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LITERATURE REVIEW OF CURRENT RESEARCH ON HEALTH EFFECTS AND ACCEPTED GUIDELINES FOR THE MANAGEMENT OF INDOOR MOULD AND WATER DAMAGE IN THE BUILT ENVIRONMENT

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Abstract: Extensive research studies have documented a strong association between exposure to dampness and amplified growth of mould and mycotoxins (including ochratoxin, aflatoxin and trichothecene) in water damaged and damp indoor environments and the incidence of respiratory symptoms, asthma, hypersensitivity pneumonitis, rhino-sinusitis, bronchitis and respiratory infections. Living in a water damaged and mouldy property is linked with poor physical health outcomes and the continual cycle of illness could eventually lead to anxiety and depression. This paper reviews the many position statements, alerts, advisory notes, guidelines and white paper documents of various cognizant international health authorities and available current scientific research on the health effects, assessment, prevention and remediation of indoor mould and water damage in the built environment.

BACKGROUND

It is estimated that 50% of illnesses are caused by indoor air pollution, of which water and mould damage are a significant contributor to adverse health effects^{1,2,3}. It is estimated that one in three homes in Australia are water and mould damaged and in the US, it is reported that one in two homes have dampness and mould issues⁴.

Cognizant international health authorities and strong, credible scientific research have confirmed associations and links between health problems (including asthma and upper respiratory problems) with indoor dampness and mould. These organisations have issued position statements/ documents, alerts, advisory notes, guidelines and white paper documents stating their respective positions (Table 1).

INTRODUCTION

Fungi/mould are ubiquitous in the indoor and outdoor environments, existing naturally in air, soil and water. It is estimated that we are routinely exposed

to around 200 types of moulds³. The majority of fungi are saprotrophic and depend on an external source of organic material for growth.

The indoor built environment contains many of the components required for mould growth, such as oxygen, organic based nutrient sources, moisture and an acceptable temperature range. When humidity and moisture within the built environment are not effectively controlled or managed, persistent dampness and water damage can occur, leading to material damage, corrosion, structural decay and microbial growth (fungi and bacteria)⁷.

Persistent dampness, water damage and microbial growth within the built environment should be avoided or minimised² as health authorities have established an association between damp buildings, mould growth and the increased potential for adverse health effects⁷. Furthermore, there is a correlation between the length of time dampness and water damage exists in the built environment and increased damage and deterioration of building components^{3,17}.

ORGANISATION	DOCUMENT	DATE
World Medical Association (WMA)	WMA Statement on Fungal Disease Diagnosis and Management ⁵	October 2013
American Industrial Hygiene Association (AIHA)	Position Statement on Mould and Dampness in the Built Environment ⁶	March 26, 2013
American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)	ASHRAE Position Document on Limiting Indoor Mold and Dampness in Buildings ⁷	January 29, 2013
American Lung Association (ALA)	Standard of Care for the New Hampshire Mould Industry ⁸	December 2012
Specialised Cleaning & Restoration Industry Association (SCRIA)	Draft Australian Water Damage Restoration Guidelines ⁹	July 2012 <i>*currently being reviewed for 2014 re-release</i>
National Collaborating Centre for Environmental Health (NCCEH)	Health Effects from Mould Exposure or Dampness in Indoor Environments ¹⁰	July 2012
National Institute for Occupational Safety and Health (NIOSH) & Centre for Disease and Prevention (CDC)	Preventing Occupational Respiratory Disease from Exposure caused by Dampness in Office Buildings, Schools, and Other Nonindustrial Buildings ¹¹	November 2012
Global Indoor Health Network (GIHN)	Common Toxins in Our Homes, Schools and Workplaces ¹²	December 17, 2012
Mycologia	AMG-2010 Australian Mould Guideline ¹³	August 2010 <i>*currently being reviewed for 2014 re-release</i>
New York State (Mould Task Force)	Final Report to the Governor and Legislature ¹⁴	2010
World Health Organisation (WHO)	WHO guidelines for indoor air quality: dampness and mould ²	2009
Institute of Inspection Cleaning and Restoration Certification (IICRC)	BSR-IICRC S520 Standard and Reference Guide for Professional Mold Remediation ¹⁵	2008 <i>*currently being reviewed for 2013/2014 re-release</i>
Institute of Inspection Cleaning and Restoration Certification (IICRC)	ANSI/IICRC S500 Standard and Reference Guide for Professional Water Damage Restoration ¹⁶	2006 <i>*currently being reviewed for 2013/2014 re-release</i>
Institute of Medicine (IOM)	Damp Indoor Spaces and Health ³	2004

Table 1: List of organisations and released documents

HEALTH EFFECTS

Extensive research studies have documented that exposure to dampness and amplified growth of mould and mycotoxins (including ochratoxin, aflatoxin and trichothecene) in water damaged and damp indoor environments has been associated with the onset of respiratory symptoms, asthma, hypersensitivity pneumonitis, rhino-sinusitis, bronchitis and respiratory infections^{2,18-21}. Chronic exposure can then lead to inflammation and oxidative stress²²⁻³⁵. Individuals with asthma or hypersensitivity pneumonitis may be at risk for progression to more severe diseases if the relationship between illness and exposure to the damp building is not recognised and exposure continues^{3,11}.

The following list of verified health effects and symptoms are associated with mould exposure in damp and water damaged built environments^{18,36-38}.

- Asthma exacerbation, new onset asthma, upper respiratory tract (sore throat, conjunctivitis, allergic rhinitis, nasal congestion, runny nose), cough, wheeze, hypersensitivity pneumonitis in sensitive individuals, dyspnea (shortness of breath), respiratory infections, bronchitis, eczema, common cold and allergy/atopy.

Airborne exposure (inhalation) is the most significant mechanism of exposure to indoor mould in water damaged and damp indoor built environments, followed by transdermal (absorption) and foodborne (ingestion) exposure. Hyphae, spores, fungal fragments, and mycotoxins (macrocyclic trichothecenes, T2 mycotoxins) can be inhaled when fungal propagules are aerosolized. Transdermal exposure most often occurs when contaminated items and belongings are brought to new locations, resulting in cross-contamination and continued exposure. Foodborne exposure occurs through the ingestion of food contaminated by spores, mycotoxins and hyphae^{22,39-42}.

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Current research has not determined conclusively the causal relationship and exact mechanism by which mould in the indoor environment causes health effects, but is likely to be from one or more of the following mechanisms: allergic and inflammatory responses (allergens), systemic infections (pathogens), or acute and chronic toxicity (toxins)^{2,18,43,44}.

Longer term mental health effects have also been studied, with results showing occupants in water damaged buildings (WDB) who are exposed to toxigenic moulds are prone to cognitive impairment due to the damage to neurological tissue. A study of children exposed to indoor mould for more than 2 years showed statistically significant reduction of 10 points in their IQ. For longer term exposures, the risk for low IQ scores was tripled⁴⁵⁻⁴⁹.

In other studies, strong associations with depressive symptoms, with reports of emotional distress, were noted in individuals living in WDB. The associations were independent of individual and housing characteristics. Exposure to toxigenic moulds and conditions in WDB is thought to dysregulate emotions through a hypo-activation of the frontal cortex. Further compounding of stress can also be attributed to the stress of chronic illness as a result of exposure to mould and the stress of dealing with mouldy conditions in the building^{47,48,50-54}. Other reported symptoms include problems with physical energy, sleep and social isolation⁵⁵⁻⁵⁷. Living in a water damaged and mouldy property is linked with poor physical health outcomes (respiratory problems, asthma exacerbation, new onset asthma, diarrhoea, nausea, headaches) and the continual cycle of illness may eventually lead to anxiety and depression⁵⁷⁻⁶⁰.

FUNGAL DISEASE DIAGNOSIS AND MANAGEMENT

The treatment of fungal diseases and illness can be difficult as many mechanisms are interacting at any given time, thus requiring a comprehensive and multi-faceted approach focussed on treating the fungal infection, removing oxidative stress in the body and instituting

treatments which focus on countering oxidative stress^{12,61,62}.

Complete removal of the individual from exposure to indoor mould, dampness and water damage and from contaminated items are critical in reducing exposure. However, this may not be enough for some individuals to regain their health. Continual persistence of symptoms and ill health may continue after exposure, likely due to genetic and nutritional factors as well as the initial severity, duration of exposure and continual exposure through cross-contamination^{12,63}. The development of new onset chemical sensitivity (previously commonly known as multiple chemical sensitivity), can often occur after exposure⁶².

Available treatment approaches include the use of sequestering agents⁶⁴⁻⁷⁰, intake and support of anti-oxidants^{61,62,71,72}, systemic, nebulised and intranasal glutathione^{107,108}, gastrointestinal probiotics⁷³⁻⁷⁶, nutritional support⁷⁷⁻⁸⁵, and the immediate treatment of persistent fungal infections or symptomatic colonisation⁸⁶.

Further epidemiologic studies and research on the burden of fungal disease, illness and treatment options is needed and such research needs to be made available to physicians. As further knowledge and understanding of the best treatment approaches for fungal diseases and illness increases, this will help physicians to provide optimal care for patients^{5,12,86}.

ASSESSMENT

There are no recommended quantitative/numerical, health-based exposure guidelines or thresholds for acceptable levels of contamination by microorganisms^{3,6,7,11,87}. Many authorities have previously published guidelines, but many have since retracted them and the current acceptable approach is that any visible mould growth indoors, regardless of species or amount, is a cause for immediate concern and needs to be removed.

If visible mould is not detected after a thorough inspection but is suspected, microbial air and surface sampling in combination with moisture

measurements from affected building materials may be carried out according to guidance documents⁸⁸⁻⁹⁰. Sampling and measurements are used to defend a hypothesis about the nature of the contamination, 'hidden' sources of contamination (behind wall or in cavities), and whether or not the indoor air is similar to outdoor air^{6,89,91}.

Assessments should be conducted by qualified and experienced investigators, with resultant reports providing useful information for the development of an action plan for remediation and rehabilitation of the affected area, a basis for protection of occupants and remediation workers and be useful for public health officials and treating physicians. Field notes should be sufficiently detailed, clear and concise to allow field work and sampling to be interpreted, verified and repeated ensuring quality assurance^{6,8,88}.

A complete holistic assessment of the indoor built environment incorporating a health and risk assessment should include the use of semi-quantitative estimates of the extent of visible mould and moisture damage (in the form of mould and dampness indices), complemented by data on the ventilation and air flow status, indoor air quality parameters, types of reservoirs present, medical practitioner diagnoses, HVAC hygiene status, air and surface sampling (where required), building investigation photo log, occupant behaviour and building history data sets^{88,87,92-95}.

PREVENTION

Building materials that have become damp or water damaged, are at a high risk of fungal growth if combined with an organic nutrient source, resulting in health problems experienced by occupants and the eventual deterioration of the building⁹⁶. It is therefore critical that building designers and architects choose materials that are appropriate to the environmental conditions and occupant use. For the control of mould in buildings, materials which are less susceptible to fungal growth (e.g., glass fibre instead of wallpaper) should be chosen and manufacturers of building materials



encouraged to develop non-toxic, fungus or water-resistant materials⁹⁶.

The water activity (a_w) of a building material is a key determining factor for fungal growth and varies with the temperature and the type of material⁹⁷. The longer a material's a_w is over 0.75, the greater the risk of fungal growth⁹⁸, as high levels of water activity allow fungi to obtain moisture from the material for growth resulting in potential damage to the material. A definitive a_w threshold does not exist for fungal growth as different fungi have different a_w preferences⁹⁹. The key is to ensure the a_w of building materials is lower than the requirements for fungal growth and thus prevent colonisation from occurring¹⁰⁰.

Two other important physical factors in the indoor environment that can affect the water requirements of fungi are temperature and the type of nutrients present on the surface. For fungal growth to occur, there is an optimal temperature range for particular species of fungi. Outside of that optimal temperature range, more water is necessary for growth. Similarly, if the nutrient source is not something the fungi normally would grow on in nature, more water is required for growth. This is because fungi are natural decomposers and break down organic compounds, thus fungi tend to grow more frequently and quickly on plant-derived or organic materials, such as wood and paper. When building materials are inorganic and do not come from a plant origin, or have been altered in some way, fungi require more water in order to grow⁹⁷.

REMEDICATION

If visible mould is present, it should be remediated, regardless of mould species. This helps to reduce the risk of new onset asthma, and result in savings in health care costs and public health improvements^{2,6}. Repair and remediation of the conditions that lead to the adverse exposure should be given priority to prevent additional loads to populations who are already immunocompromised and stressed by the increased burden of disease^{2,95}.

The end goal of the remediation is that no further health symptoms are experienced by occupants upon re-habitation of the property and that further exposure and damage to building materials and furnishings are prevented^{11,95,101}. Remediation and the removal of water and mould damaged materials should be conducted by qualified personnel as improper efforts could result in cross-contamination of microbes, spores, fragments, and toxins throughout the entire building structure^{102,103}.

Remediation protocols should include the use of proper containment procedures and personal protective equipment (including respirators) as the action of removing and handling contaminated material will result in increased aerosolisation of spores and fungal fragments containing mycotoxins, which can be dangerous to human health when inhaled^{2,11,41,43,102}.

The use of biocides, antimicrobials, sterilisers and disinfectants are often un-necessary in the remediation process and could pose further health problems for remediation workers and leave residual chemicals that may affect occupants upon re-habitation. Such products should only be used in appropriate situations such as those involving contaminated water (Class 2 & 3)^{15,16}. Biocides and disinfectants cannot be used as a substitute for mould removal^{2,101}. Appropriate PPE, operator experience and ventilation and exhaust protocols should be in place when using such products^{9,15,16,104}.

Physical removal of all mould including active mould growth, mould laden dust, physical components, mycotoxins and fungal propagules is necessary as exposure to dead or inactivated mould or its components can still result in adverse health effects^{12,13}. This is due to the structure of fungi, which incorporates an epoxide ring, thus making non-viable fungal spores, fragments and mycotoxins extremely hard to destroy¹⁰⁵. A study of common chemical based building remediation treatments (peroxide, hot air, flaming, two boron-based chemicals, drying, steam, UV light, ammonium chloride or sodium-hypochlorite based chemicals) found that no remediation treatment eliminated all the mycotoxins from the building materials¹⁰⁶.

SUMMARY AND CONCLUSION

Cognisant international health authorities and current scientific research have established an association between damp buildings, mould growth and the increased potential for adverse health effects. Persistent dampness, water damage and microbial growth within the built environment should be avoided or minimised.

There are no recommended quantitative/numerical, health-based exposure guidelines or thresholds for acceptable levels of mould contamination in the built environment. The current acceptable approach is that any visible mould growth indoors, regardless of species or amount, is a cause for immediate concern and needs to be removed.

Repair and remediation of the conditions that have led to the adverse exposure should be given priority to prevent further health effects. The end goal of the remediation is that occupants who return to their property experience no further health

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symptoms and there is no damage to building materials and furnishings.

Further epidemiologic studies and research on the burden of fungal disease, illness and treatment options is needed and such research needs to be made available to physicians to assist them in providing optimal care for their patients.

Cedric Cheong is trainer, speaker and researcher at Mycologia. Cedric was the co-host of the internationally acclaimed TV show, "Is Your House Killing You?" which highlights dangers within Australian homes. Cedric contributed to the development of the SCRIA Draft Australian Water Damage Restoration Guidelines in 2013 and the AIRAH HVAC Hygiene Guidelines in 2010 and has written over 45 publications in peer reviewed scientific journals as well as recent articles in AIHE and FM magazines. Cedric has recently released the Mycologia Position Statement on Indoor Mould and Water Damage in the Built Environment.

Cedric was an Associate Lecturer at Murdoch University and Notre Dame University in the field of Health and the Environment. Cedric has completed training in the area of microbial sampling and HVAC investigations in Phoenix, Arizona and has visited various research centres in the Netherlands, Finland, Singapore, Canada and the USA as part of his research on indoor fungi, mould remediation, cleaning and indoor air. Cedric holds current IICRC certification for water damage restoration and applied microbial remediation and has also completed training in Friable and Non-Friable Asbestos remediation.

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