containment for areas over 10 m^2. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends source containment for areas under 1 m^2, which involves covering the area of mould growth before it is removed to reduce the dispersal of spores[5].

The Institute of Medicine's *Damp Indoor Spaces*, states that containment has been shown to prevent the spread of molds, bacteria, and related microbial particles within buildings[*]. The literature search was unsuccessful in identifying additional or evidence describing containment strategies that are proven to be appropriate or effective for mould.

Limited containment: This involves limiting access to the damaged areas and affixing 6 ml polyethylene sheeting with duct tape around affected area, with a slit entry and covering flap. Limited containment situations also involve negative pressure with a HEPA filtered fan unit, and blocking supply and return air vents and doors within containment area. HEPA vacuum cleaners need to be used to remove surface dust and contamination from the area.

Full containment: This includes all measures described for limited containment, in addition using two layers of 6 ml polyethylene sheeting with one airlock chamber, negative pressure with a HEPA filtered fan unit, blocked supply and return air vents within the containment area. One paper described a carefully constructed containment area used in a hospital remediation but did not test if the containment was effective[21].

3.5 Reducing risk by implementing appropriate Quality Assurance/Quality Control

Quality Assurance and Quality Control (QA/QC) activities include any monitoring activities implemented during and after a remediation project to ensure that the source of moisture is eliminated, that mould is being removed using correct dust-reducing processes, and that appropriate containment procedures and PPE are being used. For larger projects, more extensive QA/QC is required, and may necessitate the use of an independent third party to ensure that the containment procedures are effective[2].

[*] Institute of Medicine. *Damp Indoor Spaces and Health*. Washington, DC: National Academies Press, 2004. P. 305.

Is encapsulation an alternative to mould removal?

When complete removal of mould is not possible, encapsulation is sometimes used to cover mouldy material with impenetrable paint or other sealants to prevent the escape of mould particles. Encapsulation is a concept adopted from the asbestos industry. Although encapsulation products exist[22,23] and one reference discusses it as an option[21], there is little evidence in the literature to support this approach, and it presents an ongoing risk to occupants if the paint/sealant is disturbed and the mould is released back into the indoor environment.

4 Special circumstances - flooding, hidden mould, marijuana grow operations

Each of the following circumstances presents special challenges. For this reason, homes where flooding, hidden mould or marijuana grow operations are present, require the services of remediation professionals to advise, oversee or conduct the remediation.

4.1 Flooding

Water intrusion from broken pipes or appliances, storms or floods needs to be stopped immediately and the water present needs to be removed. In the case of large amounts of water, commercial equipment might be most appropriate. If the water is contaminated with human waste or soil, experienced professionals need to be consulted, and biocides need to be used to eliminate human pathogens such as bacteria or viruses. In flood situations, wall cavities or closed spaces often need to be opened to allow them to fully dry.

4.2 Hidden mould

Hidden mould is defined by the AIHA as "*fungi on building materials or contents that is within the building enclosure but concealed from view during a normal walk-through inspection*"[*]. It can be behind drywall or under carpets, in attics or crawl spaces. Remediation of hidden mould usually involves either extensive renovations (when it is in an attic or behind walls) or disposal of carpets. While there is a growing consensus that visible indoor growth should be removed[2], hidden mould in wall cavities and enclosed spaces within the building structure presents an exposure and health concern 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. When making a decision to remediate hidden mould, many things need to be considered including any potential exposure pathways, effect of the mould on the structural integrity of the building and the susceptibility or health status of building occupants. One challenge is that while hidden moulds do not present a health risk for the building occupants if there are no identifiable pathways of significant exposure, exposure pathways are often difficult to identify. The viability and species of mould cannot be used to make this decision[2].

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

4.3 Marijuana grow operations

Several Canadian Guidelines provide recommendations for the remediation of former marijuana grow-operations (MGOs) [24,25]. Grow ops could be associated with many environmental health hazards, each with specific remediation strategies, so professionals are required for remediation in these situations.

5 Remediation strategies and procedures

Each remediation situation is unique due to differences in building characteristics, climate and occupancy. For this reason, there is not a "one size fits all" strategy for mould remediation, and many factors need to be considered in developing remediation plans. Remediation principles include the following:

5.1 Identifying and eliminating the moisture source

Identifying and eliminating the source of the moisture is the first and most important step of remediation. This may involve major repairs, or structural modifications such as adding insulation or increasing ventilation with fans, and may include changing behaviors and habits of occupants.

Once the source of moisture is addressed, all materials and contents need to be dried completely. Drying techniques for homes or contents are subject to climatic conditions, and will vary according to season and region[7]. Wet materials need to be dried immediately, as mould has been shown to grow on materials that are wet for 48 -72 hours[26].

5.2 Remediating heating, ventilation and air conditioning (HVAC) systems, if necessary

During structural remediation, heating, ventilation and air conditioning (HVAC) systems may need to be deactivated or sealed off to prevent contamination and to limit the dispersal of mould spores and dust throughout the building. HVAC systems need to be professionally remediated if they are contaminated with mould[8]. HVAC remediation is beyond the scope of this document.

5.3 Removal and remediation of contaminated contents

Before structural remediation, both contaminated and non-contaminated contents need to be removed from affected areas. Uncontaminated contents need to be removed to prevent contamination with dust or spores during remediation procedures. Contents that are contaminated either with mould growth or significant amounts of dust containing mould spores should be discarded or thoroughly cleaned using suitable methods (e.g., using a HEPA vacuum cleaner), to prevent the introduction of significant mould spore reservoirs back into the remediated space. Evidence has shown that fleecy materials (e.g., fabric, carpets) that are not adequately cleaned may act as allergen reservoirs[27].

Contents can be restored, disposed or preserved, depending on the material, extent of contamination and the cost of the remediation versus the cost of replacement. In cases where contaminated contents have other types of value such as sentimental, legal, cultural, historical or artistic, professional remediation firms should be consulted concerning appropriate techniques to preserve or restore items.

The methods for cleaning generally follow the same guidelines as those for structural remediation (section 5.4) with porous contents discarded, semi-porous contents cleaned as long as they are not too damaged, and non-porous contents cleaned. Most methods start and end with HEPA vacuuming to remove loose dust and spores. Extensive instructions for specific materials can be found in many of the guidelines[2,4,7,10,12,28].

5.4 Removal of mould from structure

Structural remediation involves the physical removal of mould from the building. Mould spores or fragments may have antigenic and/or toxic properties that exist even if the mould is dead. Therefore, the physical removal of mould is essential[5]. For this reason, any approach that simply kills or inhibits mould is not sufficient; removal needs to be conducted in a manner that prevents dispersal of mould spores and fragments[12].

Cleaning strategies are based on the types of materials present. Most guidelines are based on the concept of porosity, and materials are classified as porous, semi-porous and non-porous. Several excellent guidelines for cleaning surfaces and contents are listed at the end of the report.

Porous materials with mould growth, such as ceiling tiles, wall paper, drywall and carpets, should be removed and discarded as they cannot be effectively cleaned. Items that have been wet for extended periods of time are best discarded as a way to prevent further spread of mould[4,10,28].

Porous materials that are surface-contaminated with dust or mould spores only, but do not contain mould growth, can be decontaminated by HEPA vacuuming if dry. If wet, materials should be professionally cleaned. Items that have been wet for extended periods of time are best discarded as a way to prevent further spread of mould

Semi-porous materials with mould growth, such as wood can be surface cleaned by a combination of scraping, scrubbing and HEPA vacuuming. The integrity of structural components should be carefully examined to decide on replacement if it is established that these have been physically compromised.

Non-porous materials, such as tile or glass, can be scrubbed and cleaned.

5.5 Disposal

All contaminated materials removed from the building should be sealed in 6 ml polyethylene bags to prevent spore dispersal. In general no special disposal requirements are recommended for mould contaminated materials.

5.6 Final cleaning and rebuilding

Once the building interior and contents have been dried and mould-contaminated materials removed, dust and visible traces of debris from the remediation process should be cleaned using damp wiping and a HEPA vacuum cleaner. A final professional cleaning of the entire interior is recommended, including any areas outside of the remediation area. The IICRC recommends moving horizontally from cleaner to less clean areas and vertically from top to bottom[7].

Rebuilding involves reconstructing any part of the structure that was disassembled or removed during remediation. This needs to be done in a manner that prevents future mould growth. The sequence of mould remediation and water repair can be complex, as sometimes water/moisture repair work cannot proceed until a mould-free work environment has been provided for contractors. Once cleaning and rebuilding is completed, non-contaminated contents can be returned to the home.

Controversy: use of fungicides and antimicrobials in cleaning

The use of fungicides (to kill existing growth) and antimicrobials (to suppress or prevent future growth) is controversial. The physical removal of mould is thought to be the most effective way to prevent exposure, and many guidelines recommend the use of soap or detergent and water to physically remove mould[8,11]. Other guidelines recommend using dilute bleach if professional judgment determines it would be beneficial[3].

There is no clear consensus on the use of fungicides and antimicrobials in the literature. The reasons for this controversy are varied and include concerns regarding increased risk to occupants and remediation workers because of the toxicity of the compounds[2], and the questionable effectiveness of biocides in killing and preventing mould growth.

Biocides/disinfectants are required in cases where contaminated water is present (e.g., sewage, soil, flood water)[2,4,6,7]. New disinfectants and protocols are being developed and tested for these situations[29].

Biocides are sometimes used to coat surfaces (e.g., walls) after mould removal to prevent re-growth[30] or are used when complete removal of mould is not possible. While this approach is not generally recommended in the guidelines, some studies found that the use of biocides were effective at inhibiting new growth[31].

Table 2: Remediation strategies and evidence

Abbreviations of organizations listed in table: **ACGIH** - American Conference of Governmental Industrial Hygienists[5]; **AIHA** - American Industrial Hygiene Association[2]; **CMHC** - Canada Mortgage and Housing Corporation[10]; **USEPA** - United States Environmental Protection Agency[4]; **HC** - Health Canada[3]; **IICRC** - Institute of Inspection, Cleaning, and Restoration Certification[7]; **IOM** - Institute of Medicine[1]; **ISIAQ** - International Society of Indoor Air Quality and Climate[12]; **NIEHS** - National Institute of Environmental Health Sciences[8]; **NYCDOH** - New York City Department of Health and Mental Hygiene[6]; **OSHA** - Occupational Safety and Health Administration[11]; **WHO** - World Health Organization[32].

Remediation strategy	**Recommendation**	**Organizations supporting this approach**	**Support for recommendation:** scientific evidence, practical experience, scientific fact, risk reduction approach or consensus.	**Additional comments**
Moisture removal	Removing moisture is the recommended first step in every guideline reviewed.	Recommended by all guidelines.	This approach is supported by scientific evidence: mould requires moisture to grow. Removing moisture reduces chance of mould growth.	Moisture needs to be removed as quickly and as thoroughly as possible to prevent mould growth. Floods or major plumbing leaks require more aggressive water removal techniques.
Remediation based on threshold levels of mould	Not recommended. In most cases, if visible mould growth is present, sampling is unnecessary (OSHA, USEPA).	Most current guidelines do not support threshold levels	Currently, there is not enough data to support this approach.	Limits were previously published but retracted.
Remediation based on area size of visible mould growth	Small (<1 m^2) no professional assistance needed. Medium (1 - 4 m^2) professional consultation recommended. Large (4-10 m^2) professional remediation required.	NYDOH, USEPA, CMHC, OSHA, ISIAQ	Although recommendation was developed on common sense and practical experience, recent evidence has shown that the area of mould is correlated with the number of spores.[9]	Most guidelines agreed with this recommendation, however there are some differences in size classifications. ACGIH, USEPA say that areas under 1 m^2, can be cleaned by the occupant.
Remediation based on condition	Situations range from condition 1, normal flora, to condition 3, visible mould growth.	IICRC	Based on practical experience and risk reduction.	Takes multiple factors into consideration, including building use and location of mould in relation to occupant. As a professional standard, assumes remediation professionals always used.

Remediation based on amt of moisture damage	Remediation decisions need to be based on amount of moisture damage.	AIHA	Based on practical experience and risk reduction.	Many different factors determine if a professional is used for remediation.
Containment to limit spread of mould.	Use of isolation, dust suppression, pressure differential, ventilation control to prevent further contamination and the dispersion of dust and mould spores.	AIHA , HC, USEPA, OSHA, IOM	Recommendations adopted from asbestos/lead industries.[5] Recommendations are based on risk reduction and common sense. No evidence to support necessity or effectiveness of a strict full containment for mould.	Limited containment: 1 to 10 m^2. Involves 6ml polyethylene sheeting with duct tape, negative pressure and HEPA filtered fan, blocking supply and return air vents. HEPA vacuum cleaners should be used. Full containment: 10 m^2 or more. Isolation involves two layers of 6 ml polyethylene sheeting with one airlock chamber, negative pressure with a HEPA filtered fan unit, blocked supply and return air vents within containment area.
Negative pressure to limit spread of mould.	This is a more sophisticated way to prevent spores or mould fragments from spreading during remediation.	ACGIH	No evidence to support this.	Recommendations adopted from asbestos/lead industries. For professional use. USEPA recommends using negative pressure for areas of mould growth more than 1 m^2.
HEPA filtration/ vacuuming to limit spread of mould.	Filters air and cleans up mould during remediation.	Recommended by all guidelines.	While based mostly on practical experience, evidence shows that HEPA reduces mould and other allergens.[33,34,35]	This works for other allergens besides mould – dust mites, cat and dog allergens are reduced as well.
Full PPE for worker protection	Recommendations vary depending on the size of the project. Most recommend goggles, N-95 respirator and gloves for minimal remediation jobs, and full disposal suit with head to toe coverage and full face respirators for large jobs.	Recommended by majority of guidelines.	Based on risk reduction approach as well as common sense. No actual evidence that this is necessary.	All guidelines are consistent in recommending PPE. One paper discussed the fact that many remediation professionals are not properly using respirators (Cummings).
Cleaning non-porous surfaces to remove mould	Clean non-porous surfaces to physically remove mould.	Recommended by all guidelines.	Very little evidence, but is accepted in the field. Papers published prior to 2004 were not examined.	Many guidelines contain detailed instructions for specific types of materials.

Cleaning semi-porous surfaces	Scraping may be required.	Recommended by all guidelines.	Very little evidence, but is accepted in the field. Papers published prior to 2004 were not examined.	Many guidelines contain detailed instructions for specific types of materials.
Discarding porous surfaces/items.	Porous surfaces need to be disposed if they cannot be cleaned.	Recommended by all guidelines.	Evidence that fluffy materials can be reservoirs for mould spores.[27]	Many guidelines contain detailed instructions for specific types of materials, depending on the depth of mould growth and the structural integrity of the item.
Hidden Mould	Hidden mould needs to be removed.	Most, except AIHA	This recommendation is based on risk, not on evidence. No evidence that components of hidden mould in enclosed spaces of building structure can penetrate into occupied areas in concentrations high enough to cause significant health risks for the building occupants.[36]	HC 2004 encourages looking for hidden mould.[3] Most recent guidelines take a risk-based perspective and recommend finding and removing hidden mould.
Fungicides /Biocides.	Used only in appropriate situations, used carefully, and not as a substitute for mould removal. Necessary for when contaminated water is present.	ACGIH, HC, OSHA - most support fungicides for appropriate situations.	Using biocides to prevent mould re-growth is effective, depending on brand[22,37].	Biocides and disinfectants cannot be used as a substitute for mould removal. USEPA recommends that if you do choose to use biocides or disinfectants, always ventilate the area and exhaust the air to the outdoors. HC 1995[38] recommends surface decontamination with a 10% solution of household bleach with an optional addition of 0.1-0.7% non-ionic detergent.
Encapsulation	Encapsulation (painting, coverage) to be used instead of removing mould in situations where mould cannot be removed.	Not recommended by any of the guidelines.	Comparison study showed that 4/9 paint products were effective in controlling or inhibiting mould growth[22]. No other evidence found for or against encapsulation.	Not a substitute for removing mould, but an alternative when mould removal is not possible for financial or practical reasons.
Post remediation evaluation	Visual inspection for mould growth and moisture is best.	ACGIH, CDC	Not much evidence for what works best, but visual inspection is always necessary. Sampling often provides ambiguous results.	Several guidelines recommend doing surface sampling to see if an area is cleaned, or air sampling to determine if the amount of mould is lower than outside[2,3,4].

6 Clearance: completing the remediation

Post remediation evaluation determines if the remediation project was effective. The goal of mould remediation is not to create a sterile, fungi-free environment, but to return the space and contents to a pre-damage condition. Post-remediation evaluation can involve any method to determine if the indoor environment is clean and free of dust and debris and can involve visual inspection, olfactory evaluation, moisture measurements, as well as a black/white glove test to ensure that any dust has been removed. There is no consensus on clearance or validation procedures to ensure that a remediation was successfully completed[2,39,40].

One publication advised that collecting observational data on the building condition, structure and components is the best method for technical monitoring both during and after remediation[39]. This includes ensuring that all water and moisture problems have been identified and addressed, and that mould removal is complete, with no visible mould, mould damaged material or mouldy odours present. For larger projects, post-remediation verification needs to be done by an independent indoor environment professional.

Some of the guidelines recommend sampling after a remediation job is complete, to determine if the levels of indoor and outdoor airborne mould spores are comparable[41,42]. The same method/instrument/ technique needs to be used 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. 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. However some publications caution that these relationships are often more complex than expected[5,38,42,43].

7 Follow up and prevention

Once a home has been remediated for mould and moisture, ongoing surveillance needs to be conducted to prevent continued water ingress/condensation and to ensure that mould problems do not reoccur. Continuous maintenance and visual monitoring for moisture and mould by the building occupants is necessary to ensure the success of remediation and to prevent future mould growth, which can reappear within 12 months[30]. A follow up visit should reveal no new signs of water damage or mould regrowth.

Most guidelines support a preventative approach to improving air quality through good home maintenance[1,3,4,5,12,28,32,44]. Strategies include:

7.1 Humidity and condensation control

Strategies for reducing moisture in homes include engaging in activities that reduce humidity, such as the use of kitchen and bathroom fans. Increasing ventilation by opening the windows or encouraging air

circulation helps to reduce excess humidity. Condensation on windows and walls can be reduced by opening windows, increasing indoor temperature, and insulating cold surfaces such as indoor walls, attics and cold water pipes[4,12,32,35,44,45].

7.2 Preventative maintenance of building structures and HVAC systems

Ideally, structural remediation will have addressed any leaks or other sources of moisture. Leaks and other water damage can be prevented by ensuring that adequate, preventative maintenance is conducted, and repairs are done in a timely manner.

Preventative maintenance can include the installation of air filtration systems[45]. Equipping forced air systems with high efficiency filters resulted in 50–75% lower fungal spore levels than the other ventilation/filtration systems considered[46]. HVAC systems be inspected and maintained on a regular basis.

7.3 Awareness of activities that contribute to indoor moisture

In addition to flooding, leaks or structural damage, indoor dampness can result from normal residential activities including cooking and bathing, excessive numbers of indoor plants, pet urine, or improper use of moisture-generating appliances, such as clothes dryers vented to the indoors. By becoming more aware of how their activities generate moisture and by modifying their activities accordingly, occupants can reduce the amount of moisture in the indoor environment.

7.4 Implementation of other practices to reduce moisture and mould.

Modest environmental interventions including changes to cleaning and housekeeping habits, installation of ventilation or increased use of ventilation, fewer plants, reducing clutter, and the use of entry mats can lower indoor mould concentrations as well as other allergens[27,47].

8 Does remediation work? A review of evidence.

Various case studies have proven the effectiveness of remediation[14]. A review of the evidence supports the following:

8.1 Remediation reduces the amount of mould in an environment.

Evidence from several studies demonstrates that remediation can potentially reduce visible mould and spore counts in a building[39,48,49,50,51,52]. Not all remediation efforts are successful; some studies showed no evidence of improved indoor air quality after remediation, and in other cases spore counts were increased after initial remediation[39,49].

8.2 Remediation improves health outcomes

Several studies demonstrate that mould remediation reduces health symptoms, as measured by a significant reduction in emergency room visits and hospitalizations of asthmatic children after remediation[48,49]. The strongest evidence is from a recent study that demonstrates that a combination of mould removal, fungicide and increased ventilation reduced asthma symptoms in children over a 12 month period[30]. Other housing improvements are also effective at improving health outcomes, with

increased home insulation leading to a 50% reduction in visible mould and significant improvements in occupant health effects over a 12 month period[53].

The relationship between health effects and mould remediation can be complex. One study showed that remediation reduced the amounts of microbes in the building, and while some symptoms such as fatigue and headache were alleviated immediately after remediation, respiratory symptoms took longer to resolve[52]. Three reasons why ambiguous outcomes may have been observed in studies relating remediation and health: (1) all moisture/mould damage may not have been addressed adequately by the remediation; (2) health effects may be independent of mould; and/or (3) the methods used may not have been sensitive/specific enough to detect health improvement within the follow-up periods of the study[39].

8.3 How extensive does remediation need to be to be effective? Not determined.

Based on the studies reviewed, it was impossible to determine how extensive remediation activities need to be, to improve indoor air quality and occupant health. Remediation procedures were not always clearly described, the amount of time between remediation and measurement of air quality varied, and the methods used to determine the amount of mould in an environment differed. However, based on studies where minor changes to housekeeping and building maintenance made significant improvements to indoor air quality, minor remediation activities can be assumed to make a positive difference[27].

9 Research Gaps

The lack of evidence in this area emphasizes the need for future work in all aspects of mould remediation. Some of these areas include:

- Development of tools for monitoring and assessing the success of remediation in a building.
- Development of quality standards to determine overall effectiveness of mould remediation.
- Conduct research to determine if remediation efforts actually improve indoor air quality.
- Conduct research to determine if containment is necessary, and what specific containment activities are most effective.
- Provide evidence that remediation improves health quality.

10 Recommended resources for home owners

Much misinformation about indoor mould exists, so it is important to refer homeowners to reputable sources for accurate and up to date information. The following sources are some of the best:

Canadian Mortgage and Housing Corporation
Moisture and mould website has numerous links to specific resources for home owners, condo owners.
http://www.cmhc-schl.gc.ca/en/co/maho/yohoyohe/momo/index.cfm

Health Canada guidelines for Mould, Dampness and Humidity

http://www.hc-sc.gc.ca/ewh-semt/air/in/poll/mould-moisissure/rid-debarrasser-eng.php

National Institute of Environmental Health Sciences (NIH)
http://www.niehs.nih.gov/health/topics/agents/mold/index.cfm

US Centre for Disease Control
Mould control website with links to a number of other resources: http://www.cdc.gov/mold/

US Environmental Protection Agency
http://www.epa.gov/mold/moldguide.html

11 Appendix: Research process for mould intervention paper

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 remediation. The approach used to identify and evaluate guidelines and papers reviewed in this document as well as the list of guidelines reviewed, are described in the appendix of the companion document: *Mould Assessment in Indoor Environments - Reviewing Guidelines & Evidence.*

11.1 Challenges in evaluating remediation evidence

Studies to determine the effects of remediation are difficult, expensive and time consuming[54]. There are many confounding variables, and unlike other types of studies (such as clinical trials), studies examining remediation efforts in homes are almost impossible to blind, so measuring the effectiveness or success of remediation is a challenge. Studies are difficult to compare because (a) remediation is site-specific and activities are hard to standardize; (b) most studies do not adequately describe the specific remediation activities conducted in each case; (c) there is no standardized measure to judge the success of remediation, with some studies using indoor air quality while others measuring health outcomes. As a result, there have been very few controlled studies conducted on the effectiveness of remediation actions in reducing mould contamination in the short and long term and of the effects of remediation on health of building occupants. Most remediation papers reviewed are included in Table 3.

Table 3– Remediation evidence papers reviewed (sorted alphabetically)

Author	Title	Key conclusion	What they did, exactly
Barnes, *et al.* 2007[49]	Comparison of indoor fungal spore levels before and after professional home remediation	Remediation significantly reduces asthma triggers and in many cases, improves children's respiratory health.	Airborne spore samples were taken in 17 homes, both before and after professional remediation as per EPA guidelines followed by cleaning, consisting of washing with soap and water for any suitable surfaces and disinfected using a suitable biocide (eg, bleach).
Bernstein, *et al.* 2005[33]	A pilot study to investigate the effects of combined dehumidification and HEPA filtration on dew point and airborne mold spore counts in day care centers.	Dehumidification and HEPA filtration was effective at controlling indoor moisture and reducing airborne culturable fungal spore levels.	Set up dehumidifiers/HEPA in daycare centres; dew point and airborne fungal spore measurements were taken at baseline and over the next year.
Burr, *et al.* 2007[30]	Effects on patients with asthma of eradicating visible indoor mould: a randomised controlled trial	Provides some evidence that eradicating visible mould benefits patients by improving symptoms of asthma and rhinitis and enabling them to reduce their medications.	Houses of patients with asthma were randomly allocated into two groups: (1) indoor mould was removed, fungicide was applied and a fan was installed in the loft; (2) intervention was delayed for 12 months. Questionnaires were administered and peak expiratory flow rate was measured at baseline, 6 months and 12 months.
Cheong, *et al.* 2004[34]	intervention study of airborne fungal spora in homes with portable HEPA filtration units	The installation of portable air filters brought about immediate reductions in indoor fungal levels in the air filter homes.	The concentrations and composition of airborne fungal spores in homes fitted with portable HEPA filtration units. A novel method for simulating activity/impaction on carpeted environments was also investigated.
Chew, *et al*. 2006[20]	Mold and Endotoxin Levels in the Aftermath of Hurricane Katrina: A Pilot Project of Homes in New Orleans Undergoing Renovation	Construction remediation aimed at the root cause of moisture sources and combined with a medical/ behavioral intervention significantly reduces symptom days and health care use for asthmatic children who live in homes with a documented mold problem.	Remediation for three houses: removed ≥ 1.2 m of drywall, conducted HEPA vacuuming, used a borate salt solution to help prevent mold growth, and used bleach as a disinfectant. Measured indoor and outdoor bioaerosols before, during, and after intervention.
Haverinen-Shaughnessy, *et al.* 2008[39]	Monitoring success of remediation: Seven case studies of moisture and mold damaged buildings	Collecting observational data on building condition and structures/components is the most applicable method for technical monitoring both during and after remediation. There is a need for enhanced development of validated tools and protocols for assessment of the success of remediation process.	Looked at the success of remediation of seven different buildings, based on measurable change in the situations before and after remediation. Measured performance of building structures and heating, ventilation and air conditioning (HVAC) systems, microbial monitoring of indoor air quality (IAQ), and health effects studies of building occupants.

Huttunen, *et al.* 2008[40]	Indoor air particles and bioaerosols before and after renovation of moisture damaged buildings: The effect on biological activity and microbial flora	There is not yet a single analysis that would describe all possible harmful agents in mold and moisture-damaged buildings. The effects of remediation on the indoor air quality may not necessarily be readily \ measurable either with microbial or toxicological parameters. This may be associated with different spectrum of harmful agents in different mold and moisture-damaged buildings.	Air samples were collected and particle concentrations measured from indoor air of moisture problem building before and after remediation in two different locations. Samples from reference building were collected as well. Remediation was not detailed.
Johnson, *et al.*2009[35]	Low-cost interventions improve indoor air quality and children's health	Simple low-cost interventions (heating, ventilation, and air conditioning (HVAC) service, dehumidification, room air cleaners) directed to producing cleaner indoor air coupled with healthy home education improve the indoor air quality and health in asthmatic children.	interventions included dehumidification, air filtration, furnace servicing, and high-efficiency furnace filters. When present, gross fungal contamination was remediated.
Kercsmar, *et al.* 2006[48]	Reduction in asthma morbidity in children as a result of home remediation aimed at moisture sources.	Remediation for indoor fungal spore contamination can significantly reduce spore counts. Demonstrated the feasibility of performing successful home remediation for mold and moisture and the resultant improvement in asthma morbidity associated with reduction in indoor mold.	Remediation included reduction of water infiltration, removal of water-damaged building materials, and heating/ ventilation/air-conditioning alterations Measured children's biological samples and environmental dust. Follow up period was one year. Study examined dust mite, cockroach, rodent urinary protein, endotoxin, and fungi. The follow-up period was 1 year.
Klitzman, *et al*. 2005[51]	A multihazard, multistrategy approach to home remediation: Results of a pilot study	During baseline and intervention, mold and endotoxin levels were similar to those found in agricultural environments. After intervention, levels of mold and endotoxin were generally lower (sometimes, orders of magnitude). The average WPF against fungal spores for elastomeric respirators was higher than for the N-95 respirators.	Paint stabilization, dust lead cleaning, integrated pest management (IPM), mold cleaning, and safety devices. Environmental conditions evaluated prior to, immediately following, and an average of 5 months after remediation.
Menetrez, *et al*. 2009[22]	Mold Growth on Gypsum Wallboard—A Summary of Three Techniques	Results (of triplicate samples) of 14 cleaning products for the six types of GWB surfaces varied extensively. Results for the nine types of paint products on GWB surfaces varied; three antimicrobial encapsulant paint products exhibited perfect results.	Comparison of 13 separate antimicrobial cleaners and nine varieties of antimicrobial (encapsulant) paint on contaminated GWB was performed in laboratory testing
Myatt, *et al*. 2008[46]	Control of asthma triggers in indoor air with air cleaners: a modeling analysis	The use of high efficiency in-duct air cleaners provide an effective means of controlling allergen levels not only in a single room, like a portable air cleaner, but the whole house.	Used an indoor air quality modeling system to examine peak and time-integrated concentrations of fungal spores, environmental tobacco smoke, respiratory viruses, and cat allergen in indoor air associated with natural ventilation, portable air cleaners, and forced air ventilation equipped with conventional and high efficiency filtration systems.

Patovirta, *et al*. 2004[52]	Effects of mould remediation on school teachers' health	Significant reduction was found in symptoms of fatigue and headache after the cessation of exposure, while respiratory symptoms need much longer time to relieve after the remediation.	Follow-up study of the health of teachers (n=56) of three mould damage schools were done with self-administered symptom questionnaire before and 1 year after the remediation of school buildings. Technical and microbiological investigations were done parallel at the same time.
Rockwell W. 2005[50]	Prompt Remediation of Water Intrusion Corrects the Resultant Mold Contamination in a Home	Once the presence of indoor mold growth is found, a prompt and thorough remediation can bring mold levels back to near-baseline level and minimize negative health effects for occupants.	Indoor air quality was tested using volumetric spore counts in 50 homes where homeowners reported no mold-related health problems and in one mold-contaminated home that was remediated.
Sahakian, *et al*. 2008[18]	Dampness and Mold in the Indoor Environment: Implications for Asthma	There is some evidence that remediation reduces respiratory health effects, but lower respiratory symptoms may take some time to resolve and dampness-related asthma among occupants may not completely resolve.	This review article presents epidemiologic findings pertinent to asthma and asthma-like symptoms in relation to exposure to dampness/mold in homes, schools, and workplaces. Describes remediation studies.
Tranter, *et al*. 2009[27]	Indoor Allergens in Minnesota Schools and Child Care Centers	Modest environmental interventions including: changes to cleaning, ventilation, entry mats, furnishings, flooring, and classroom items, can be implemented which should result in lower allergen concentrations.	Settled dust samples were collected from carpet, vinyl tile floors, and upholstered furniture in six schools and seven child care centers before and after interventions. The amount of total dust, culturable fungi, and indoor allergens—cockroach, dust mite, cat, and dog— were quantified in the dust samples.
Wilson, *et al.* 2004[37]	An investigation into techniques for cleaning mold-contaminated home contents.	Gamma irradiation was successful in inactivating spores but not the mycotoxins. Washing with bleach and a commercial detergent was effective against most spores and against the tested mycotoxins for cloth and paper materials, but not carpet and wood. The steam cleaning technique was successful only with spores of *S. chartarum* and *C. globosum* on wood material.	Examined the efficacy of (1) gamma irradiation (2) a detergent/bleach wash, and (3) a steam cleaning technique to reduce fungal spore and mycotoxin levels on paper, cloth, wood, and carpet .
Wu and Takaro, 2007[45]	Childhood Asthma and Environmental interventions	The effects of remediation on the indoor air quality may not necessarily be readily measurable either with microbial or toxicological parameters. The current study highlights the complexity and individual characteristics of buildings with moisture-related indoor air problems.	Looked at a variety of studies falling into three categories: those that focused on one or more mechanical methods to reduce home environmental triggers, those that focused on education of asthmatic children and their parents, and those that used a combination of interventions incorporating both of the above.

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