Scoping assessment of the residential indoor air hazards landscape: Identifying gaps and opportunities for public health

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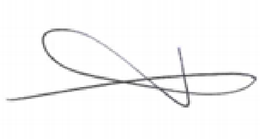

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EXECUTIVE SUMMARY

This report provides an overview of residential indoor air hazards in Aotearoa New Zealand, with a focus on identifying current gaps and opportunities to improve public health. Poor air quality and hazardous indoor environments are significant contributors to both communicable and non-communicable diseases, particularly in populations who spend a large proportion of their time indoors. With whānau spending approximately 70% of their time at home, exposure to indoor air hazards—such as dampness, mould, gas pollutants, lead, particulate matter, and volatile organic compounds—contribute to the burden of cardiovascular and respiratory diseases, cancers, and immune disorders.

The report is structured into three main sections: a review of relevant legislation, standards, and guidelines; a description of key agencies and organisations involved in indoor air quality; and an analysis of the literature on indoor air hazards in the Aotearoa New Zealand context. The first section includes an examination of existing laws such as the Building Act, Residential Tenancies Act, and the Healthy Homes Guarantee Act, and identifies areas where these regulations may need to be updated or better enforced. Gaps in the current legislative and operational systems are identified, with a focus on improving housing conditions, ensuring acceptable indoor air quality, and addressing the specific needs of structurally disadvantaged populations.

The report highlights the inequities in exposure to indoor air hazards, particularly among structurally disadvantaged groups, such as Māori, Pacific peoples, and low socioeconomic communities. Colonial histories, housing policy shortcomings, and structural racism have contributed to disparities in housing quality and health outcomes. Māori and Pacific whānau are more likely to live in overcrowded, poorly insulated homes that increase exposure to indoor air hazards, amplifying health inequities. The report concludes that addressing these inequities through targeted policies and public health actions can improve overall health outcomes and equity.

Key findings indicate that while New Zealand has some legislation and standards addressing indoor air hazards, there are notable gaps in enforcement, monitoring, and compliance, particularly in rental properties, and an absence of indoor air quality standards. There is a wide range of agencies and organisations involved in indoor air hazards in Aotearoa New Zealand homes. However, several hazards lack any reference in legislation, standards, guidelines or the roles of organisations in New Zealand. Additionally, while the presence of cold, damp and mouldy housing is well studied in New Zealand, for all other hazards there is a lack of good quality data on exposure in the New Zealand residential setting. This makes it challenging to assess the true burden of disease of indoor air hazards in the home in New Zealand.

The report advocates for more robust and comprehensive policies that focus on improving ventilation, insulation, and overall housing quality, especially in structurally disadvantaged communities and rental property regulations. It highlights the need for better application of Te Tiriti o Waitangi principles into housing policy and indoor air quality standards, ensuring that Māori and Pacific communities have safe, healthy homes that align with their cultural needs. This report provides insights into opportunities for public health agencies, local and central government, and community organisations to work collaboratively to improve residential air quality, reduce health inequities, and promote healthier, more sustainable housing environments in New Zealand.

1. INTRODUCTION

1.1 BACKGROUND

Poor indoor air quality and hazardous indoor environments contribute significantly to communicable and non-communicable disease in Aotearoa New Zealand (NZ) (Howden-Chapman et al., 2023; Howden-Chapman et al., 2021; Riggs et al., 2021; Tin Tin et al., 2016; Vardoulakis et al., 2020). People may experience substantial exposure to indoor air hazards, as large amounts of time per day may be spent in the home environment. In NZ, whānau spend approximately 70% of their time indoors at home (Khajehzadeh & Vale, 2017). While NZ have standards for outdoor air quality, there are currently no national standards for indoor air quality.

Access to safe housing is a human right (Bennett et al., 2022). The NZ Human Rights Commission states that housing must be safe, warm, and culturally appropriate. Residential indoor air hazards are impacted by the quality, design, suitability, and location of houses, as well as activities inside the house (Vardoulakis et al., 2020). While each hazard will cause different health impacts, in general indoor air hazards may contribute to a wide variety of health impacts including cardiovascular disease, respiratory illness, skin conditions, cancers, and immune disorders (Vardoulakis et al., 2020).

Indoor air hazards may originate from both inside and outside the building. Hazards may accumulate in an indoor air environment if ventilation is not adequate. The United States (US) Environmental Protection Agency reports that indoor air pollutant levels may be two-to-five times higher than outdoor levels, in some cases reaching levels 100 times higher (Bennett et al., 2022). Comprehensive exposure and risk assessments for indoor air hazards are complicated due to the wide range of possible hazards present in air (Phipps, 2017). Indoor air pollution comes from several sources; therefore, prevalence and concentrations of pollutants in indoor air will vary (Maung et al., 2022; Vardoulakis et al., 2020). Additionally, older buildings and modern buildings face different challenges relating to indoor air hazards. This report aims to provide an overview of the current residential indoor air landscape to identify gaps and opportunities to improve public health in NZ.

1.2 EQUITY AND TE TIRITI O WAITANGI RELATING TO INDOOR AIR

Studies both internationally and within NZ show there are inequities in the exposure to indoor air hazards (Howden-Chapman et al., 2023; Howden-Chapman et al., 2021; Howden-

Chapman et al., 2012; Phipps, 2017; Riggs et al., 2021). Structurally disadvantaged populations, such as Māori, Pacific peoples, and low socioeconomic groups, are disproportionately exposed to hazards in the home environment (Howden-Chapman et al., 2023; Howden-Chapman et al., 2021; Howden-Chapman et al., 2012; Ingham et al., 2019; Phipps, 2017). Differences in housing quality, such as with increased levels of dampness and mould, are well studied in the NZ setting.

For Māori, inequitable exposure to residential indoor air hazards has been driven by colonisation. Large scale loss of land and urban migration resulted in lower land and home ownership, and loss of spiritual and cultural connection to place (Anderson & Spray, 2020). The Crown has obligations under Te Tiriti o Waitangi to allow Māori to exercise tino rangatiratanga, to eliminate inequities, and to support partnerships to allow Māori rights to be met. In NZ, the constitutional status of te Tiriti o Waitangi means that the right to safe housing must be read alongside, and grounded in, te Tiriti (Anderson & Spray, 2020).

Due to the ongoing impacts of colonisation, structural racism, and shortcomings in housing policy, Māori and Pacific whānau are over-represented in low-income households, and are more likely to experience poor quality housing with higher levels of indoor air hazards (Anderson & Spray, 2020; Beukes et al., 2024). This influences inequities in health outcomes, with housing being a key social determinant of health (Howden-Chapman et al., 2021). Renters are also more likely to experience unacceptable levels of indoor air hazards, with approximately 30% reporting living in poor quality housing compared to 10% of owner-occupied properties.[1] Outdoor air quality impacts the presence of indoor air hazards, particularly for particulate matter (PM) and gas phase pollutants (e.g. nitrogen dioxide) (BRANZ, 2019). A social inequity and air quality study showed inequities in exposure to poor outdoor air quality (ESR, 2023). Those living in areas with higher levels of socioeconomic deprivation are more likely to be adversely affected by air pollution (ESR, 2023).

It is important to note that residential properties may not be fit for purpose for whānau for a variety of reasons. For example, NZ housing stock is largely set up for nuclear families with a Eurocentric view on housing needs, which may exacerbate inequities (Anderson & Spray, 2020). Multigenerational or shared living spaces are not commonly available in NZ's housing stock, particularly social housing - only 4% of houses in NZ have five or more bedrooms. This lack of availability increases the risk of overcrowding, with housing not corresponding to diverse cultural norms. Further, even where housing is large enough, the cost of heating

[1] [2015 House Condition Survey results | BRANZ]

poorly insulated cold homes may result in functional overcrowding as people need to be in smaller spaces to stay warm (Baker & Howden-Chapman, 2012)

Across the residential indoor air quality landscape there are a range of factors that contribute to inequities in the exposure to indoor air hazards. Poor quality rental housing, disproportionate exposure to outdoor air pollution and housing not meeting diverse needs all contribute to increased exposure to air hazards. Importantly, policy that targets reduction in air hazards in structurally disadvantaged areas, and groups, will deliver greater health benefits (ESR, 2023).

1.3 APPROACH

An initial scoping document was shared with the Te Whatu Ora Environmental Health team for feedback on the selected indoor air hazards for review, to ensure the hazards selected were relevant for the report and based on evidence of presence in indoor residential environments. The agreed approach taken to complete the report included:

1. Undertake a literature review (including peer-reviewed reports, grey literature, media reports, agency and other websites) to identify potential indoor air hazards of relevance in the NZ context.

2. Identify relevant legislation (Acts, regulations, bylaws) standards, codes, guidelines and good practice guides that may relate to indoor air hazards in NZ.

3. Undertake a stocktake of central and local government agencies specified in relevant legislation, standards, and guidelines, and identify their roles and responsibilities.

4. Search published and grey literature relating to indoor airborne hazards in NZ to identify other organisations (including universities and NGOs) with roles and responsibilities, including any evidence of monitoring and responding to indoor airborne hazards in NZ.

5. Review the literature relating to the key elements of wider indoor airborne hazards to, where possible:

   - assess risks from indoor air hazards, particularly for populations who are structurally disadvantaged, including for iwi, hapū and Māori communities, tangata whaikaha, and Pacific peoples.
   - identify gaps in the legislative or operational delivery system,
   - identify and prioritise opportunities for public health action.

The report is structured into three sections, firstly reviewing relevant legislation, standards or guidelines for each hazard, secondly, describing the organisations or agencies responsible for the hazard, and thirdly reviewing the literature with a focus on the NZ context and equity for the health risks associated with the hazard. Gaps and opportunities for improving public health are discussed in a final chapter to provide an overview, taking into account each hazard presented. Where possible, research in New Zealand is prioritised to ensure the findings are most relevant to the New Zealand context.

1.4 SCOPE

For the purpose of this report, indoor air is classified as the air inside a building and the scope will be limited to residential buildings including standalone homes, townhouses, units and apartments. This includes both rented and owner-occupied properties. Residential care facilities, education facilities and workplace environments are not included in the scope of the report. The home environment has been selected as the focus of the review as most people spend the largest proportion of indoor time in their home, particularly populations at higher risk of adverse impacts from indoor air hazards, such as children and elderly. Outdoor air contributes to the quality of the air inside the home. However, for the purpose of this report, indoor sources of the selected hazards have been focused on where possible.

A literature review which included peer-reviewed literature, grey literature, media reports, and agency websites was completed to identify potential indoor air hazards relevant to the NZ setting. Hazards were included if there was evidence of being a current or emerging issue in New Zealand. Absence of legislation, bylaws, standards or guidelines did not necessarily imply the absence of a hazard. Second hand smoke, construction practices, and legionellosis are not included in the scope of the project.

Ventilation is discussed throughout the report as it relates to most of the identified contaminants selected and can be seen as both a mitigating and exacerbating factor, depending on the quality of ventilation. The selected indoor air hazards are listed below:

1. Dampness and mould
2. Gas phase pollutants – e.g. carbon monoxide, nitrogen dioxide, carbon dioxide
3. Lead and other heavy metals
4. Microbiological contaminants – e.g. bacteria, viruses,
5. Particulate matter
6. Temperature
7. Volatile organic compounds e.g. benzene and formaldehyde

This report is not intended to be a risk assessment for indoor air hazards in the residential home. Hazards are identified and described in the report, alongside information related to the context in the New Zealand setting, to highlight any gaps and opportunities for improving public health. Where possible from the available literature, estimates of the burden of disease caused by hazards are discussed.

Finally, while some gaps and opportunities are discussed later in the report. The report is not intended as a comprehensive assessment of all policies and interventions available to improve residential indoor air quality. Detailed analysis of options for addressing indoor air hazards were considered out of scope.

2. LEGISLATION, STANDARDS AND GUIDELINES

The following section outlines various legislation, standards and guidelines, and details where each may be associated with the selected indoor air hazards in a residential setting. A brief overview of outdoor (ambient) air quality legislation, standards and guidelines is also included to begin with as this is an important factor in determining indoor air quality.

2.1 LEGISLATION

Legislation available in NZ relating to managing and protecting the quality of outdoor air includes The Resource Management Act 1991, Health and Safety at Work Act 2015, and the Health Act 1956. The Health Act 1956 also has provisions for nuisance relating to outdoor air, which may include odours. Notifications may be sent to the Medical Officer of Health for poisoning from chemical contamination of the environment, which may include discharges to outdoor air, or indoor air issues such as carbon monoxide poisoning. Air quality implications are also considered under the Land Transport Management Act 2003.

The following pieces of legislation relate to residential indoor air hazards.

2.1.1 Building Act 2004

The Building Act 2004 is a key piece of legislation relating to residential indoor air hazards. The Act states that people who use buildings need to be able do so safely without endangering health and that buildings must contribute appropriately to health. An insanitary building is defined in the Act as one that is offensive or likely to be injurious to health. The Building Code is contained under the Building Act 2004.

2.1.2 Residential Tenancies Act 1986

Landlords must provide and maintain a premises that is in a reasonable state of repair and comply with all requirements of buildings health and safety. Therefore, under the Act, a landlord is required to protect a tenant from indoor air hazards relating to the housing quality and condition, such as lead contamination or dampness and mould.

2.1.3 Healthy Homes Guarantee Act 2017

The Healthy Homes Guarantee Act 2017 has mandated minimum standards for rental properties, which are defined in detail in the Residential Tenancies (Healthy Homes

Standards) Regulations 2019. The regulations were due to have been met by July 2024 for Kāinga Ora and community housing providers, and July 2025 for private landlords. Compliance standards are not formally monitored and there is no formal registration for meeting standards. The regulations are secondary legislation and include minimum standards for:

- heating
- insulation
- ventilation
- moisture ingress (dampness) and drainage
- draught stopping.

2.1.4 Kāinga Ora – Homes and Communities Act 2019

In the Kāinga Ora – Homes and Communities Act there is no specific mention of air quality, but it does make reference to quality homes, that are warm, dry and healthy, which will impact levels of indoor air hazards relevant to this report. The Act also dictates that Kāinga Ora operates to support development of commercial, industrial, community and infrastructure. This will impact on outdoor air quality, which in turn impacts indoor air hazards. Of note, a Māori interests' section is included within the Act stating that Kāinga Ora must uphold Te Tiriti o Waitangi in its work.

2.1.5 Health Act 1956

The Health Act section 120C has provisions allowing prescribed standards of fitness for regulations relating to housing improvement and overcrowding. The Health Act also legislates lead absorption equal to or in excess of 0.24 μmol/l and poisoning arising from chemical contamination of the environment as notifiable to the Medical Officer of Health. Additionally, the Medical Officer of Health may require a territorial authority to repair or close an insanitary building.

2.1.6 Pae Ora (healthy futures) Act 2022

Requires the health system to protect and promote and improve all people's health. It also requires the health system to achieve equity, particularly for Māori. The Act states that one of the functions of Te Whatu Ora is to *"collaborate with other agencies, organisations, and individuals to improve health and wellbeing outcomes and to address the wider determinants of health outcomes".* This may include housing and indoor air hazards as a determinant of health.

2.1.7 Health and Safety at Work Act 2015

While health and safety at work is beyond the scope of this report, it is worth noting that this Act requires workers/companies to protect themselves and others from harm. In relation to indoor air hazards, this may be relevant to removal of lead-based paint and asbestos, and companies and workers being required to remove safely to reduce risk of exposure for workers, and subsequently household members.

2.2 STANDARDS

2.2.1 The Resource Management (National Environmental Standards for Air Quality) Regulations 2004

The National Environmental Standards for Air Quality are led by the Ministry for Environment. The Standards set the minimum level of protection for ambient air quality for New Zealanders. They comprise 14 interlinked standards including banning activities that discharge significant quantities of certain toxins in the air, design standards for new wood burners, and five standards for ambient air quality.

2.2.2 Ventilation for Acceptable Indoor Air Quality (NZS 4303:1990)

The purpose of this standard is to provide minimum ventilation rates to avoid adverse health effects from poor indoor air quality. The scope of the standard includes all indoor or enclosed spaces that people occupy. It also includes moisture release in residential bathrooms and kitchens. Indoor air is considered acceptable if outdoor air is below standard values, and if there are adequate rates of ventilation of acceptable outdoor air provided. This standard was last reviewed in 1990.

2.2.3 Thermal Insulation – Housing and Small Buildings (NZS 4218:2009)

The Standard provides the specific thermal insulation requirements for housing and small buildings. It provides three methods for demonstrating compliance with the NZ Building Code.

2.2.4 Building Code Standards

The NZ Building Code is administered by the Ministry of Business, Innovation and Employment (MBIE) and provides the performance standards for new and renovated building to comply with. Standards for health and wellbeing relating to indoor air hazards within the code include those for energy efficiency, insulation, indoor moisture and ventilation. The Building Code was updated in 2021 to increase the insulation requirements for new and renovated homes in NZ.

2.3 GUIDELINES

2.3.1 The World Health Organization Guidelines for Air Quality

The indoor air quality guidelines were published in 2011 and include guidelines for nine selected pollutants. These guidelines are not legally binding in NZ, and not all the pollutants are relevant to the indoor residential air hazards NZ context. The WHO also published global air quality guidelines in 2021 which are applicable to indoor and outdoor settings.

2.3.2 Guidelines for the Management of Lead Based Paint

The Ministry of Health (MoH) have guidelines for the management of lead based paint. These were completed in 2013. Since completion some changes have been made to the management of lead exposure in NZ. The blood lead level for notification reduced to 0.24 µmol/L in 2021 and the Health and Safety at Work Act 2015 has been established requiring protection of people from harm from lead.

2.3.3 The Environmental Case Management of Lead-Exposed Persons: Guidelines for Public Health Officers

The Te Whatu Ora Guidelines for Public Health Officers on Environmental Management of Lead Exposed Persons were updated in 2024. They provide guidance on investigation of environmental sources, including the residential setting, and mitigation of lead exposure in a non-occupational setting.

2.4 SUMMARY

Legislation in Aotearoa largely focuses on residential buildings being good quality, warm and dry, and complying with health and safety requirements. Overall, indoor air hazards are not specifically mentioned in any legislation, except for dampness and temperature. Outdoor air standards and legislation are more specific and have greater controls for managing and protecting outdoor air quality. Of note, indoor ventilation to improve air quality has become more of a focus during and subsequent to the COVID-19 pandemic.

3. AGENCIES AND ORGANISATIONS

The following section details agencies and organisations with responsibilities and/or interests relating to residential indoor air hazards.

3.1 CENTRAL GOVERNMENT

Ministry of Health

The MoH is responsible for administration of the Health Act and the Pae Ora Act. The MoH have the function of improving, promoting, and protecting public health. The Public Health Agency (part of the MoH) was established as part of the Pae Ora Act to provide national leadership on public health in NZ. The MoH published the guidelines for management of lead-based paint as previously mentioned. They also provide advice on heating, ventilation, and management of mould and dampness in homes.

Ministry of Housing and Urban Development

The Ministry for Housing and Urban Development (HUD) supports the work programmes and strategy development for housing and urban development in NZ. HUD have a role in administering the Housing Act, The Residential Tenancies Act, the Kāinga Ora- Homes and Communities Act.

Ministry of Business, Innovation and Employment

MBIE supports building and construction performance and regulation. They administer the building code. Part of their operational functions is to ensure that buildings meet requirements to be safe, durable and healthy. MBIE have also completed evaluations of changes to the Residential Tenancies Act (last completed in 2018).

Tenancy Services

Tenancy Services is administered through MBIE. It is the national body responsible for tenanted housing. It provides information and advice on people’s rights and responsibilities as tenants or landlords. Tenancy Services administers the Residential Tenancies Act 1986, Unit Titles Act 2010 and the Healthy Homes Guarantee Act 2017. Finally, it monitors and enforces compliance with the Healthy Homes Act and the Residential Tenancies Act, and the regulations associated with these.

3.2 LOCAL GOVERNMENT

Under the Building Act 2004, territorial authorities (TAs) are required to hold policies on insanitary and dangerous buildings. If the TA is satisfied that a building is likely to cause injury to human health or cause death it can prevent building access and give written notice for remedial work to be completed. TAs may also issue cleansing orders, require repairs, and issue closing orders under the Health Act 1956 where a home is likely to cause injury to the resident's health. Finally, the TA can be directed by a Medical Officer of Health to issue such orders, and a Medical Officer of Health may issue a closing order if the TA fails to act.

Under the Resource Management Act regional councils and unitary authorities hold responsibilities for outdoor air quality. They are required to monitor air quality in areas where it is known or likely to exceed standards. Building consents are managed through local councils, which require information on mode of heating and mechanical ventilation requirements. Finally, some local and regional councils have information on their websites on lead-based paint and reducing the risk of lead exposure in home environments.

3.3 CROWN ENTITIES

Kāinga Ora

Kāinga Ora is a Crown agent established by the Homes and Communities Act 2019. It is administered through HUD. Kāinga Ora's objective is to "*contribute to sustainable inclusive and thriving communities".* It also states that communities should be provided with good quality housing that will meet the diverse needs of communities in NZ. Kāinga Ora is the landlord to around 65,000 publicly owned homes. Kāinga Ora provide advice to tenants on controlling dampness and mould, and safely managing lead-based paint in the home. These are not formal guidelines, but short information sheets for tenants.

Te Whatu Ora – National Public Health Service

Under the Pae Ora Act, Te Whatu Ora is required to protect and promote and improve all people's health and collaborate in intersectoral action to promote health. Housing is a major determinant of health so supporting reductions in exposure to indoor air hazards will be required to improve health and equity.

Te Whatu Ora is also involved in the statutory controls on lead poisoning, where elevated blood lead levels above 0.24 µmol/L is notifiable to a medical officer of health. Non-occupational cases of elevated blood levels are investigated by local public health service.

As previously mentioned, a medical officer of health may be able to apply cleansing orders or closing orders to a property that could cause injury to an occupier or is insanitary.

3.4 NON-GOVERNMENTAL ORGANISATIONS AND PRIVATE SECTOR

Indoor Air Quality Research Centre

An indoor air quality research group has been established with members from BRANZ, GNS Science, Massey University, The Air Quality Collective, University of Canterbury, University of Otago and Victoria University of Wellington. They complete independent research and advocate for improved indoor air quality.

BRANZ

BRANZ is an independent science-led organisation. It completes independent research with a focus on identifying solutions to improve the performance of New Zealand's buildings. BRANZ have led or partnered on several reports relating to indoor air hazards in the home environment.

Community Housing Providers

There are community housing organisations across NZ that support individuals and whānau to access rental accommodation. They provide public housing, similar to state housing through Kāinga Ora, to those in need from the social housing register held through the Ministry of Social Development.

3.5 UNIVERSITIES

Universities in NZ are involved in research on housing and health outcomes in NZ. These largely relate to dampness, mould, microbial pathogen transmission, and temperature. Research conducted by these groups has supported the development of policy to improve NZ housing quality and promote public health.

Most notably, the University of Otago He Kāinga Oranga research group examines housing quality to identify causal relationships between housing and health outcomes, it has also tested several interventions to inform policy changes.

Environmental Health Intelligence New Zealand (EHINZ) is operated through Massey University but is primarily funded by the Ministry of Health. It provides data on indoor environment health indicators, and annual lead notifications from non-occupational exposure.

3.6 SUMMARY

There are several ministries with responsibilities and interests in indoor air hazards. However, as with legislation, standards and guidelines, most of the hazards are not specifically mentioned in the ministry's responsibilities. There are several research units, including universities and independent research groups, that have contributed to knowledge of health hazards in the home and inform and evaluate policy changes.

4. INDOOR AIR HAZARDS

This section briefly describes the potential health impacts of each hazard, and where possible, discusses the possible burden of disease attributable to each hazard in NZ.

4.1 DAMPNESS AND MOULD

There is a significant body of literature relating to dampness and mould in NZ homes. Overall, the NZ housing stock is poor quality, and dampness and mould are common in both owner-occupied and tenanted housing. The 2018 census found that 36% of people reported mouldy homes, and 34% reported dampness (Howden-Chapman et al., 2021). Dampness is also disproportionately experienced by tenants in rental homes (Taptiklis et al., 2022). Warmer homes with adequate ventilation can reduce exposure to dampness and mould in the home environment (Howden-Chapman et al., 2005). This can be achieved with measures such as adequate insulation for the climate, dry heating sources (e.g. heat pumps), and installing extraction fans in the kitchen and bathrooms.

Dampness and mould exposure in the home primarily contribute to the development of respiratory conditions and allergic skin conditions. People exposed to dampness and mould in the home are more likely to experience cough, asthma, bronchitis, respiratory infections, and wheeze (Ingham et al., 2019; Riggs et al., 2021). There are significant inequities in exposure to dampness and mould, which contribute to health inequities. Data from the 2018 census showed that 40.3% of Māori and 45.9% of Pacific peoples reported living in damp homes.[2] This is reflected in health inequities, for example Māori and Pacific children are more likely to experience respiratory illness than other ethnicities (Howden-Chapman et al., 2021; EHINZ, 2022). Census data have also demonstrated that tangata whaikaha are more likely to experience damp, mouldy and cold housing in NZ (McIntosh & Leah, 2017).

A 2021 study investigating the environmental burden of disease in substandard housing in NZ found that damp and mould contributed a significant proportion of the total burden of disease from unsafe housing (Riggs et al., 2021). Data were sourced from the New Zealand General Social Survey on the proportion of people who felt their home was damp and mouldy. The population attributable fraction for conditions related to damp or mouldy housing (e.g. bronchitis and asthma) ranged from 12.3 to 17.5%. It was estimated that annually, damp and mouldy housing contribute to 6,276 hospital admissions, costing almost

[2] More than 2 in 5 Māori and Pacific people live in a damp house – corrected | Stats NZ

NZ$ 36 million per year. Additionally, damp and mouldy homes were estimated to contribute to 145 deaths per year, compared to 16 per year for cold homes (Riggs et al., 2021). Finally, a NZ health impact assessment of environmental health indicators for the home environment estimated that 15% of asthma hospitalisations could be attributed to damp and mouldy housing (Mason et al., 2018). Neither of these studies broke the burden of disease down further into different demographic groups.

4.2 GAS PHASE POLLUTANTS

Gas phase pollutants with significant indoor air sources include carbon monoxide (CO), carbon dioxide (CO_2) and nitrogen dioxide (NO_2). These gas phase pollutants are combustion products from the burning of fuels, both fossil and biofuel (such as wood). The following section will discuss indoor exposure to these gas phase pollutants in the home and the health impacts associated with this.

Carbon Monoxide (CO)

CO is hazardous to health as it is taken up in blood in preference to oxygen, which can lead to death at high levels of exposure as oxygen delivery to tissues is significantly reduced (WHO, 2010). Lower levels will cause headaches, fatigue and flu-like symptoms (WHO, 2010). Exposure can exacerbate pre-existing respiratory and cardiovascular conditions due to reduced oxygen delivery (WHO, 2010). Chronic low level exposure may result in neurodevelopmental harms in utero, low birthweight, and contributions to cardiovascular illness (WHO, 2010).

CO is an odourless and colourless gas and is produced indoors largely by combustion heating, gas appliances and smoking. Poorly maintained gas appliances emit higher levels of CO (Phipps, 2017). Homes with attached garages also show elevated levels of CO due to car activity in the garage. CO detection monitors are required in some countries but are used infrequently in NZ. There was little information found on CO exposure in the home environment in NZ. One study measuring residential CO concentrations in NZ found that levels were lower in NZ houses than found in international studies, and on average were low at 0.37 ppm in the home environment (Lim et al., 2015).

Carbon Dioxide (CO_2)

Carbon dioxide is largely produced indoors through people breathing, as exhaled air is primarily CO_2. CO_2 concentration may be used as an indicator for indoor air quality and ventilation rates, with indoor air standards setting a maximum level of exposure (Mendell et al, 2024). It is therefore important for consideration of monitoring and guideline values for indoor air quality. Levels under 1000ppm are most used in indoor guidelines as the maximum value (Mendell et al, 2024). The importance of building ventilation and corresponding CO2 levels has become more widely recognised since the COVID-19 pandemic (Mendell et al, 2024).

In air quality guidelines internationally, the impact of elevated CO2 levels is largely discussed in the context of reduced ventilation in a building increasing transmission of infectious diseases (Mendell et al, 2024). Additionally, recent research has suggested that higher CO_2 levels may increase the aerostability of viral particles (Haddrell et al, 2024). However, more research is required to understand this relationship and the consequences for disease transmission (Haddrell et al, 2024). There is some evidence that low level CO2 (Starting around 1000ppm but less than 5000ppm) indoors may reduce cognitive performance, however other indoor pollutants may also contribute to this (Azuma et al, 2018; Satish et al, 2012).

Nitrogen Dioxide (NO2)

NO_2 is produced indoors by indoor gas combustion appliances, such as gas fires, unflued gas heaters and cooking stoves (WHO, 2010; Paulin et al., 2014). NO_2 exposure is associated with a higher risk of cardiovascular and respiratory mortality (Huang et al, 2021). It increases the risk of the development and exacerbation of asthma, and respiratory function can also be impacted in those without pre-existing asthma (WHO, 2010).

NZ studies have shown that asthmatic children living in homes without gas stovetops and gas heaters had less severe asthma than those with gas cooking and heating (Gillespie-Bennett et al. 2011; Tin Tin et al., 2016). Acute respiratory infection (ARI) hospitalisations are higher in children younger than five when a gas heater is used in an infant's bedroom, and when gas heaters are the sole form of household heating (Tin Tin et al., 2016). Children under five in homes that only used gas heating were 1.64 times more likely to be hospitalised with ARI when other risk factors were adjusted for (Tin Tin et al., 2016).

The WHO indoor air quality guidelines maximum exposure limit for NO_2 is 200 $\mu g/m^3$ as a 1 hour average and 40 $\mu g/m^3$ for the annual average (WHO, 2010). However, research suggests that adverse health effects may be experienced below these limits (WHO, 2013). Use of a gas stove and unflued gas heating indoors has been found to increase indoor NO_2 levels in homes up to three time higher than those without gas appliances, and unflued gas heater use may result in levels above WHO guidelines (Boulic, 2012; Gillespie-Bennett et al. 2011).

There were no studies identified in the NZ setting estimating the burden of disease from indoor sources of NO_2 specifically in the home. However, a NZ study estimated that 356 deaths per year could be attributed to pollution from heating sources generally (Fisher et al., 2007). A UK study estimated that household indoor NO_2 contributes to 120 disability adjusted life years (DALYS) per 100,000 persons per year (Morantes et al., 2024).

4.3 LEAD

Lead is recognised as a significant public health issue, ranked among the World Health Organization top 10 chemicals of concern. Elevated blood lead levels (>0.24mmol/L) is notifiable under the Health Act. Lead based paint is the most common source of exposure in the non-occupational setting. Unsafe removal of lead-based paint may result in lead dust in the home environment. Additionally, lead may have contaminated the soil surrounding the home resulting in dirt and dust with lead contamination tracking into the home contaminating the air (Keet, 2011). Finally, aging paint may chip and leave pieces that children and animals can directly consume. While ingestion of lead may be the primary route of exposure, particularly for children, it is included as an air hazard in this report due to its presence in dust and the significant health impacts associated with exposure.

Statistics NZ estimates that around 450,000 wooden houses were constructed prior to lead-based paint being banned in 1965. Additionally, they estimate that more than 160,000 houses were built prior to 1940 when the concentrations of lead in paint were much higher. An Official Information Act request revealed that over 80% of Housing NZ properties, approximately 52,383 homes, have some form of lead-based paint.[3] The hundreds of thousands of homes built prior to 1965 suggest that there are significant numbers of people potentially exposed to lead in the home environment.

The Ministry of Health reduced the blood lead level required for notification in 2021 (the level was halved to 0.24 µmol/L due to increasing evidence of irreversible health effects at levels lower than previously thought, particularly in children). Since then, notifications have doubled for non-occupational cases (EHINZ, 2023). Children have lower rates of notification compared to adults, however they are at higher risk due to increased exposure from activity and behaviour (e.g. hand to mouth), high absorption, a developing nervous system more sensitive to lead, and low calcium and iron in diet may increase lead absorption (Reuben et al., 2019; Manne'tje et al., 2020; EHINZ, 2023).

Even at low concentrations, lead poisoning can impact the kidneys, blood, reproductive system and brain. Exposure in pregnant people and children is of particular concern given the lasting impacts of lead poisoning on neurodevelopment and behaviour, which continue into adult life.(Reuben et al., 2019; Reuben et al., 2017) There is no known safe level of lead exposure. As symptoms may not be present at lower concentrations, and that symptoms may be non-specific, lead exposure and poisoning may be under reported in NZ. In 2023, there were 954 notifications of non-occupational lead poisoning, with 282 attributed to lead

[3] More than 50,000 Housing NZ homes still contain toxic lead-based paint | Stuff

based paint (EHINZ, 2023). There is no formal active surveillance or system triggers for conducting lead testing. Given this, it is difficult to estimate the true burden of disease in NZ.

Lead is ubiquitous in the environment and in a 2014-2016 study of blood levels in NZ, all participants, including children, had detectable lead levels indicating background lead exposure (Manne'tje et al., 2020). New Zealanders' blood lead levels have declined over time, with the study finding a 90% reduction in levels over 36 years (Manne'tje et al., 2020). For children, homes built prior to 1945 and living with peeling paint were associated with higher blood lead levels, with an increased risk of 1.20 and 1.16 respectively (Manne'tje et al., 2020). Keet (2015) completed a cost benefit analysis on lead-based paint interventions in NZ homes, the results indicate that there is a significant economic cost to NZ from exposure to lead based paint in the home. Policy and interventions to reduce lead contamination may have net social benefits given the potential for cognitive and behavioural impacts following childhood exposure (Keet, 2015).

4.4 MICROBIOLOGICAL CONTAMINANTS

The COVID-19 pandemic has drawn public attention to the risk of transmission of communicable diseases in indoor environments, particularly those with poor ventilation. Poor quality and inadequate housing contribute to the transmission of a wide range of communicable diseases and exposure to allergens. Respiratory, airborne or droplet spread pathogens will all have increased risk of transmission in houses with poor ventilation, and those that are overcrowded. Additionally, damp housing increases the prevalence of bio contaminants in the home (Phipps, 2017). Key microbiological contaminants include bacteria, viruses, and mould (Phipps, 2017). Examples of health impacts may include respiratory illnesses, skin disease, bacteraemia, sepsis, and meningococcal disease.

Poor ventilation, poor sanitation and higher density of occupants are key contributors to increased disease transmission indoors (Gao et al., 2009; Harvey et al., 2023). Ventilation may be limited in the home, particularly in winter, where natural ventilation (opening windows and doors) is the only option due to issues with thermal comfort and energy use (Burridge et al., 2021; Howden-Chapman et al., 2012). Mechanical ventilation with filtration is effective at reducing transmission of airborne infectious diseases (Gao et al., 2009; Morawska et al., 2020).

Alongside poor ventilation, overcrowding including functional overcrowding, contributes to increased risk of transmission of some microbiological contaminants in the home, including respiratory viruses, Group A strep, and meningococcal disease (Mason et al., 2018). Renters are more likely to experience overcrowding, as are Māori and Pacific whānau (Harvey et al., 2023). Household crowding influences contact patterns between occupants and may increase the concentration of infectious particles for transmission in a living space (Harvey et al., 2023).

A study to develop environmental health indicators for housing found that the population attributable fraction from household crowding was 10% of lower respiratory tract infection hospitalisations, 16% of bronchiolitis admissions from respiratory syncytial virus and 15% of meningococcal notifications (Mason et al., 2018). All of these health conditions are disproportionately experienced by Māori and Pacific children (Mason et al., 2018). A NZ study estimated that 1,343 hospitalisations annually in NZ could be attributed to household crowding (Baker et al., 2013). For European ethnicity, 331 admissions could be attributed to household crowding, compared to 790 and 692 admissions in Māori and Pacific ethnicity groups respectively, highlighting the inequities present in health outcomes relating to housing (Baker et al., 2013).

4.5 PARTICULATE MATTER

Particulate matter (PM) describes tiny pieces of airborne matter. Typically, two sizes are tested for, PM_{10} are 10 micrometres or less and $PM_{2.5}$ are 2.5 micrometres or less. The smaller particles, less than 2.5 micrometres, are of greater concern for health impacts due to the ability to be inhaled into the lungs and then absorbed into the blood stream (Vardoulakis et al., 2020). There are both ambient air and indoor sources for PM that people will be exposed to in the home environment, including combustion of fuels for cooking, heating and lighting and smoking indoors. Additionally, outdoor air PM readily migrates into indoor environments (Phipps, 2017).

PM exposure has been shown to contribute to negative respiratory and cardiovascular health outcomes. Higher concentrations of indoor PM are associated with asthma and new onset of wheeze in children (Vardoulakis et al., 2020). Additionally, there is an increased risk of lower respiratory tract infections and exacerbations of chronic obstructive pulmonary disease (Kumar et al., 2023; Vardoulakis et al., 2020). Chronic exposure to PM increases the risk of cardiovascular events such as ischaemic heart disease and stroke (Kumar et al., 2023).

The Global Burden of Disease study shows that exposure to indoor air pollution from PM contributes to around 2.6 million deaths annually and approximately 150 million DALYs lost globally (Gakidou et al., 2017). The DALYs primarily result from respiratory diseases (such as asthma, chronic obstructive pulmonary disease, and pneumonia), cardiovascular diseases (including ischemic heart disease and stroke), and some cancers (lung cancer) (Gakidou et al., 2017; Zhang et al., 2021). Impact will vary by region due to differences in cooking and heating practices globally, as well as the quality of ambient air (Zhang et al., 2021). In Global Burden of Disease studies, the burden of disease for PM is particularly high in low- and middle-income countries, where reliance on solid fuels for cooking and heating is widespread (Gakidou et al., 2017; Shupler et al., 2018). A study estimating the burden of disease for indoor air contaminants in the US found that $PM_{2.5}$ had the highest loss of DALYs at 1.1×10^2 per unit intake (Morantes et al., 2023). A UK based study found that indoor air $PM_{2.5}$ was attributed to 1600 DALYS lost per 100,000 persons per year (Morantes et al., 2024).

There were no studies identified estimating the burden of disease associated with household indoor sources of PM in New Zealand. Studies show that indoor sources of PM remain a significant exposure source in high income settings, such as New Zealand (Chakraborty et al., 2020; Jones et al., 2000). However, most monitoring and exposure studies in NZ assess outdoor air PM. A NZ study of six homes in Wellington assessed indoor PM_{10} concentrations. Peaks were largely driven by cooking activities in the houses, $PM_{2.5}$ concentrations were not assessed (BRANZ, 2019).

Several international studies showed elevated levels of PM in homes, with large peaks during periods of cooking and smoking (Chakraborty et al., 2020; Jones et al., 2000; Maung et al., 2022). Even if PM levels on average are below recommended PM levels indoors, epidemiological evidence increasingly demonstrates the negative health impacts of short elevated exposure levels to PM in the home associated with cooking (Chakraborty et al., 2020). Further, research has found that all stove types result in emissions of PM into the home (Chakraborty et al., 2020).

4.6 TEMPERATURE

Having the indoor home environment at a comfortable temperature is important for physical and mental wellbeing. The WHO recommends indoor air temperatures of 18 – 24 degrees Celsius, with a minimum temperature of at least 20 degrees in homes with children, elderly or people with health conditions (Ormandy & Ezratty, 2012). This section is split into discussing the different health impacts from cold housing and overheated housing in NZ.

Cold

Cold housing is a substantial issue in New Zealand, most notably in structurally disadvantaged communities, in older homes and in regions with cooler climates, such as the South Island (Rangiwhetu et al., 2018). Many houses in New Zealand, particularly rental properties, are poorly insulated, and heating is often insufficient or inefficient. Cold housing disproportionately affects structurally disadvantaged communities, such as Māori, Pacific peoples, and lower-income households (Beukes et al., 2024; Howden-Chapman et al., 2021; Rangiwhetu et al., 2018). Structurally disadvantaged communities are more likely to live in homes with inadequate heating systems or structural issues that lead to dampness and cold, causing and exacerbating health inequities (Howden-Chapman et al., 2021). Rental homes are particularly at risk, as tenants often face barriers to making improvements, such as upgrading insulation or installing heating systems. Research by BRANZ has shown that rental homes are three times more likely to be cold and damp (Buckett, 2012). Additionally, rising energy costs make it harder for low-income households to afford adequate heating, further increasing the health risks and inequities associated with cold homes (Baker et al., 2017).

Stats NZ report that 33% of homes are below 18 degrees Celsius in winter.[4] A study on the environmental health burden from substandard housing showed in the study population 21% experienced cold housing, which increased the risk of wheeze (1.75 times more likely) and influenza and winter colds (1.85 times more likely) independent of other factors (Riggs et al., 2021). Approximately 625 hospitalisations were attributable to cold housing annually (Riggs et al., 2021). An Australian modelling study estimated that 86,000 health adjusted life years (HALYs) could be gained from eliminating cold housing (Mishra et al. 2023). The largest health gains were seen in the most structurally deprived communities (Mishra et al. 2023).

Cold housing is associated with a wide range of negative health outcomes, particularly in at-risk populations such as children, the elderly, and people with pre-existing health conditions

[4] Around a third of homes too cold in winter and too warm in summer | Stats NZ

(Beukes et al., 2024; Ormandy & Ezratty, 2012). Research consistently shows that living in poorly insulated, cold homes contributes to both physical and mental health problems, and excess winter mortality (Rangiwhetu et al., 2018). Exposure to cold and damp living conditions has been linked to increased rates of respiratory conditions such as asthma, bronchitis, and pneumonia (Pierse et al., 2013; Pierse et al., 2020; Riggs et al., 2021). Cold indoor temperatures are also a significant risk factor for poor cardiovascular health outcomes (Liddell & Morris, 2010).Living in cold, damp conditions is also associated with negative mental health outcomes. Cold homes can contribute to depression and anxiety in adults and youths (Liddell & Morris, 2010). Overcrowding increases risk of transmission of communicable diseases, such as Group A Streptococcus (Anderson & Spray, 2020).

Overheating

Much of the focus relating to temperature and housing, particularly in NZ research to date, is on cold housing, however the risk of overheating is also relevant. Overheating is a risk to health and wellbeing and is becoming an increasingly important issue due to rising temperatures globally, poor housing design and urban heat island effects (Bi et al., 2011; Hatvani-Kovacs et al., 2016; Maller & Strengers, 2011). Recently in NZ there has been media attention on new build townhouses in Auckland, with occupants facing significant issues with overheating in the summer months (Birchmore et al., 2023).[5] Poorly designed homes, lacking natural ventilation or cooling systems, often experience markedly higher temperatures than outdoor conditions, which increases the risk of heat stress (Birchmore et al., 2017; Maller & Strengers, 2011). A study set in Auckland found that roof space temperatures reached 51 degrees Celsius in summer months (Birchmore et al., 2017). Homes may not have air conditioning units available to cool down the house, and even if available they may be too expensive to run, particularly for structurally disadvantaged groups (Basu & Samet, 2002).

Additionally, structurally disadvantaged communities are more likely to experience negative health impacts from heat (Maller & Strengers, 2011). A recently published study reviewing heat related hospital admissions for children under five in NZ found that there was an increased risk of hospitalisations when temperatures were over 24.1 degrees Celsius, and that there was greater heat sensitivity in structurally disadvantaged groups including Māori and Pacific children (Lai et al., 2024).

[5] Some newly built Auckland homes too hot, council study shows | RNZ News

The data for heat related health impacts largely comes from assessing ambient air temperature and heat, rather than specifically assessing indoor temperature. High temperature is associated with increases in both cardiovascular and all-cause mortality, and increased emergency hospitalisations (Basu & Samet, 2002; Bi et al., 2011). It is of particular concern for children, elderly and those with comorbidities (Bi et al., 2011). Acute impacts also include heat related conditions, ranging from mild heat stroke to heat exhaustion (Maller & Strengers, 2011). Heat waves have also been associated with loss of social productivity and negative mental health impacts (Maller & Strengers, 2011).

4.7 VOLATILE ORGANIC COMPOUNDS

Volatile organic compounds (VOCs) are a group of organic chemicals, studies have shown 50-300 different chemicals may be measurable in any given indoor air environments (Phipps, 2017). Additionally, VOCs may react together and produce other compounds (Phipps, 2017). This complexity makes it challenging to conduct exposure assessments and understand the impacts of exposures to individual VOCs on health (Phipps, 2017). VOCs are emitted as gases, usually from paint or building materials, but also come from gas cooking and heating. VOC concentrations are usually higher indoors than in ambient air due to the increased number of indoor sources of VOCs (Bari et al., 2015).

VOC levels from housing materials and new furnishings are usually highest when a house is newly built while materials off-gas the most freely evaporated VOCs. VOC levels then fall as time goes by (Salthammer et al., 2010). VOCs can be controlled by careful choice of products and by ventilating the house well. Gas stove combustion has also been found to emit the VOCs benzene and formaldehyde, with a US study finding elevated kitchen concentrations with gas stove use, and migration of benzene to bedroom spaces (Kashtan et al., 2023).

Currently, there is little available epidemiological evidence on the health impacts of VOCs from residential indoor air exposure, and the health impacts from interactions between VOCs and other pollutants. However, there is good information on effects due to exposure to individual VOCs, with some VOCs having been found to be carcinogenic. The International Agency for Research on Cancer recognises both benzene and formaldehyde as carcinogens (WHO, 2010). Other recognised health impacts of VOCs include irritation of the eyes, nose and throat, headaches, nausea, and damage to the kidneys, liver and central nervous system (WHO, 2010). Benzene and formaldehyde are among the WHO top indoor pollutants of concern in the indoor air quality guidelines (WHO, 2010). Formaldehyde gases have an irritating, pungent odour and are considered to have an adverse effect on health (including cancer risk) when levels are above about 0.1 parts per million (WHO, 2010). There is no known safe level of exposure for benzene (WHO, 2010). There is no guideline value available for total VOC concentrations (Hernandez et al., 2020).

International research has demonstrated that VOC concentrations in residential environments have reduced over recent decades (Herbarth & Matysik, 2013). However VOCs, including formaldehyde and benzene, continue to be found at elevated levels in residential environments in developed countries and often exceed indoor air standards (Sekar et al., 2019). Concentrations of benzene ranged from 1.5 to 15.3 $\mu g/m^3$ in studies of

European households (WHO, 2010; Sekar et al., 2019). A small NZ indoor air quality monitoring study in six houses in Wellington found occasional low concentrations of VOCs in three houses thought to be following episodes of cleaning or adhesive use, though concentrations were not specified in the report (BRANZ, 2019). A study of two townhouses in Auckland found that levels of benzene ranged from 1.5-6.1 μg/m^3 (Hernandez et al., 2020). The current ambient air limit for benzene in NZ outdoor air standards is 3.6 μg/m^3.

5. DISCUSSION: CONCLUSIONS, GAPS AND OPPORTUNITIES

Indoor air hazards are a risk to health and wellbeing given the large proportion of time people spend inside the home environment, particularly to those who may be at higher risk to health impacts from exposure. There are a range of indoor air hazards that contribute to negative health outcomes in the home environment in NZ. This report has demonstrated the diverse range of potential air hazards in homes, and where possible discussed the presence of the hazards in the NZ setting and the health burden associated with these. Comparison of hazards is challenging given the varying levels of data available for each hazard and the differing health effects associated with the hazards. Additionally, where relative risks and burden of disease are reported, they may be measured differently, limiting the ability to compare further.

A further challenge in assessing the health risks from indoor air hazards is that knowledge of indoor air quality in NZ is markedly less than that for outdoor air quality. While there is a substantial body of research on cold, damp, mouldy housing, there was minimal data available on the remaining hazards in the NZ home setting. Overall, there were very few studies available to quantify the burden of disease attributable to hazards in the indoor home environment. Because of this, it is difficult to know the true burden of disease in NZ for several of the hazards assessed in this report. There however, is clear evidence of the burden of disease relating to mould, dampness, cold housing and infectious diseases in NZ. These should remain core risk factors to address housing interventions and policy decisions, while growing the evidence base for and addressing other residential indoor air hazards in NZ.

The legislation relating to indoor air hazards in the home setting is largely non-specific to the identified potential hazards. The key pieces of legislation are those relating to rental housing quality and safety for tenants, such as the Residential Tenancies Act 1986 and the Healthy Homes Guarantee Act 2017. The Health Act 1956 provides options for medical officers of health to require closure or remediation of homes, however, in reality, this power is rarely used. Standards and guidelines are available to support healthy home environments, however again few specifically mention the indoor air hazards identified for this report.

Gaps and Opportunities

As previously mentioned, there is a knowledge gap in the levels of exposure to indoor air hazards in NZ homes. While there is a substantial body of evidence assessing cold, damp and mouldy housing in NZ, the other hazards identified are less well studied in the indoor residential environment. To understand the magnitude of exposure to indoor air hazards it would be beneficial to get a clearer picture of the concentration of hazards across the range of housing in NZ. Furthermore, without monitoring of hazards, it is difficult to know how the risk of hazards is changing over time.

A key gap in the indoor air landscape in NZ is the absence of standards or guidelines. NZ currently does not have national standards or guidelines for indoor air quality. Currently, only the WHO guidelines for indoor air quality are available, however these have not been adopted in NZ and are not specific to the NZ setting. Alongside this, there have been calls from public health experts for establishment of an organisation within NZ to address indoor air quality issues, including standards and a well-resourced national strategy (Bennett et al., 2022).

To address persistent inequities in indoor air hazards relating to housing quality and health outcomes, it is essential that interventions, policy changes, and advocacy are focused on achieving health equity and ensuring healthy home environments for structurally disadvantaged communities. A focus on meeting Te Tiriti obligations will support equitable outcomes for Māori relating to indoor air hazards exposure (Anderson & Spray, 2020). Despite various government programs and policies aimed at improving housing quality, challenges remain in addressing the widespread problem of cold, damp and mouldy homes, particularly among the structurally disadvantaged and renters.

Further investment in housing improvements, strengthening residential tenancy house quality requirements, better enforcement of housing standards, and increased support for structurally disadvantaged populations are essential and will be effective to mitigate the health impacts of poor-quality housing in New Zealand (Bennett et al., 2016; Howden-Chapman et al., 2023; Howden-Chapman et al., 2012; Mishra et al.; Riggs et al., 2021). Importantly, interventions targeting poor quality, and particularly rental housing, are likely to have the greatest impact on structurally disadvantaged communities. Pro-equity policy and interventions are essential to meet Te Tiriti o Waitangi obligations and to achieve health equity in NZ (Anderson & Spray, 2020; Beukes et al., 2024). Additionally, funding and upscaling existing effective community-led strategies to improve housing quality would be beneficial.

The Healthy Homes Standards and recent updates to the Building Code to improve insulation will support a reduction in damp and mould in homes. However, there is room to strengthen policy to ensure these Standards are formally monitored and regulated, and to look to at least maintain and ideally improve current insulation standards. At time of writing, there is currently consideration of rolling back the new insulation standards. MBIE advice estimated that homes insulated to the new standards, would require 40% less heating compared to older homes. The updated standards remain below the levels of insulation required in other countries (such as Ireland and Australia), however rolling these back would result in standards that are half (or less than half) that of these countries. There is clear evidence that retrofitting of insulation is more effective than only installing heaters due to the risk of fuel poverty (Howden-Chapman et al., 2023). A policy for the NZ government subsidising retrofitting insulation showed significant benefit to cost ratio of four-to-one (Chapman et al., 2009). There are opportunities in evidence-based policy and interventions for local and central Government to improve the indoor air environment in the home (Chapman et al., 2009; Howden-Chapman et al., 2012).

While new homes with increasingly less ventilation due to air tightness of building materials improve energy efficiency, they may also allow for build-up of indoor air hazards, such as PM, NO_2 and VOCs (Wallis et al., 2019), necessitating effective ventilation systems. Natural ventilation, such as through opening windows, is important to reduce the concentration of indoor sources, however overall air quality will depend on quality of the ambient air (Wallis et al., 2019). Filtration systems through mechanical ventilation can be effective to reduce PM concentration in the home environment (Hernandez et al., 2020; Wallis et al., 2019). Additionally, effective ventilation and filtration can reduce the spread of communicable diseases. Other air cleaning technologies, such as high-efficiency particulate air (HEPA) filters and ultraviolet light (UV) can also reduce the concentration of some indoor air hazards.

There was no clear focus from organisations reviewed on the health impacts of VOCs in homes. There was also no clear public health guidance identified in NZ for minimising VOC exposure sources in the home. International data has shown health risks of benzene and formaldehyde exposure with gas use in the home, however little NZ guidance and monitoring was identified. Further, with homes becoming increasingly airtight, and often having open plan spaces this may increase exposure to VOCs as hazards can accumulate (Vardoulakis et al., 2020; Wallis et al., 2019). It is essential to promote mechanical ventilation where possible, reduce gas use (particularly unflued gas heaters), and encourage the use of low VOC building materials (Vardoulakis et al., 2020).

Unflued gas heaters result in higher levels of dampness and mould growth in homes (Boulic et al., 2015), and gas stovetops also increase the concentration of hazards such as NO_2 and VOCs in the home (Kashtan et al., 2023). The state of Victoria in Australia recently moved to ban new gas connections in homes.[6] Policy changes such as this may be beneficial to reduce indoor air contamination in the home as well as having co-benefits for climate change mitigation. Changing cooking methods has been shown to be an effective way to reduce NO_2, with levels reduced by 51% in kitchens and 42% in bedrooms after changing to an electric cooking appliances (Paulin et al., 2014). Installing a HEPA filter showed a 20% NO_2 reduction in the kitchen but no significant reduction in bedrooms, while using an extraction fan showed no change in NO_2 levels (Paulin et al., 2014).

It is also important to note that improvements in housing quality will produce health benefits across air hazards. For example, improved ventilation and installation of mechanical ventilation or air filtration devices will help reduce exposure to a wide range of hazards including microbiological contaminants, dampness, heat, PM, gas phase pollutants, and VOCs. Additionally, increasing insulation and energy efficiency will support keeping homes at a comfortable temperature, while also reducing dampness, mould and microbiological contaminants.

There is no clear single agency leading control and reduction of household lead exposure in NZ. WasteMINZ is an advocacy organisation with a working group focusing on reducing the harm from lead poisoning in NZ and has recommended a single agency take the lead-on-lead harm reduction.[7] Several agencies and pieces of legislation relate directly or indirectly to lead in residential settings. While the Ministry of Health and Te Whatu Ora have a specified role in responding to lead poisoning in non-occupational settings, there are no specified roles for the management of risk of exposure and monitoring of lead poisoning in NZ. While studies have shown that lead levels have reduced in recent decades (Mannetje et al., 2020), opportunities remain to further reduce exposure to lead in the home setting and identify at risk groups. There may be an opportunity for an agency to take a lead role on reducing household lead exposure. Research and monitoring in areas with older housing stock likely to have lead paint or surveillance programmes, particularly for at risk children, could be considered as in other countries (Ettinger et al., 2019; Yi Lu, 2023).

Finally, to effectively mitigate the risks from indoor air hazards, intersectoral action is essential. Building standards, urban design and housing policy should centre health as a key

[6] Victoria bans gas to new homes from 2024 in push to cut emissions | RNZ News
[7] Experts call for a single agency to manage lead exposure in residential properties | WasteMINZ

outcome measure (Bennett et al., 2016; Werna et al., 2022). Currently the Building Code does not centre health, and updates to the building code should consider changing this to reflect the significant influence of building quality on health outcomes (Bennett et al., 2022). Health organisations are well positioned to advocate for and work alongside key stakeholders (e.g. MBIE, Kāinga Ora, HUD, and community housing organisations) in the housing development and building landscape to ensure we are working towards housing that keeps people healthy and meets the needs of a diverse NZ population.

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