Indoor air quality, largely neglected and in urgent need of a refresh

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Despite people in high- and middle-income countries spending 85–90% of their time indoors,[1] and adults inhaling 11,000 litres of air every day,[2] the health impacts of indoor air quality in Aotearoa New Zealand are barely recognised by Government agencies. While outdoor air quality is managed under the Resource Management Act 1991, which sets National Environmental Standards for outdoor air, no equivalent legislation exists for indoor air quality. The World Health Organization (WHO) recognises that healthy indoor air is a basic human right, stating that the quality of the air people breathe in buildings is an important determinant of health and wellbeing.[3]

According to the Environmental Protection Agency (EPA) in the United States (US), indoor air pollutant levels are typically two-to-five times higher than outdoor levels, and in some cases exceed outdoor levels of the same pollutants by a 100 times.[4] Globally around 2.6 billion people still use solid fuels and kerosene for cooking, and the United Nations notes that indoor and ambient air pollution are the greatest environmental health risk.[5] Time spent indoors combined with higher indoor concentrations of pollutants make the health risks associated with poor air quality usually greater indoors than outdoors.

More recently, the COVID-19 pandemic has highlighted the additional importance of indoor air quality for reducing the transmission of infectious respiratory diseases. While initial public health efforts focused on measures to reduce fomite transmission, such as hand-washing, it is now well-recognised that airborne exposure is the predominant transmission route of SARS-CoV-2 (the virus that causes COVID-19).[6] International consensus on airborne transmission was achieved in part through cutting-edge research conducted by New Zealand experts, but New Zealand health authorities have been slow to apply this key insight beyond border settings.[7] It is imperative that national bodies responsible for the control of the pandemic incorporate the importance of airborne transmission to inform an evidence-based strategy and implement a range of highly effective measures that can prevent airborne transmission of the SARS-CoV-2 virus and other respiratory pathogens, including influenza.[8,9,10,11]

The most effective approach to lowering concentrations of indoor air pollutants, including any pathogens that may be in the air, is usually to increase ventilation,[12] exchanging polluted indoor air for cleaner outdoor air. Understanding and controlling building ventilation can improve the quality of the air we breathe and protect population health, including reducing the transmission of SARS-CoV-2 and other respiratory pathogens.

The European Centres for Disease Prevention and Control have been providing specific guidance on ventilation in the context of COVID-19 since November 2020.[13] While in March 2021, the WHO published a roadmap to ensure good indoor ventilation in the context of COVID-19.[14] The US Centers for Disease Control and Prevention[15] and the EPA[16,17] continuously update advice on ventilation as evidence emerges.

New Zealand's combination of construction styles, climate and geological conditions are unlike any European or North American country. The majority of New Zealand homes rely on natural ventilation and do not have heat-recovery units, and in winter many homes cannot be heated to healthy temperatures. For these reasons, New Zealand-specific solutions are needed, and ventilation improvements should not come at the cost of healthy indoor temperatures. The New Zealand Building Code lags behind other comparable countries, with new buildings still having the potential to be cold, mouldy and unhealthy. While the Building Act 2004 acknowledges health, health is not placed at front and centre of the code. For decades, a range of experts have called for these standards to be improved, but although a recent review was conducted during the COVID-19 pandemic, there appears to be minimal change to ventilation requirements.[18] In addition, sys-

tematic science-based approaches to improve indoor air quality in New Zealand buildings are missing. This gap is in stark contrast to outdoor air quality guidelines, standards, and national monitoring that occurs throughout New Zealand and internationally.

In France, an indoor air quality observatory (OQAI) was established in July 2001 to undertake a national campaign to measure indoor air pollution in homes, schools, office spaces, healthcare and social establishments. This observatory estimated that prior to the COVID-19 pandemic poor indoor air quality in France was contributing to around 28,000 illness episodes and 20,000 deaths per year, representing an annual cost of 19 billion euros (~30 billion NZD, 2022 costs).[19]

Given these issues, we are advocating for the immediate establishment of a long overdue national organisation to address indoor air quality, with a focus on health and wellbeing outcomes. Aotearoa New Zealand urgently needs leadership, coordination, and an adequately resourced national strategy to improve indoor air quality. Such a strategy should set national standards for acceptable indoor air quality, as is already available for outdoor air quality. As well as setting maximum values for particulate matter and chemicals, such as carbon monoxide and nitrogen dioxide, this strategy should also include levels for carbon dioxide as a proxy for ventilation, which will help reduce the transmission of airborne pathogens. Pollutant standards for heating and cooking appliances, particularly for appliances that use unflued gas should also be considered.[20]

An investment in clean indoor air could bring benefits other than reducing COVID-19 transmission, including reduced sick leave and school absenteeism caused by other respiratory infections, particularly influenza and other allergies.[21] Less absenteeism—with associated adverse effect on productivity—could save companies significant costs.[22] Furthermore, there is growing evidence that improved ventilation can improve cognitive functioning of workers and students,[23] which can improve both wellbeing, sleep and productivity.[24] Ventilation can also reduce indoor moisture particularly in homes, which will reduce exposure to respiratory allergens and irritants such as dust mites and mould, resulting in reduced incidence of asthma, rhinitis and allergy symptoms. Improved ventilation would result in a reduction in general practitioner (GP) visits for respiratory illness[25] and a significant reduction in hospitalisations,[26] especially for young children and Māori. We look forward to rapid New Zealand Government action to leverage off the COVID-19 pandemic and make sustained improvements to indoor air quality.

COMPETING INTERESTS
Nil.

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REFERENCES
1. Kumar R, Goel N, Gupta N, Singh K, Nagar S, Mittal J. Indoor air pollution and respiratory illness in children from rural India: a pilot study. Indian J Chest Dis Allied Sci. 2014;56:79-83.
2. Chourpiliadis C BA. Physiology, Respiratory Rate: StatPearls Publishing, Treasure Island, 2022.
3. World Health Organization. Guidelines for indoor air quality: dampness and mould. Geneva: WHO, 2009.
4. US Environmental Protection Agency. Indoor Air Quality (IAQ). Edition., cited 1 April 2022. [Available from: https://www.epa.gov/indoor-air-quality-iaq].
5. United Nations. Sustainable development goals. Goal 3: Ensure healthy lives and promote well-being for all ages: United Nations, 2017.
6. Morawska L, Cao J. Airborne transmission of SARS-CoV-2: The world should face the reality. Environment International. 2020;139:105730.
7. Fox-Lewis A, Williamson F, Harrower J, et al. Airborne Transmission of SARS-CoV-2 Delta Variant within Tightly Monitored Isolation Facility, New Zealand (Aotearoa). Emerg Infect Dis. 2022;28:501-9.
8. Chartier Y, Pessoa-Silva C. Natural ventilation for infection control in health-care settings. 2009.
9. Xiao S, Li Y, Wong T-w, Hui DS. Role of fomites in SARS transmission during the largest hospital outbreak in Hong Kong. PloS one. 2017; 12:e0181558.
10. Turner RD, Bothamley GH. Cough and the Transmission of Tuberculosis. The Journal of Infectious Diseases. 2014;211:1367-72.
11. Herfst S, Schrauwen EJ, Linster M, et al. Airborne transmission of influenza A/H5N1 virus between ferrets. science. 2012;336:1534-41.
12. US Environmental Protection Agency. Ventialtion and coronavirus (Covid-19). Edition., EPA, cited 1 April 2022. [Available from: https://www.epa.gov/coronavirus/ventilation-and-coronavirus-covid-19].
13. Centres for Disease Precention and Control

Prevention. Heating, ventilation and air-conditioning systems in the context of Covid-19: first update. Edition., cited 5 April 2022. [Available from: https://www.ecdc.europa.eu/sites/default/files/documents/Heating-ventilation-air-conditioning-systems-in-the-context-of-COVID-19-first-update.pdf].
14. World Health Organization. Roadmap to improve and ensure good indoor ventilation in the context of COVID-19 Licence: CC BY-NC-SA 30 IGO. Geneva, 2021.
15. Centres for Disease Prevention and Control. Improving ventialtion in your home. Edition. United States of America: CDC, cited 1 April 2022. [Available from: https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/Improving-Ventilation-Home.html].
16. US Environmental Protection Agency. Ventilation and coronavirus (Covid-19). Edition., cited 5 April 2022. [Available from: https://www.epa.gov/coronavirus/ventilation-and-coronavirus-covid-19].
17. US Environmental Protection Agency. Indoor air and coronavirus (Covid-19). Edition., cited 5 April 2022. [Available from: https://www.epa.gov/coronavirus/indoor-air-and-coronavirus-covid-19].
18. Ministry of Business Innovation and Employment. 2021 Building Code Update. Edition. Wellington, cited 5 April 2022. [Available from: https://www.building.govt.nz/building-code-compliance/annual-building-code-updates/2021-building-code-update/].
19. Mandin C. The Indoor Air Quality Observatory (OQAI): a unique project to understand air pollution in our living spaces. OpenEdition Journals. 2020:18-23.
20. Gillespie-Bennett J, Pierse N, Wickens K, et al. Sources of nitrogen dioxide (NO2) in New Zealand homes: findings from a community randomized controlled trial of heater substitutions. Indoor Air. 2008;18:521-8.
21. Sundell J, Levin H, Nazaroff WW, et al. Ventilation rates and health: multidisciplinary review of the scientific literature. Indoor air. 2011;21:191-204.
22. Bramley TJ, Lerner D, Sarnes M. Productivity losses related to the common cold. Journal of occupational and environmental medicine. 2002:822-9.
23. Wang W, Chen J, Jin X, Ping Y, Wu C. Association between indoor ventilation frequency and cognitive function among community-dwelling older adults in China: results from the Chinese longitudinal healthy longevity survey. BMC Geriatr. 2022;22:106.
24. Strøm-Tejsen P, Zukowska D, Wargocki P, Wyon DP. The effects of bedroom air quality on sleep and next-day performance. Indoor Air. 2016;26:679-86.
25. Dowell A, Darlow B, Macrae J, Stubbe M, Turner N, McBain L. Childhood respiratory illness presentation and service utilisation in primary care: a six-year cohort study in Wellington, New Zealand, using natural language processing (NLP) software. BMJ Open. 2017;7:e017146.
26. Ingham T, Keall M, Jones B, et al. Damp mouldy housing and early childhood hospital admissions for acute respiratory infection: a case control study. Thorax. 2019;74:849-57.