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Indoor Mould –

Health Risk Assessment and Management

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ACKNOWLEDGEMENT OF COUNTRY AND PEOPLE

The Environmental Health Directorate at the Department of Health acknowledge the Aboriginal people of the many traditional lands and language groups of Western Australia. We acknowledge the wisdom of Aboriginal Elders both past and present and pay respect to Aboriginal communities of today.

Contents

Abbreviations and acronyms

CDC	Centers for Disease Control and Prevention
CIRS	Chronic Inflammatory Response Syndrome
COPD	Chronic Obstructive Pulmonary Disorder
DFES	Department of Fire and Emergency Services
DMAT	Dampness and Mold Assessment Tool
DoH	Department of Health
EHD	Environmental Health Directorate
IoM	Institute of Medicine
PAPR	Powered air purifying respirators
PPE	Personal Protective Equipment
SES	State Emergency Services
UK	United Kingdom
US	United States of America
USEPA	US Environmental Protection Agency
WA	Western Australia
WA Guidelines	WA Health Guidelines for Managing Mould and Dampness Related Public Health Risks in Buildings
WHO	World Health Organization

Executive Summary

Indoor mould is a common problem affecting a significant percentage of homes and workplaces globally. In Australia, recent studies estimate that one-third to half of homes are affected. Factors like moisture, dampness, and poor ventilation contribute to mould growth on organic materials and building surfaces. Even if not visible, mould can be present behind walls or under carpets.

Health effects of indoor mould

Evidence demonstrates that indoor mould exposure is associated with respiratory health effects, and emerging evidence shows it has a causal relationship with development and exacerbation of asthma in children. Evidence for other health impacts like invasive infections, hypersensitivity reactions, toxigenic effects, and non-respiratory issues is currently insufficient or inconclusive.

Sensitive populations, including children, pregnant individuals, and those with immunocompromising conditions, atopy, or respiratory diseases, are likely more vulnerable to the health effects of indoor mould exposure.

Assessment of indoor mould and environmental factors

Major international health agencies, including the United States (US) Centers for Disease Control (CDC), US Environmental Protection Agency (USEPA), Health Canada, and the United Kingdom (UK) Government, do not recommend routine testing for mould. They emphasize visual inspection and to consider testing under specific situations, such as confirming remediation success or identifying hidden mould. This is consistent with recommendations across jurisdictions in Australia.

The risk of indoor mould can be reduced by addressing environmental factors. This includes controlling moisture, maintaining the building envelope, ensuring proper ventilation, and promptly addressing excess moisture or water damage.

Safety considerations when managing or dealing with mould

Sensitive populations should avoid settings with indoor mould and be informed about potential health risks and suitable recommendations to minimise exposure, such as safe remediation methods and how and when to use personal protective equipment (PPE).

A risk rating should be applied to guide mitigation measures against exposure risk to mould when assessing and remediating indoor mould. A risk rating has been developed and is stratified by susceptibility to health effects and details the level of PPE recommended for various levels of likely exposure.

Indoor mould post-flooding

After flooding events, it can be assumed that there may be extensive mould growth in buildings that have been wet for over 24-48 hours. Therefore, it is recommended

that early investigation to identify early signs of mould, or conditions that support mould growth, occurs, so that it can be rapidly resolved to prevent wide-spread damage and mould infestation. Special attention is needed for susceptible individuals during post-flooding remediation activities, emphasising the importance of mould exposure avoidance and adherence to protective measures.

Recommendations

1. The Environmental Health Directorate (EHD) should update resources, or where absent develop resources, on how to prevent and reduce mould growth, the potential health risks of mould, and recommendations on PPE to safely assess and remediate mould, including resources specifically targeted to first responders and occupants.
2. EHD should consider developing a standardised indoor mould assessment tool for use by local government environmental health officers. The assessment tool should be useful for environmental health officers in their practice.
3. WA Health should consider developing a surveillance system to undertake enhanced monitoring and surveillance of health effects following flooding events and severe weather events, with a focus on identifying increases in potential mould-related health harms.

1 Introduction

1.1 Background

In December 2022 and January 2023, the Kimberley region of Western Australia (WA) faced severe flooding events following heavy rainfall in the region caused by ex-tropical cyclone Ellie.[1] After the floodwaters receded, the extent of housing damage became apparent. Upon initial evaluation by the State Emergency Service (SES) and Department of Fire and Emergency Services (DFES), it was discovered that certain flood-affected homes had developed a serious problem with mould growth.

This raised concerns regarding occupational health risks from exposure to mould, leading to concern for first responders in entering affected premises. Consequently, this situation led to concern amongst community members which was further exacerbated by delays in assessing the homes post-flooding due to the risk of mould exposure.[2] Furthermore, despite the absence of significant structural damage, some residents were unable to return home following recession of the floodwaters due to significant mould growth, or because mould was suspected, and there was a need for the use of specialised occupational health consultants to clean and validate that the homes were safe and free from mould.

Precautionary guidance was developed by the EHD shortly after the floods which provided advice on the potential health implications of indoor mould exposure and drew upon the existing WA guidelines to outline measures to assess and remediate indoor mould.[3] On review, it was identified that there was a need to develop evidence-based guidance or update the existing guidelines to include recommendations on the:

- health effects of indoor mould,
- potential health risks and recommended precautions for first responders and occupants to take in assessing complex mould, and
- measures to manage complex mould in flood-affected housing and other indoor settings with mould growth.

1.2 Purpose

This report has been produced by the EHD to assist the WA Department of Health (DoH) in developing resources to address mould, particularly in the context of flood-affected housing. The purpose of this report is to:

1. Identify environmental factors that lead to indoor mould growth.
2. Summarise the evidence on exposure to indoor mould and associated health effects, including identifying people who are susceptible to potential health effects of mould exposure.
3. Inform WA DoH guidance on the public health risks of indoor mould exposure and managing mould in an indoor setting, with reference to complex mould post-flooding.

1.3 Scope

There are various ways for humans to be exposed to mould including exposure in both indoor and outdoor settings via inhalation, ingestion and dermal absorption. This report focuses on the negative health effects from exposure to mould growth in indoor settings.

Other mould related issues that are outside the scope of this document include:

- mould exposure in outdoor settings or ingestion of mould as food
- potential health benefits of fungi and mould
- exposure to other biotoxins or microbiomes such as bacteria and biotoxins produced by plants, which may be present in settings with indoor mould

Management of health effects due to mould exposure are also out of scope of this assessment. At an international level, there is a lack of guidelines on the diagnoses and management of indoor mould related exposures, and this is contributed to by the lack of strong evidence on the health effects of exposure to indoor mould and understanding of the dose-response relationship.

1.4 Methods

This work was undertaken as a desktop health risk assessment and comprised of accessing and interpreting information from peer-reviewed scientific and non-peer-reviewed literature. Literature was identified from key documents, scientific citation databases and searches of websites with a focus on any publications from official government agencies. A comprehensive review of published and grey literature was undertaken, using combinations of key words and phrases on search engines. Google Scholar, PubMed and Google search was conducted of English language articles between August and September 2023 and reflects information available during this period. The search strategy was not limited in scope and was adapted in response to findings identified as the work progressed. Non-peer reviewed sources, such as national and sub-national guidelines and reports, as well as sources cited in key papers but not otherwise identified in searches of the literature, were located and reviewed for relevance. All sources have been acknowledged throughout this work.

2 Mould

2.1 Mould in the indoor environment

Mould is common and ubiquitous in the natural environment. Indoor mould growth is a common issue that occurs in homes and workplaces across Australia and was estimated by the World Health Organization (WHO) in 2009 to affect 10% to 50% of indoor environments in Australia, Europe, North America, India and Japan.[4] In more recent prevalence studies, it is estimated that indoor mould affects between 21 – 45% of European homes, 30 – 47% of North American homes, 12 – 78% of New Zealand homes and 12 – 50% of homes in China.[5-7] In Australia, studies in 2019 and

2020 suggest that between a third and half of all homes in Australia are affected by indoor mould growth.[5,8]

Mould produces spores which are not visible to the naked eye. These spores can be carried in the air and seed on objects where they can grow or be transferred elsewhere via movement of the contaminated object. Mould can enter an indoor environment via a variety of methods including directly through open doorways, windows, vents and heating and air conditioning systems. Mould can also enter the indoor environment via indirect routes including spread via movement of contaminated objects such as clothing, shoes and pets from the outdoor environment.

While mould is common indoors, certain environmental factors promote the growth of mould such as moisture, dampness and inadequate ventilation. Mould can grow and thrive on any organic matter, and indoor dust and dirt usually provide sufficient nutrients to support growth.[9] Building materials such as wood, paper, carpet and insulation also provide sufficient nutrients for mould to grow, however, not all materials are equally susceptible to mould growth.[4,10] Where mould is present, there is a risk for mould growth on building materials if the materials are subjected to moisture and exceed the critical moisture threshold for mould growth.[10]

Mould can also be present in the indoor environment, even if nothing can be seen. Mould can exist behind walls, wallpaper, panelling and on the underside of carpets and pads. The presence of mould should be considered in circumstances where water damage to the building has occurred, where the indoor air is persistently humid and has poor ventilation, where a mouldy or earthy odour is present and where condensation occurs regularly on indoor surfaces. Visible mould usually has a fuzzy, smudged or discoloured appearance, and commonly presents as black, white or yellow mould.[4] Mould can also be other colours including grey, orange and brown, and can also change appearances whilst growing and aging.[11]

Mould growth may increase the number of spores, allergens and other toxins in indoor air, which may result in poorer indoor air quality and risk to human health. The exact causative agents of adverse health effects from indoor mould exposure have not been conclusively categorised. People may also be simultaneously exposed to many different microbial agents at any time. Any excess level of mould spores, allergens or other toxins released by mould in an indoor environment will affect indoor air quality and represents potential health hazards.

2.2 Common fungi found indoors

In Australia, there is an estimated 160,000 to 250,000 fungal species, of which less than five per cent have been described.[12] Common types of mould in indoor Australian settings include genus of fungi such as *Fusarium spp., Aspergillus spp., Penicillum spp., Alternaria spp., Cladosporium spp., Acremonium spp.,* and *Zygomycetes.*[4,13]

Some mould species, such as *Aspergillus versicolour* and *Stachybortrys chartarum*, produce mycotoxins which have known risks to human health.[14,15] Mycotoxins are metabolites produced by some fungi which can be toxic to human health. A recent review of mycotoxins reported in the indoor environment found over 140 different toxins present from indoor samples.[11] The health effects of many of the different mycotoxins were based on animal studies with limited information available on human health risks. Some mould species are also known to opportunistically cause infection in humans and include species such as *Aspergillus fumigatus* and *Trichoderma.*[16]

Indoor mould is highly diverse. Each species of mould has unique and variable characteristics which likely result in different risks to human health, such as differing growth requirements, variability in propensity to aerosolise spores and differences in ability to produce mycotoxins.[17] It is currently not known which specific mould species, combinations of mould species, or what concentration of indoor mould are associated with the various health risks that have been described. However, there is sufficient epidemiological evidence that collective indoor mould exposure is linked with health risks, so it is prudent to understand and address factors that contribute to mould growth in an indoor setting.

2.3 Environmental factors supporting the growth of indoor mould

The presence of indoor mould growth is contributed to by complex interactions between the outdoor environment, built indoor environment and occupant behaviours. Moisture in the indoor environment is the main determinant that facilitates mould growth.[4] People spend most of their time indoors and undertake a variety of moisture generating activities including breathing, showering, cooking and drying clothes indoors.[18,19] Furthermore, the variable use of heating, housing ventilation and maintenance patterns of homes can impact factors that support indoor mould growth such as humidity, temperature and ventilation.[20,21]

2.3.1 Outdoor environment

The types of mould spores in the outdoor environment vary seasonally and the variation has been correlated with the types of mould present in indoor environments.[21,22] Studies have identified that the incidence of invasive aspergillosis, an opportunistic fungal infection, varies according to seasonal weather changes and high environmental spore counts.[23] The concentration of airborne mould in the environment is also influenced by nearby vegetation, road congestion and weather conditions such as wind and rainfall.[22,24-26] Heavy rainfall and severe weather events such as flooding have also been linked to increased water damage and ingress to the build environment and thus increases risk of mould growth.[27] Furthermore, natural fluctuations in outdoor climate conditions including temperature and humidity are reflected in variations in the indoor environment.[4]

2.3.2 Dampness

Dampness relates to the phenomena of excess moisture, water or water vapour existing on surfaces or materials. Excessive indoor dampness itself has been described as a risk factor for human health; however, this has usually been in the context of the moisture supporting the growth of microbiomes.[29,29] Excess moisture in indoor settings can be caused by use of water for hygiene and cooking, transpiration of indoor plants and through breathing and exhalation by occupants, for example, exhaled breath condensate is often seen during cold temperatures. Other causes of damp and excess moisture include leaking water pipes, water table rises leading to rising damp in basement or ground floors, wastewater breaches and the weather.[4,30] Rain, severe weather events and high humidity environments may lead to dampness, especially if there are pathways or breaches in a building envelope allowing for moisture to intrude into a building.[31]

2.3.3 Humidity

Mould growth thrives in humid conditions. Optimal growth of mould requires high levels of relative humidity, typically above 70-80%, but has been demonstrated to grow in indoor settings from levels as low as 60%.[5,21,32] In the United Kingdom (UK), approximately a third of homes have issues with humidity in the indoor setting, increasing the risk of condensation and dampness which support mould growth.[33]

Indoor humidity can be improved using air-conditioning, heaters, fans and dehumidifiers; however, not all homes can afford regular use of energy services to reduce the humidity to a level that limits mould growth. Furthermore, homes in naturally humid areas are susceptible to high levels of humidity indoors as the outdoor environment is often reflected indoors; this can be further impacted upon by water vapour emission from indoor occupant activities.[32] Previous studies have found that the indoor humidity ratio was closely correlated with outdoor levels but was on average, slightly higher than outdoors.[34]

Northern Australia is particularly susceptible to high humidity during monsoon season, with relative humidity over summer months usually above 70% (see Appendix 11.1).[5,35] In a ten-year analysis of the climatic data of Darwin, the average relative humidity varied from 66 to 77% throughout the year, highlighting the broader need to address indoor humidity issues through housing and building practices, given the persistently humid natural environment.[35,36]

The indoor environment in many Australian homes is also considered susceptible to outdoor humidity. A recent review noted that: Australian homes often have subfloor ventilation and naturally ventilated roof spaces; occupants often use natural ventilation of windows and doors to cool homes on warmer days; and the building envelope of residential housing is usually not tight or fully mechanically cooled or ventilated.[5] Furthermore, there is limited evidence available in literature on environmental and climate conditions in the Australian context and occurrence of indoor mould; where studies exist, they usually occur in cooler climates such as New

South Wales and Victoria.[5] Various building, engineering and cultural heritage preservation guidelines recommend keeping relative humidity between 35 - 65%, to restrict conditions for mould colonisation and growth.[37]

2.3.4 Temperature

Biochemical and growth processes for mould development can vary depending on environmental temperatures.[38] The temperature requirements for mould growth are generally met in indoor environments, with most moulds able to grow between 5 - 35°C.[39] Some species of mould also grow better in colder temperatures, whereas others grow better in higher temperatures and include common species such as *Cladosporium spp., Aspergillus spp.,* and *Penicillium spp*..[4] Furthermore, higher temperatures increase the mould spore buoyancy; however, how this affects airborne spore concentrations in an indoor setting is unknown.[40,41]

The dew point is the temperature at which water vapour condenses and varies according to temperature and humidity.[42] The climate in Northern Australia consists of high humidity and high temperatures during summer months.[43] This climate can create ideal conditions for dew point problems to occur in indoor settings which can lead to increased moisture problems and promote a suitable environment for mould growth.[43]

2.3.5 Ventilation

Ventilation plays an important role in the development of indoor mould. Poor ventilation can increase the humidity of indoor spaces.[38] Studies have demonstrated that in poorly ventilated indoor settings, the concentration of airborne microflora are significantly greater than in indoor settings that use air-conditioning or natural ventilation practices such as opening windows or doors.[40,44] Furthermore, ventilation has been associated with reduction of reported health effects from mould exposure in previous studies.[4] Air-conditioning, heating and ventilation systems that are contaminated, however, can contribute to adverse health effects.[4,5] Systems that are poorly designed and inadequately maintained can lead to contamination by microbiomes such as mould, permit the passage of mould into the indoor environment, and contribute to adverse health effects.[4]

2.4 Social determinants

Housing in Australia varies significantly in architecture, age and materials. Households of lower socioeconomic status are likely to experience poorer indoor air quality.[45] Occupant behaviours can influence indoor air quality, for example, residents may not use natural ventilation practices due to concerns regarding security, cost or noise pollution. Occupants who are of lower socioeconomic status are more likely to experience overcrowding, live in homes that have inadequate insulation, and are poorly maintained.[5] Furthermore, lower socioeconomic groups may experience difficulty in affording to run air-conditioning or ventilation systems. Social determinants will impact the built environment and occupants' behaviours and

may put people who are from lower socioeconomic backgrounds at greater risk of indoor mould growth, and subsequently potential health risks.

3 Mould Following Weather Events

The aftermath of a major weather event such flooding and severe storms may provide ideal conditions for mould to grow.[46] Climate change and associated increases in heavy rain, flood frequency and sea-level rises will affect buildings, particularly those in flood-prone areas.[47] Ongoing water damage will exacerbate any existing structural defects, making buildings more prone to water ingress and leaks in the building envelope, which may continue to promote conditions ideal for indoor mould growth.[48,49] Furthermore, the effect of minor or gradual increases in temperature, such as warming secondary to climate change, and how this affects the ecology of fungi and mould is not well understood. However, it has been theorised that fungal growth, distribution and dispersal will be affected.[50,51]

A study that investigated mould concentrations following flooding in New Orleans, found significantly elevated spore counts in both the indoor and outdoor environment.[52] Furthermore, a total of 45 different fungal taxa was found in indoor samples post-flooding, with the most common mould species detected including *Cladosporium spp., Aspergillus spp.,* and *Penicillium spp.. Stachybotrys spp.* was also found in some indoor samples. The study concluded a lack of association between toxins, flooding and mould concentrations.[52] Following hurricanes Katrina and Rita in New Orleans, studies also found significant fungal growth in houses that were moderately and severely affected by water damage, with the predominant moulds being *Aspergillus spp., Penicillium spp., Trichoderma spp.* and *Paecilomyces spp..*[48] A significant pattern in adverse health effects was not identified and there were no significant increases in mould-related infections amongst occupants of flood-affected homes following the aftermath of hurricanes Katrina and Rita.[46,50] There were, however, reports of colonisation of *Syncephalastrum spp.*, and one infection of *Cladosporium spp*. in a significantly immunocompromised individual; however, invasive infection did not occur.[53] A recent study also found that mould infested homes were associated with a history of indoor flooding and greater indoor humidity.[54] The evidence demonstrates that severe weather events can cause water damage to building structures and create environments that support and promote indoor mould growth.

The extent of health effects as a result of increased mould exposure following severe weather events is currently not comprehensively understood. Studies have, however, demonstrated that severe weather events may lead to water-damaged homes and create a moist environment that supports indoor mould growth.

4 Health Effects

The WHO acknowledges that microbial pollution, which includes mould, is a key element of indoor air pollution.[4] A number of comprehensive reviews have been

undertaken which identify associations between mould exposure and respiratory health effects such as asthma development and exacerbation; lower respiratory tract effects such as infection, cough, wheeze and dyspnoea; and upper respiratory tract symptoms including coryza, congestion and irritation.[4,56-58] Although it is widely recognised that an association exists with exposure to indoor mould and a range of respiratory health effects, there is still ambiguity as to whether a direct cause and effect relationship exists. Furthermore, there is currently insufficient evidence to make conclusions of associations between indoor mould exposure and other health effects such as hypersensitivity reactions, toxigenic health effects and invasive infections. Jurisdictions in Australia vary in the advice provided on the health effects from indoor mould exposure (see Appendix 11.2).

Currently there are no quantitative health-based exposure guideline values or thresholds for acceptable or tolerable levels of individual exposure to mould. The development of reliable, health-based quantitative mould exposure limits is challenging and not feasible at this time. These challenges include:

- The existing body of evidence does not provide suitable information for derivation of exposure limits.[59]
- There is difficulty determining which disease-causing mould agents may be responsible for adverse health effects.[59]
- There is a lack of standardised, quantitative methods of measuring exposure to mould.[59]
- Biological human samples such as antibody testing to mould cannot be reliably used to define exposure in a non-infectious setting and indoor setting as these tests are not scientifically validated for those purposes.[59,60]

A number of comprehensive reviews on indoor mould exposure and risk to human health have been previously described. The most comprehensive reviews include those conducted by the US Institute of Medicine (IoM) in 2014, a meta-analysis published in 2007 by Fisk *et al*., the WHO Guidelines for Indoor Air Quality: dampness and mould published in 2011 and a review by Caillaud *et al.* published in 2018.[55-58] A review on the literature on health effects of mould is presented below, noting that the current body of evidence is still limited and may not conclude causal relationships or definite associations between indoor mould exposure and all the health effects described. Unless specified as causal or associated, the health effects identified represent the *potential* health effects of mould.

4.1 Respiratory health effects

The WHO Guidelines built on the conclusions made by the IoM review and at the time of the publication in 2011, found that there was sufficient evidence in the body of literature to conclude that mould in housing was consistently associated with symptoms of asthma exacerbation and development, wheeze, cough, respiratory infections, upper respiratory tract symptoms, and dyspnoea.[4] These associations were described in infants, children and adults. The WHO also concluded that the

evidence for asthma exacerbation following mould exposure was almost sufficient to document causality. A more recent review by Caillaud *et al.* included literature published up until 2017 and concluded that there was sufficient evidence to conclude a causal relationship between children exposed to indoor mould and the development and exacerbation of asthma.[58] This same conclusion, however, has not been made for adults due to fewer population-based studies and heterogeneity in the studies that were available.[58] More recently published studies further support a link between exposure to mould and respiratory health effects particularly in children.[61,62]

Despite this conclusion, and previously established associations between respiratory health effects and indoor mould exposure, a number of important factors remain unknown. There remains insufficient evidence to determine the quantity and duration of exposure required to cause asthma in children or other respiratory health effects, whether there is a dose-response relationship with mould exposure and respiratory health effects or whether specific types of mould species represent a greater risk of health harms. Despite these limitations, it is widely accepted that there is an association between respiratory health effects and indoor mould association with emerging evidence demonstrating that indoor mould exposure can cause asthma in children.[58,63-64] It would be prudent to take a precautionary approach and reduce and avoid excess mould exposure as much as feasible.

4.2 Invasive infections

The exposure of healthy individuals to indoor mould does not usually result in invasive fungal infection.[65] Invasive fungal infection in immunocompromised individuals, however, are a significant and emerging challenge, particularly with the increasing adoption of aggressive immunosuppressive therapy for certain conditions.[14] Invasive fungal infection mechanisms remain unclear.[16] A common hypothesis is airborne infection by inhalation of spores. In immunocompromised individuals with impaired host defences, the infection then spreads from the respiratory system via the blood and lymphatic system to organs.[66]

Certain fungi such as *Aspergillus spp*. and *Candida spp*. are also known to colonise individuals, who may later develop immunocompromising conditions or commence treatment that is immunosuppressive and thus become prone to developing invasive fungal infections.[26] Invasive fungal infections have also previously been associated with nosocomial infections in situations where hospitals had inadequate ventilation systems.[67] Several observational studies have demonstrated that improved air filtration in a hospital setting has been associated with lower rates of invasive fungal infections in high-risk patients.[68,69]

The types of mould species that cause human infection depend on certain factors. These include the ability of the mould to grow at body temperature, and pathogenic factors that play a role in the infectious potential of fungi such as adhesive factors, enzymes, toxins and melanin which support the fungi in penetrating or circumventing host barriers and withstand the hosts immune system.[65,69,70] The role of the quantity

and duration of exposure to infectious spores from an environmental setting and its effect on the development of invasive fungal infections remains unknown, even with air-sampling studies. Schweer *et al*. found no correlation between airborne *Aspergillus spp.* spore concentration in an indoor environment and the development of probable or proven invasive aspergillosis amongst immunocompromised individuals.[71] The current evidence body does not clearly demonstrate a threshold values for mould exposure and risk of invasive fungal infection. Quantitative health risk assessments are also not currently possible.[48]

4.3 Hypersensitivity reactions and allergies

Fungi are known to cause hypersensitivity reactions and allergies which are immunologic responses to allergens.[14,72] It is estimated that around 3 to 10% of the population have IgE antibodies to common inhalant moulds associated with allergens, including allergens from the four genera of fungi including *Alternaria spp*., *Cladosporium spp*., *Aspergillus spp*. and *Penicillium spp*..[14,73-75] Studies have concluded that exposure to indoor mould during gestation and infancy was associated with the development of atopic dermatitis in children.[76,77] Hypersensitivity reactions to fungi that have been previously described include allergic asthma, allergic fungal sinusitis, allergic alveolitis, allergic bronchopulmonary mycosis, and hypersensitivity pneumonitis.[63,78,79]

The relationship between indoor mould exposure and associated hypersensitivity reactions, however, is poorly understood and there is insufficient evidence to determine a causal relationship. It is known that some of the moulds that cause hypersensitivity reactions exist in indoor settings and associations between exposure and hypersensitivity reactions have been previously described.[80-82] Understanding the relationship between hypersensitivity reactions from indoor mould exposure is further complicated by the complex interplay between the inducing allergen, host genetic factors and other environmental factors – only a small number of people exposed to allergens ever develop hypersensitivity reactions.[81,83,84] Furthermore, identification of a causal allergen when dealing with hypersensitivity reactions is challenging due to lack of standardised techniques in antigen identification.[83,85] A review by Nogueira *et al*. on antigen diversity and implications on hypersensitivity pneumonitis notes that the identification of causal antigens is impossible in about 30-60% cases.[83] This is also complicated by the fact that there are many other potential triggering antigens in an indoor setting beyond mould such as bacterial, animal, vegetable and chemical antigens.

4.4 Toxigenic health effects

Health effects from mycotoxin exposure in humans is mostly commonly described with ingestion of contaminated foods. Inhalation and dermal absorption are also possible when mycotoxins are present in an indoor environment.[86] Toxicological and clinical evidence from *in vivo* animal studies and *in vitro* findings support the risk of

toxic responses to mycotoxins. However, the association between health problems caused by mycotoxins due to indoor mould exposure is still weak.

A recent review led by Eaton *et al*. identified over 140 different fungal metabolites in indoor environmental samples.[11] The review concluded that there are several limitations in describing the toxic health effects of mycotoxins found in indoor environments. Current studies usually focus on the ingestion of mycotoxins, with limited evidence available on dermal or inhalational exposure routes.[11] A number of the health effects that have been described were also based on animal studies alone.[11] Furthermore, the methods of quantification of mycotoxins present in indoor environments is complex and variable, limiting the ability to determine any dose-response relationships between mycotoxins and health effects.

'Toxic black mould' in indoor settings is caused by *Stachybotrys chartarum* and has been previously described to be associated with idiopathic pulmonary haemorrhage in infants. This association has since been refuted and no causal link could be established.[78,87] Despite this, there is still considerable public concern over the presence of 'toxic black mould', which has led to further research investigating the potential toxigenic health effects of *S. chartarum.* The evidence remains equivocal and potential health outcomes from *S. chartarum* mycotoxin exposure are likely multi-factorial.[87]

The Australian Government undertook an inquiry in 2019 to investigate biotoxin-related illnesses which include mycotoxins and toxins produced by other organisms such as plants.[88] They concluded that there is insufficient evidence to support a causal relationship between biotoxins associated with indoor mould and water-damaged buildings and potential adverse health effects. Furthermore, it examined the Chronic Inflammatory Response Syndrome (CIRS), which has previously reported as a result of exposure to water-damaged homes and mould. It concluded that CIRS is not widely recognised as a medical condition in Australia, and there is currently insufficient evidence to conclude a relationship between environmental biotoxin exposure including mould and CIRS.[88] Studies on mycotoxins and their concentrations on surfaces or in air, their toxic health effects after touch or inhalation, and the potential cumulative effects of multiple fungal agents, are still required to evaluate potential causal associations between indoor mould exposure and toxigenic health risk.[71,89]

4.5 Other health effects

4.5.1 General

Numerous other health effects have been described in literature, but the evidence base supporting a true association or causal relationship between these health effects and indoor mould exposure is lacking.

Two observational studies have previously reported increased exposure to indoor mould exposure in cases of sarcoidosis including cardiac sarcoidosis.[90,91] Major

limitations in the study design need to be considered when interpreting these results. A recent study in China reported that household dampness and mould exposure were linked with hypertension and cardiovascular symptoms including chest pain in one cohort, but this finding was not consistent across the two study cohorts.[92]

Another study conducted in Finland found increased reports of neurological symptoms and musculoskeletal pain in individuals who were exposed to indoor mould, compared to individuals who were not exposed to mould. Again, there were major limitations in the retrospective cohort study design.[93]

4.5.2 Genotoxicity

Some forms of mycotoxins are known to be genotoxic and exposure to mycotoxins have been previously linked to increase risk of cancer in occupational settings and toxicological studies.[94-96] How these findings relate to exposure to mould in indoor settings is still unknown and studies suggesting any link between cancer development and indoor mould exposure are limited to *in vitro* and *in vivo* studies.[97] Studies have also hypothesized that mycotoxin exposure may be affiliated with increased risk of cancer development through secondary mechanisms such as increased oxidative damage and stress.[98] A recent *in vitro* study has also suggested that different species of the genus *Aspergillus spp.* can produce metabolites which have varying synergistic or antagonistic effects on the genotoxic and cytotoxic potency of mycotoxins, further highlighting the complex physicochemical interactions that might occur with exposure to indoor mould.[99] Currently, an epidemiological relationship between indoor mould exposure and genotoxic outcomes has not been established.

4.5.3 Reproductive toxicity

The evidence base does not support a relationship or association between exposure to indoor mould, their mycotoxins and potential effects on reproductive health. Akin to genotoxic studies, current evidence on reproductive toxicity related to mycotoxin exposure is limited to *in vitro* and *in vivo* animal studies. Some mycotoxins have been demonstrated, through *in vivo* animal spermatogenesis studies, to be steroidogenic-like and have toxic effects on spermatogenesis in mice.[100] However, there is very limited literature supporting this.[100] Other mycotoxins, such beauvericin, enniatins and moniliformin, which are produced by *Fusarium spp.*, have been implicated in reproductive disorders in animals.[101] Furthermore, animal models of exposure to ochratoxin A, produced by *Aspergillus spp.* and *Penicillum spp*. have demonstrated feto-toxicity in mice and reproductive toxicity in their offspring.[102]

4.5.4 Developmental toxicity

There are limited epidemiological studies reporting the relationship of indoor mould exposure and developmental outcomes. The studies that do report a relationship have limitations including small sample sizes, subjective methods of exposure assessment, and inability to determine causality. They do, however, explore potential

developmental health effects of mould exposure. A retrospective nationwide cohort study in China reported an association with in utero persistent and mouldy odour exposure with low birth weight in the foetus.[103] In a Polish prospective cohort study, early and chronic postnatal exposure to indoor moulds was reported to be associated with poorer cognitive function in children.[104] Another study reported that pre-natal exposure to environmental pollutants, including indoor mould, was associated with worse developmental trajectories in offspring through seven years, although, the significance of indoor mould exposure alone was not described.[105] Furthermore, another study reported visible mould on walls during pregnancy as an independent predictive factor for asthma development in female children by the age of five years.[106]

4.6 Summary of health effects

The evidence base reports a number of different health effects with varying levels of evidence including epidemiological, clinical and toxicological. In summary, the current evidence base demonstrates a causal relationship between indoor mould exposure and asthma development and exacerbation in children, and an association between indoor mould exposure and other respiratory health effects. Mould is known to cause invasive infections and hypersensitivity reactions and is known to have toxicological health effects; however, the epidemiological evidence is not sufficient to conclude any causal relationships or definitive associations between indoor mould exposure and these health effects. Furthermore, a major limitation in understanding the health effects of indoor mould exposure is the scarcity in evidence informing an understanding of a dose-response relationship between mould exposure and human health effects.

5 Host factors

People spend a significant amount of time indoors, with estimates as much as 90% of their lives spent indoors.[107] The more time people spend in mould-affected indoor settings, the more they pose a potential health risk to themselves. Furthermore, the more time people spend indoors, the more likelihood that they will undertake moisture-generating activities which may also worsen mould growth.[108] When considering the body of evidence of indoor mould exposure on potential health effects and general toxicological principles, several sensitive populations are indicated and include children, pregnant persons, people with immunocompromising conditions or on immunocompromising medications, atopy and respiratory diseases.

5.1 Children

Children differ from adults in a range of behavioural and physiological parameters. Children's play activities are likely to put them in more frequent contact with mould on indoor surfaces, and they are also more likely to indulge in poorer hand hygiene practices. Furthermore, children have immature immune systems and a greater potential future duration of life, which means that any irreversible adverse effects from indoor mould exposure may influence their health throughout their life. The

body of evidence of mould exposure causing health effects in children is strongest for the development and exacerbation of asthma.[58] Associations between other respiratory health effects have also been established. In Australia, a comparative risk assessment modelling study estimates that visible indoor mould accounts for 7.9% of childhood asthma burden.[18]

5.2 Pregnancy

Some observational studies describe an association between mould exposure in pregnancy with poorer health outcomes in offspring, although these are limited in their strength.[103-105]

5.3 People with comorbidities

5.3.1 Immunocompromise

It is widely accepted by Australian health departments and international health protection agencies that immunocompromised individuals should be protected from mould exposure.[109,110] Some mould pathogens are known to cause invasive opportunistic infections in immunocompromised people. Epidemiological evidence supporting a strong relationship between indoor mould exposure and increased risk of invasive infections has not been established.

5.3.2 Atopy

Individuals with atopy and allergies are at risk for some allergic effects, such as allergic rhinitis, from mould exposure.[58]

5.3.3 Other conditions – respiratory

People with a history of respiratory diseases are likely to be at greater risk of health effects from indoor mould exposure. There is clinical evidence that some hypersensitivity reactions and invasive infections are more common in individuals with respiratory comorbidities. Allergy to *Aspergillus spp.* is more common amongst asthmatics, people with chronic obstructive pulmonary disease (COPD) and people with cystic fibrosis with previous reports of allergy to *Aspergillus spp.* in up to 57% of patients with cystic fibrosis.[78,110,111] Furthermore, these conditions have also been described to be complicated by allergic bronchopulmonary mycosis, a hypersensitivity reaction.[78,112]

An observational study has previously described a relationship between increased mould exposure in patients with COPD and poorer adverse COPD outcomes, suggesting that environmental mould exposure may play a role in the development and exacerbation of respiratory outcomes.[113] The role of indoor mould exposure in the pathophysiology and development of COPD has not been described.[111]

6 Mould exposure routes

Taking into consideration the data on the health risks associated with indoor mould exposure, inhalational appears to be the primary route of exposure to indoor mould. This is evidenced by observational studies that establish an association between indoor mould exposure and respiratory health effects. Studies investigating the toxic health effects of aerosolised mycotoxins in residential settings are few.[114]

Mycotoxins are known to cause health effects when ingested, as demonstrated through *in vitro* animal studies.[14,115] Ingestion, therefore, may represent a potential route of exposure if mycotoxins are aerosolised in an indoor environment and land on food or objects that are later ingested, although evidence supporting this is limited.

Clinical, *in vivo* and *in vitro* studies have also previously demonstrated that mycotoxins can also cause toxicity through dermal absorption. The amount of absorption varies and depends on potency of the toxin, blood flow to skin area, and rate of absorption.[57,116]

The levels of mycotoxins produced by indoor mould, dose-response relationships between health effects and indoor mould exposure and thresholds of indoor mould exposure causing adverse health effects have not been described. Furthermore, inconsistency in health outcomes from varying levels of reported exposures in studies demonstrate that the current understanding on the bioavailability of mould, their metabolites and mycotoxins and subsequent health effects from exposure is limited.

7 Assessment of Indoor Mould Levels

As quantitative methods in assessing indoor mould exposure are difficult, complex and have major limitations, most indoor mould assessment advice from health protection agencies take a binary approach (presence or absence of mould). There are some jurisdictions and agencies that undertake a semi-quantitative assessment, which considers the size of the mould growth, to determine remediation approaches.[117] Most epidemiological studies to date that investigate the health effects of indoor mould exposure utilise qualitative measurements, such as presence of dampness, visible mould and mouldy odour but the quantity of visible mould growth has not been correlated with risk of health events.[117] Although some studies look at air sampling and spore concentrations, the findings have not been congruent with associated health risks, and a dose-response relationship between amount of mould detected and health effects has not been established.[58] Conventional methods to assess indoor mould may fail to consider hidden mould, which can be common.

Due to these limitations and gaps in understanding the health impact from the presence of indoor mould and the quantity, the CDC in the US do not recommend testing for mould.[118] Furthermore, the USEPA notes that if visible mould growth is

present, sampling is unnecessary for assessment, with surface sampling only to be considered to confirm that an area has been adequately cleaned or remediated.[119] Similarly, Health Canada does not recommend testing the air for mould, as air sampling does not provide sufficient information to determine potential health risks.[120] Where a home has had water-damage, from flooding or leaking pipes, Health Canada notes that a non-viable air test for mould spores could be considered to identify and quantify high spore count which may indicate hidden mould.[120] The UK Government also notes that in many cases, a visible assessment of mould growth, odour, moisture and water damage is possible and sufficient. In more complex situations, the UK Government notes that chemical testing and physical testing may be required and that this testing should be undertaken by a professional who is experienced in managing mould and damp problems.[121]

In Australia, different jurisdictional health departments have varying recommendations regarding mould assessment. Currently, no jurisdictions recommend testing (see Appendix 11.3). In WA, recommendations regarding mould assessment include visual inspection using indicators such as visible mould, visible water damage, excess condensation, presence of standing water and mouldy odour.[122] WA guidance notes that surface or air sampling of mould spores is not recommended for establishing the level of health risk. However, sampling may assist in determining the extent of mould contamination, especially where hidden mould is suspected. Victorian, New South Wales and Tasmanian health departments similarly note that specialist services could be used for mould testing in circumstances where mould is suspected but cannot be identified.[123-125]

Queensland WorkSafe advises that an assessment should be undertaken to identify the risk, existing control measures in place, what controls can be implemented and how urgent the response should be.[126] The risk assessment template adapted from Workplace Health and Safety Queensland outlines aspects such as the hazard, risk assessment, control measures and implementation plan. The template is generic and does not provide specific considerations when assessing indoor mould growth.[126]

Recognising that mould exposure and risk assessment is complicated, and that current methods for environmental sampling for mould does not indicate health risks, the National Institute for Occupational Safety and Health developed an observational assessment method called the Dampness and Mold Assessment Tool (DMAT).[127,128] DMAT utilises a semi-quantitative scoring method to better differentiate factors related to mould growth and mould-related damage compared to a binary (present or absent) approach. By using the DMAT tool successively, it allows for comparison of the presence of past and current mould and allow for prioritisation of remediation and management.

The quantity of mould in indoor settings has not been correlated with health risks and a dose-response relationship has not yet been established, so the semi-quantitative scoring method has limitations in providing information on potential health risks. However, it can be used to identify factors leading to mould and identify the level of remediation required. In assessing the indoor environment when mould is identified, the environmental factors that precipitate and promote mould growth should be considered, such as presence of moisture, dampness, humidity, temperature and ventilation.

Where mould is identified in an indoor setting, a reasonable and precautionary approach would be to undertake remediation and implement control measures. The presence of mould in an indoor setting is known to be associated with health effects, contributed to by poor ventilation and water ingress, and lack of action may lead to further mould growth, property damage and the potential for increased risk to health. By correcting environmental factors and ensuring that they are adequately controlled, ongoing mould growth may be prevented thus reducing potential health risks to occupants.

The wider adoption of a scoring tool, such as the DMAT tool, would be useful to categorise extent of water-damage and mould growth and provide context of the historic water-damage and indoor mould found in the building. Furthermore, by using a standardised scoring tool, it would allow for better comparisons of the extent of indoor mould growth and associated potential health effects in future epidemiological studies.

7.1 Assessing for potential mould in homes

When considering the factors that promote mould growth, the presence of mould should be considered and investigated for in any circumstance where moisture is persistently present. A number of occupant behaviours can also contribute to the presence of moisture, including failure to use exhaust fans when showering, cooking or bathing, drying clothes indoors, growing plants indoors, and improper or poor ventilation practices. Where mould is identified, the factors leading to mould growth should be addressed and mould remediated.

The presence of mould should be considered when:

- Water-damage has recently occurred in the home from severe weather events, building envelope breaches or water leaks. Signs of this may be water stains or discolouration on flooring, carpets or walls, peeling paint, wrinkled wallpaper or efflorescence.
- Dampness is consistently present in the form of condensation on surfaces or when objects feel wet.
- Occupants identify musty and mouldy smells.
- The relative humidity is persistently high and there is poor ventilation.

The *WA Health Guidelines for Managing Mould and Dampness Related Public Health Risks in Buildings* (WA Guidelines) provides an overview of assessment procedures for mould in the indoor environment.[129]

7.2 Assessing water-damaged homes following flooding for mould

When assessing water-damaged homes from flooding, other hazards should be considered as they may represent additional significant health risks. These include hazards such as sewage contaminated floodwater, hazardous chemicals, asbestos, lead, electrical hazards and presence of pests, rodents or insects.

International health protection agencies advise that mould can grow within 24 to 48 hours in flood-affected homes with excessive moisture.[130-132] It is imperative that homes are cleaned and dried out as soon as possible, following a flooding event, to prevent mould growth. In circumstances where flood-affected housing has not been cleaned and dried within 48 hours, it is likely that mould growth has already contaminated the home. In these situations, occupants and first responders should take precautions and ensure that they do not have any predisposing conditions that would put them at higher potential risk to health effects from indoor mould exposure and that they use appropriate PPE when assessing the home.

8 Mould Remediation and Management

Where mould is present, remediation steps should be undertaken to address mould exposure. In addition, the cause of the mould and any environmental factors supporting the growth of mould need to be addressed.

The WA Guidelines provides an overview of remediation procedures for mould in the indoor environment.[129] The WA Guidelines disaggregate indoor mould into simple and complex mould, where simple mould can be appropriately remediated by internal staff or building occupants.[129] Complex mould would typically require professional help, and encompasses mould that meets one or more of the below characteristics:

- The growth is larger than 1m^2 or is found in multiple rooms or places
- There is evidence of recurring and persistent mould or dampness
- If any mould growth is confirmed or suspected in the heating, ventilation and air-conditioning system – not including low level mould growth within a single split-system
- When the underlying causes of excess moisture are due to the faults in building design or structure and are difficult to repair
- Where there is highly contaminated water incursion (for example, black water that is unsanitary and contains pathogens. It includes toilet overflow water containing urine and faeces waste, sewage water and floodwater from rivers or streams)
- When there are mouldy odours or unexplained illness associated with occupancy but no obvious visual signs of water or mould damage
- When other hazards are also involved (such as asbestos or toxic chemicals)

8.1 Prevention

Building owners and managers and occupants can reduce the risk of indoor mould by addressing environmental factors that support the growth of mould. This includes preventing and controlling moisture, ensuring the building envelope is adequately maintained, ensuring appropriate ventilation and addressing water damage or mould growth as soon as possible. The WA Guidelines provides an overview of moisture reduction strategies and mould prevention considerations.[129]

8.2 Remediation

Where there is indoor mould present, it should be addressed and remediated. Addressing the root cause of moisture present in the indoor environment will prevent ongoing growth, and this includes elimination of any structural cause (e.g., leaky tap), drying out of materials with mould growth, and where remediation is unable to address mould in porous materials, removal of the mould contaminated item completely.

Across health agencies, there is inconsistency in the advice provided for mould management and remediation (see Appendix 11.4 and Appendix 11.5). Different cleaning agents have been described in public advice including the use of home-based detergents and vinegars, hypochlorite bleach, alcohol and detergent-based biocides. Across Australia, most jurisdictions advise the first line use of a mild detergent or vinegar diluted in a water solution, or household products such as methylated spirits or commercial household products. There is variation amongst jurisdictions regarding the use of bleach. Most jurisdictions acknowledge bleach as an option and advise against mixing bleach with other cleaning products that contain ammonia due to risk of harmful by-products created during mixing.

The WA Guidelines currently recommend soapy water as the first line in removing mould, as it appears to be effective, is easily available and has no potential environmental or health side-effects.[129] This is in line with a review that found that most literature recommends cleaning with soap and water.[133] Other options such as commercially available biocides, antimicrobials, disinfectants and natural biocide, such as vinegar, alcohol and essential oils, are described in the Guidelines as potential options as well. The decision to use products other than the first line recommendation by the WA Guidelines would be a personal decision of the remediator. In circumstances where a commercial product is used, the remediator should always read the label carefully, follow any instructions for use and ensure that the product was designed for indoor use. Household chemical products should never be mixed, as harmful toxic gases may result.

8.3 Remediation by susceptible individuals

The amount of mould growth and the relationship with health risks has not been identified; however, some individuals are likely to be greater risk of the known health effects and the potential health effects. This includes people who are immunocompromised, have a history of respiratory conditions and atopy, children, and pregnant women. Where possible, these individuals should avoid indoor settings with mould growth. until appropriate remediation and control measures have been implemented and avoid undertaking remediation themselves due to their greater risk of adverse health effects. Susceptible individuals should also be provided

information on the potential health risks associated with indoor mould exposure, and methods they can take to reduce the risk of mould growth in an indoor setting.

8.4 Considerations following flooding events

When assessing homes following the aftermath of a flood, it should be assumed that indoor mould growth is present in buildings that have been wet for >24 to 48 hours and that the growth can be extensive. Excessive exposure in these settings, without appropriate PPE, may increase the risk of adverse health effects.

Any initial assessment of flood-affected homes needs to consider other hazards such as exposure to sewage contaminated floodwater, hazardous chemicals, asbestos, lead, electrical hazards and presence of pests, rodents or insects, and dead animals. Some of these factors mean that flood-affected homes with mould growth will likely result in complex mould growth.

There is evidence to suggest that appropriate and prompt remediation of flood-affected homes improves indoor air quality and reduces levels of bioaerosols including mould; however, during remediation, an increase in respiratory health effects was reported such as allergy and rhinitis.[134] It is prudent to address mould in flood-affected homes promptly; however, careful consideration of appropriate PPE and other risk mitigation measures such as opening up buildings must be undertaken to reduce risk of health harms.

8.4.1 First responders

First responders should consider their health history and the potential health risk from mould. A risk rating is presented below (see 8.5 Risk Rating and Protective Equipment Recommendations).

First responders should avoid entering flood-affected homes without the appropriate level of PPE, as per the recommended risk rating. Where the first responder has health risk factors that put them at greater risk, such as immunocompromising conditions, they should avoid entering the flood-affected home.

8.4.2 Steps to minimise mould after a flood

Mould will grow in homes subjected to excess moisture, such as flood-affected homes. To prevent excessive mould growth, prompt action should be taken to reduce sources of moisture in an indoor setting following a flood. This includes:

1. Implement ventilation practices as soon as possible. Where flood-affected buildings have been closed up for several days, enter briefly to open doors and windows and let the house be ventilated (at least 30 minutes) before staying on premises for any period of time.[135]
2. Open windows and doors, and keep them open when departing, to allow for ongoing ventilation. The risks of keeping the windows and door open need to be weighed considered and might include ongoing heavy rain and other factors such as wildlife and insects.[135]
3. Open interior doors such as room doors, closets, kitchen cabinets, bathroom vanity doors and drawers to allow those closed spaces to be ventilated.
4. Remove mud, dirt and debris from the house using a bucket with soapy water and a cloth, changed regularly. In some situations, a hose may be necessary.

Cleaning should start from the highest point and work down to the lowest level. This includes, where affected, the ceiling, walls and floors.
5. Remove all sources of pooled water.
6. Remove all wet or flood-damaged items, including floor coverings, rugs, mats, furniture, bedding, linen and clothing. If floor coverings are removed, thoroughly clean and dry the floor underneath before new material is laid.
7. Walls damaged by flood waters may need to be removed to dry out internal wall spaces. Walls may need to be replaced. Consider risk of other hazards such as asbestos contamination, dangerous structures, electrical wiring, plumbing, drainage and gas fittings. Licensed builders or professional services may be required.
8. Remove all soft or absorbent materials with mould growth.
9. If items are required for an insurance claim, temporarily store damaged or discarded items outside the home, in a safe, clean, dry place such as a shed or garage. Otherwise liaise with the local council to identify how rubbish and waste can be disposed of.
10. Clean and disinfect all surfaces using an appropriate cleaning agent (see 8.2 Remediation) inside the house, including floors, walls, the kitchen, bathroom and laundry. Ensure each area affected by floodwater is cleaned, including cupboards.
11. Allow the house to dry throughout by opening doors and windows during dry days, using fans (do not use diesel-powered equipment in enclosed spaces as fumes can cause health harms), draining water away from under the house to increase airflow, and checking for any trapped water and mud in wall or floor cavities.

8.4.3 Surveillance of health effects following flood-events

Following flooding events, enhanced surveillance of mould-related diseases can improve the understanding of potential health effects from mould exposure and the effectiveness of prevention methods.[136] The information collected through a surveillance system may also assist EHD in refining guidelines for mould exposure management, PPE and health risks from remediation of mould due to flooding. WA Health should consider the capacity and need to develop an enhanced surveillance system to support surveillance of health effects following flood-events, including mould-related symptoms.

8.5 Risk Rating and Protective Equipment Recommendations

Everyone should avoid mould exposure where possible. This is particularly important in individuals who are susceptible to potential health effects. A risk matrix is presented below which has been adapted from the CDC's *Population-Specific Recommendations for Protection From Exposure to Mold in Flooded Buildings by Specific Activity and Risk Factor*, to the WA context.[137,138]

In addition to the PPE recommendations, long sleeves and long pants should always be worn. The exposed items of clothing should be taken off when leaving the mould-contaminated area and laundered separately to other clothing to prevent spread of mould spores and other mould particles. Alternatively, an impervious disposable garment can be worn for protection against transfer of mould spores. The remediator should also use effective hygiene practices such as showering with

standard soap and warm water following being in the mould-contaminated area to reduce the spread of mould spores and other mould particles.

In situations where extensive dust may be generated, and the risk of mould aerosolisation is high, more substantial protection will be required such as equipment in line with remediation of complex mould.

8.5.1 Flooding situations and the risk rating

Where the indoor setting has been flood-affected for more than 24 to 48 hours, people should assume extensive growth and risk of complex mould upon entering the building. Protection equipment should be in line with remediation of complex mould. Remediation of complex mould typically requires professional help.

8.5.2 Practical considerations post-flooding

Agencies recommend avoidance of mould exposure by immunocompromised people, due to the higher risk of invasive fungal infections which can be associated with significant morbidity and mortality.[109,110] CDC conducted a survey following Hurricane Harvey, to identify immunocompromised persons and their practices following flood-damaged homes after the Hurricane.[139] Almost half of the survey respondents who were considered immunocompromised engaged in clean-up and remediation activities in flood-affected buildings, despite CDC's recommendation against for this cohort.[139] Furthermore, there was poor adherence to CDC PPE recommendations. This demonstrates that avoidance of mould-contaminated sites and buildings in a post-flooding event may be difficult for susceptible individuals.[139] Recovery communications need to emphasise the recommendation of mould-exposure avoidance for susceptible individuals, the potential health risks of exposure to mould and clearly articulate PPE recommendations to reduce any risk if mould-exposure is unavoidable.

Table 1. PPE recommendations for various exposure activities undertaken when assessing, managing and remediating indoor mould.

Exposure activities					
Risk factors	**Assessment^ of simple mould**	**Assessment^ of complex mould**	**Contact with items contaminated with mould e.g. recovery**	**Remediation of simple mould**	**Remediation of complex mould***
No risk factors	No precautions needed	P2 mask+, goggles	Gloves, P2 mask, goggles ± gown	Gloves, P2 mask, goggles± gown	Gloves, PAPR, non-breathable overalls, goggles
Immunocompromised people	Avoid exposure	Avoid exposure	Avoid exposure	Avoid exposure	Avoid exposure
People with atopy and hypersensitivity	P2 mask	P2 mask, goggles	Gloves, P2 mask, goggles ± gown	Avoid exposure	Avoid exposure

People with respiratory comorbidities	P2 mask	P2 mask, goggles	Gloves, P2 mask, goggles ± gown	Avoid exposure	Avoid exposure
Children	Avoid exposure	Avoid exposure	Avoid exposure	Avoid exposure	Avoid exposure
Pregnant	P2 mask	P2 mask, goggles	Gloves, P2 mask, goggles ± gown	Avoid exposure	Avoid exposure

^ Assessment only – does not involve disturbing mould or dust

* Remediation of complex mould typically requires professional help. Remediators should follow WorkSafe Australian/New Zealand Standard Respiratory Protection Standards (AS/NZS1716)

+ Visit healthywa for more information about P2 respiratory facemasks: https://www.healthywa.wa.gov.au/Articles/N_R/P1-and-P2-face-masks

P2 mask: A P2 respirator facemask (the equivalent standard in the US is known as a N95 respirator facemask) should be worn to reduce exposure to airborne mould spores and other mould particles. These masks are readily available at many stores.

Gloves: Long gloves that extend to the middle of the forearm are recommended. When working with water and a mild detergent, ordinary household rubber gloves may be used. If the remediator uses a disinfectant, a biocide such as chlorine bleach, or a strong cleaning solution, gloves that are made from natural rubber, neoprene, nitrile, polyurethane, or PVC should be used.

Safety goggles: Goggles or glasses are recommended to avoid getting spores or dust in eyes.

Gown: An impervious disposable garment can be used gowns can also be worn for protection against transfer of mould spores.

PAPR: Powered air purifying respirators (PAPR) should be used when remediating complex mould situations given the high likelihood of significant mould exposure. Alternatively, where these are not available, for example during a flood response, use a P3 particulate filtering facepiece to protect against airborne mould spores and other mould particles with an appropriate hood or face covering to achieve similar protection to PAPR use.

Non-breathable disposable overalls: The disposable coveralls should provide full-body protection**.**

Protective footwear: Waterproof/watertight boots should be used where available.

9 Conclusions

Indoor mould is common. A number of environmental factors promote the growth of mould such as excess moisture, dampness, humidity and poor indoor ventilation. Where these factors exist, mould can often proliferate readily. The behaviours of occupants of buildings also impact mould growth. Circumstances such as a flooding event also significantly increases the risk of mould growth in indoor settings.

Indoor mould exposure is known to cause health harms including the development and exacerbation of asthma in children and is associated with a range of other respiratory health effects. Furthermore, clinical and toxicological studies demonstrate that mould can produce toxins which can be harmful to human health and can cause hypersensitivity reactions and invasive infection. Individuals who are likely more susceptible to the potential health effects of indoor mould should be appropriately protected to prevent such adverse health effects. Despite this understanding, the relationship between indoor mould exposure and its association with health effects is not well established. A precautionary approach should be adopted and where mould is identified, appropriate remediation methods should be prioritised.

This review has identified a number of elements that can be incorporated into the WA Guidelines, including detailing further information on the health effects of exposure to indoor mould, the risk rating matrix and PPE recommendations. Overall, the evidence supporting recommendations in the WA Guidelines for assessment and remediation for indoor mould remain up to date. However, there is a need to develop evidence-based recommendations on addressing mould in flood-affected homes. Furthermore, there is a need to develop resources that target the susceptible populations to ensure that they understand the potential health risks of mould exposure and take appropriate measures to mitigate that risk.

There is growing interest in the health effects of indoor mould, although a number of elements remain poorly understood. Further research and work on identifying the potential health effects of indoor mould exposure, the prevalence of indoor mould in an Australian context and assessment methods of indoor mould is needed. The evolving body of evidence should be constantly reviewed as more information is made available to enable a clearer understanding of the health effects of indoor mould and allow for ongoing development of evidence-based risk assessments and evidence-based guidelines to prevent health harms from indoor mould.

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11 Appendices

11.1 Climate zones in Australia

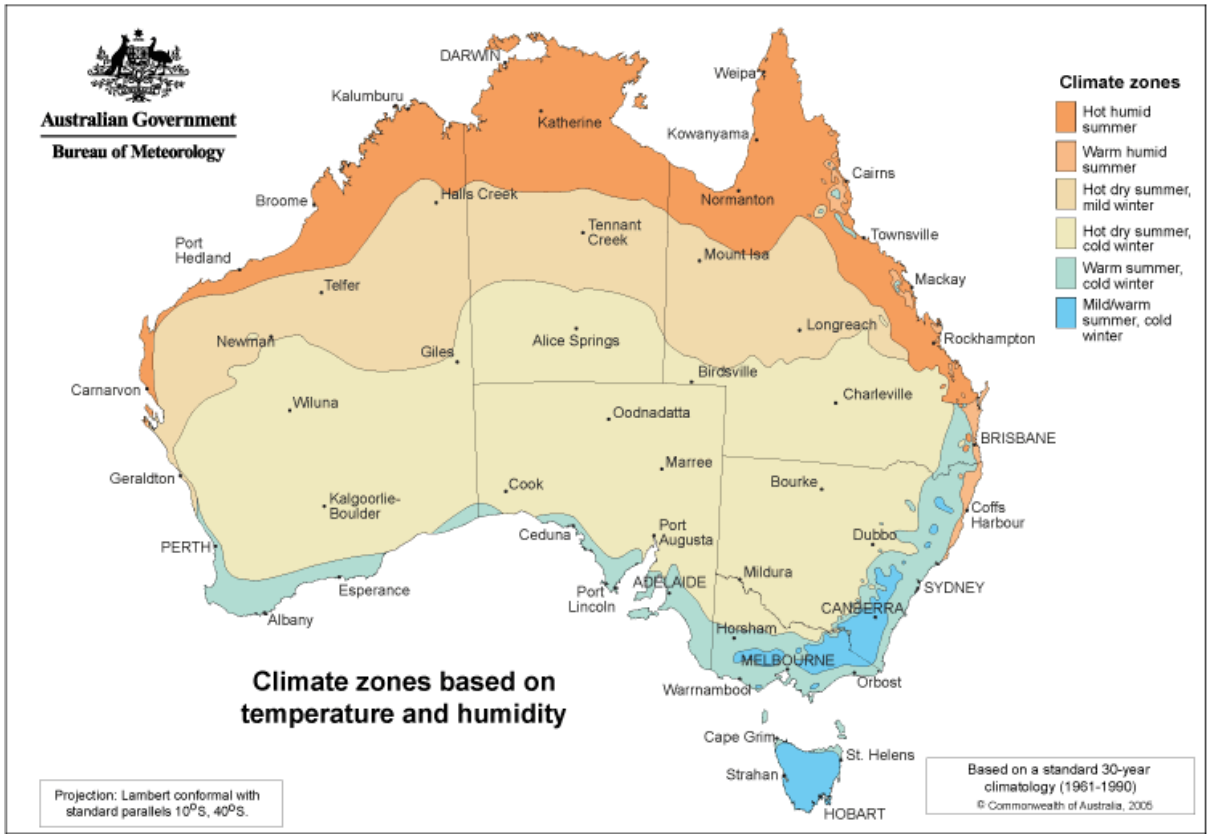

Figure 1 - Australian Climate Zones from the Bureau of Meteorology.[a]

[a] Source: http://www.bom.gov.au/climate/maps/averages/climate-classification/

11.2 Australian State and Territory health department public advice on the health effects of mould

Table 2. Health effects from indoor mould exposure by Australian health departments.

State or Territory	Health effects
Australian Capital Territory[b]	Nasal congestion, sneezing, cough, wheeze, respiratory infections Worsen asthma and allergic conditions
New South Wales[c]	Runny or blocked nose, irritation of the eyes and skin, and wheezing Trigger asthma attacks Severe mould infection, usually in the lungs, such as hypersensitivity pneumonitis
Queensland[d]	Health problems
South Australia[e]	Nasal congestion, runny nose, headache, sneezing, coughing or wheezing, and respiratory infections including fever and difficulty breathing. Trigger asthma and allergic conditions. Irritate eyes and skin.
Tasmania[f]	Coughing, a runny or blocked nose, sneezing, skin and eye irritation, and wheezing. Trigger allergic reactions.
Victoria[g]	Trigger nasal congestion, sneezing, cough, wheeze, respiratory infections and worsen asthma and allergic conditions.
Western Australia[h]	Asthma attacks; watery, itchy, red eyes; respiratory infections; rashes (dermatitis) e.g. eczema (atopic dermatitis); sinus problems, blocked noses
Commonwealth Department of Health and Aged Care[i]	Nasal congestion, sneezing, coughing or wheezing, and respiratory infections. It can also worsen asthma and allergic conditions. Contact with mould can also irritate eyes and skin.

[b] Source: https://www.health.act.gov.au/sites/default/files/2019-01/Mould.pdf
[c] Source: https://www.health.nsw.gov.au/environment/factsheets/Pages/mould.aspx
[d] Source: https://www.health.qld.gov.au/__data/assets/pdf_file/0018/713421/dm-mould.pdf
[e] Source: https://www.sahealth.sa.gov.au/wps/wcm/connect/14931f68-2bb1-4b98-8e03-ccf30d7b88b0/20230220+Controlling+mould+after+a+flood+fact+sheet.pdf?MOD=AJPERES&CACHEID=ROOTWORKSPACE-14931f68-2bb1-4b98-8e03-ccf30d7b88b0-opXPj6A
[f] Source: https://www.health.tas.gov.au/health-topics/environmental-health/environmental-health-services/mould#what-are-the-health-effects-of-mould
[g] Source: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/mould-and-your-health#how-does-mould-affect-health
[h] Source: https://www.healthywa.wa.gov.au/Articles/J_M/Mould-and-dampness
[i] Source: https://www.health.gov.au/sites/default/files/documents/2022/07/enhealth-guidance-potential-health-effects-of-mould-in-the-environment.pdf

11.3 Australian State and Territory health department public advice on mould assessment and testing

Table 3. Advice for testing for indoor mould exposure by Australian health departments.

State or territory	Advice on testing
Australian Capital Territory	No advice regarding testing
New South Wales[j]	Since most mould is visible, it is generally not necessary to test for mould in the home. However, some mould contamination may be present in cavities or the ceiling. If you think you have mould in your home but cannot find the source of the problem, you could employ an occupational hygienist. For a fee, these professionals can provide specialist mould testing and consultancy services.
Queensland	No advice regarding testing
South Australia	No advice regarding testing
Tasmania[k]	Most mould is visible, so it is generally unnecessary to test for mould in the home. We do not recommend testing for mould because mould is everywhere, and there are no health guidelines to compare test results.
Victoria[l]	Most mould is visible, so it is generally unnecessary to test for mould in the home. We do not recommend testing for mould because mould is everywhere, and there are no health guidelines to compare test results.
Western Australia[m]	Mould sampling is not necessary to determine the health risk. Any mould or dampness problems should be considered a potential health risk and should be remediated as soon as possible
Australian Capital Territory	No advice regarding testing

[j] Source: https://www.health.nsw.gov.au/environment/factsheets/Pages/mould.aspx
[k] Source: https://www.health.tas.gov.au/health-topics/environmental-health/environmental-health-services/mould#testing-for-mould
[l] Source: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/mould-and-your-health#how-does-mould-affect-health
[m] Source: https://www.healthywa.wa.gov.au/Articles/J_M/Mould-and-dampness

11.4 Australian State and Territory health department public advice on using agents for mould remediation

Table 4. Advice on using cleaning agents for mould remediation advice by Australian health departments.

State or territory	Advice on remediation
Australian Capital Territory	No advice regarding remediation
New South Wales[n]	For routine clean-up of mouldy surfaces, use mild detergent or vinegar diluted in water solution (4 parts vinegar to 1 part water). If the mould is not readily removed and the item cannot be discarded, use diluted bleach solution (250mls of bleach in 4 litres of water) to clean the surface.
Queensland Health – Flood fact sheet[o]	Household cleaning agents or detergents can do an effective job if used correctly, as can white fermented vinegar cleaning solution. The use of bleach may not be effective in killing mould on porous surfaces. However, bleach will help to minimise other disease-causing organisms that may be present because of contaminated floodwaters.
South Australia[p]	Small areas of mould can be cleaned by using a bleach mixture (1 part bleach to 3 parts water) or a suitable commercial product (follow the manufacturer's instructions).
Tasmania[q]	Small areas of mould can be cleaned by using a mild detergent or a vinegar mixture (four parts vinegar to one part water). If the mould is not readily removed, use diluted bleach (one part bleach to three parts water).
Victoria[r]	Small areas of mould can be cleaned by using a mild detergent or a vinegar mixture (four parts vinegar to one part water). If the mould is not readily removed, use diluted bleach (one part bleach to three parts water).
Western Australia[s]	Soapy water is usually sufficient for removing mould. Other products that can be used include: - commercially available products - natural anti-fungal agents such as vinegar, tea-tree oil. Remember, fungicides that are developed for outdoor use should not be used for indoor mould.

[n] Source: https://www.health.nsw.gov.au/environment/factsheets/Pages/mould.aspx
[o] Source: https://www.health.qld.gov.au/__data/assets/pdf_file/0018/713421/dm-mould.pdf
[p] Source: https://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/public+health/living+conditions+and+sanitation/mould+in+the+house
[q] Source: https://www.health.tas.gov.au/health-topics/environmental-health/environmental-health-services/mould
[r] Source: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/mould-and-your-health#how-does-mould-affect-health
[s] Source: https://www.healthywa.wa.gov.au/Articles/J_M/Mould-and-dampness

11.5 International agencies advice on using agents for mould remediation

Table 5. Advice on using cleaning agents for mould remediation advice by various international government agencies.

Agency	Advice
Centers for Disease Control and Prevention[t]	Scrub cleanable surfaces (wood, tile, stone) with soapy water and thistle brush Thoroughly clean all hard surfaces with water and dish detergent Use a bleach solution of no more than 1 cup household laundry bleach per 1 gallon of water to kill mould on surfaces
United States Environmental Protection Agency[u]	Scrub mold off hard surfaces with detergent and water, and dry completely. Biocides are substances that can destroy living organisms. The use of a chemical or biocide that kills organisms such as mold (chlorine bleach, for example) is not recommended as a routine practice during mold cleanup. There may be instances, however, when professional judgment may indicate its use (for example, when immune-compromised individuals are present).
United Kingdom Government[v]	Mould and mildew products should be used in preference to bleach, for health and safety reasons.
New Zealand Education Government[w]	Remove mould with a commercial mould cleaner or hypochlorite bleach. Combine one and a half cups of household bleach to four litres of water, wipe on any mouldy areas and leave for 10 minutes before rinsing and drying.
New Zealand Homes and Communities Government[x]	White vinegar is the best way to kill or clean mould. Note it has a bleaching effect so don't use it on surfaces that might discolour. Spray directly onto the mould using a spray bottle or wipe it on using a clean cloth.

[t] https://www.cdc.gov/mold/mold-cleanup-bleach.html
[u] https://www.epa.gov/mold/brief-guide-mold-moisture-and-your-home
[v] https://www.gov.uk/government/publications/damp-and-mould-understanding-and-addressing-the-health-risks-for-rented-housing-providers/understanding-and-addressing-the-health-risks-of-damp-and-mould-in-the-home--2
[w] https://www.education.govt.nz/school/property-and-transport/health-and-safety-management/moulds-and-fungi/
[x] https://kaingaora.govt.nz/assets/Tenants-and-communities/Documents/Controlling-mould-in-your-home.pdf