Project: Indoor air quality in New Zealand homes and garages

The indoor air quality of seven homes in the Wellington region was monitored over May-September 2017. The houses represented different ages and construction types. Airtightness was found to be correlated with house age, with the older houses having higher natural ventilation/air leakage. Indoor airborne particulates were generally higher than outside, mostly generated from cooking and wood burners. Outdoor air pollution infiltrates indoors unimpeded. Most occupied bedrooms had higher levels of carbon dioxide than recommended due to poor ventilation when occupied.

These were the houses in the study:

- House 1: built in 1980, 260 m², 4 bedrooms, 5 occupants, timber cladding, iron/slate roof.
- House 2: built in 1948, 130 m², 3 bedrooms, 5 occupants, brick cladding, tile roof.
- House 3: built in 1965, 140 m², 4 bedrooms, 7 occupants, weatherboard cladding, tile roof.
- House 4: built in 2014, 178 m², 3 bedrooms, 4 occupants, plaster styrofoam cladding, iron roof. The newest house, House 4 was the most airtight with an average 0.09 air changes per hour at ambient pressures.
- House 5: built in 1977, 110 m², 4 bedrooms, 7 occupants, timber cladding, iron roof.
- House 6: built in 1956, 90 m², 2 bedrooms, 5 occupants, weatherboard cladding, iron roof. This was the least airtight house, likely getting on average ~1.03 air changes per hour at ambient pressure without opening windows.
- House 7: built in 2011, 100 m², 2 bedrooms, 2 occupants, brick cladding, tile roof.

In each house, measures were taken of:

- temperature and relative humidity (RH)
- carbon dioxide (CO_2) measured in parts per million (ppm)
- carbon monoxide (CO)
- volatile organic compounds (VOCs)
- particulates - tiny pieces of solid or liquid matter.

TEMPERATURE AND HUMIDITY

Temperature and humidity were relatively stable in all rooms, but average temperatures were typically lower in one or more bedrooms (14-18°C) than in the lounge, with the exception of House 4. This relatively new home (built in 2014) had stable 18-20°C temperatures in all rooms. The World Health Organization's Housing and Health Guidelines, published in 2018 with a lot of New Zealand input, proposes 18°C as a safe indoor temperature to protect the health of general populations in temperate or colder countries.

Humidity was typically higher in occupied bedrooms (60-85%) than the lounge (45-65%).

The humidity level in bedrooms of all houses (except House 4) was above the recommended range of 40-60%. Where RH is above 60%, dust mites (linked to asthma) and airborne pathogen numbers increase. The newer House 4 had stable humidity around 50-60% in all rooms.

CARBON DIOXIDE

In the lounges of most of the houses, CO_2 peaks were usually found at 7-8 am and 6-9 pm. CO_2 above background levels (approximately 400 ppm) reflected house occupancy. In many cases, there were greater day/night variations and higher peak concentrations in the bedrooms compared to the lounge. Less well-ventilated bedrooms or those with multiple occupants reached maximum concentrations up to 4,000 ppm in the worst cases. NZS 4303:1990 *Ventilation for acceptable indoor air quality* recommends ventilation sufficient to keep CO_2 levels below 1,000 ppm. Breathing high levels of carbon dioxide can result in headaches, tiredness, increased frequency of illness and impacted cognitive function.

House 5 alone had lower CO_2 peaks in the bedrooms, indicating that the rooms were likely to be reasonably well ventilated.

In the garages of houses that had internal garages, CO_2 peaks probably came from motor vehicle tailpipe emissions.

CARBON MONOXIDE

Little or no carbon monoxide was found in most of the houses. In Houses 1 and 2, CO was related to the use of gas appliances. In House 3, it may have come from vehicle start-up outside the house. In House 7, CO in the lounge seemed to be related to motor vehicle movements in and out of the attached garage. Other CO in the house may have come from cigarette smoking. CO concentrations did not appear to challenge health guidelines.

VOLATILE ORGANIC COMPOUNDS

Volatile organic compounds (VOCs) were recorded in three houses in one-off events, most likely from cleaning spray or adhesive use.

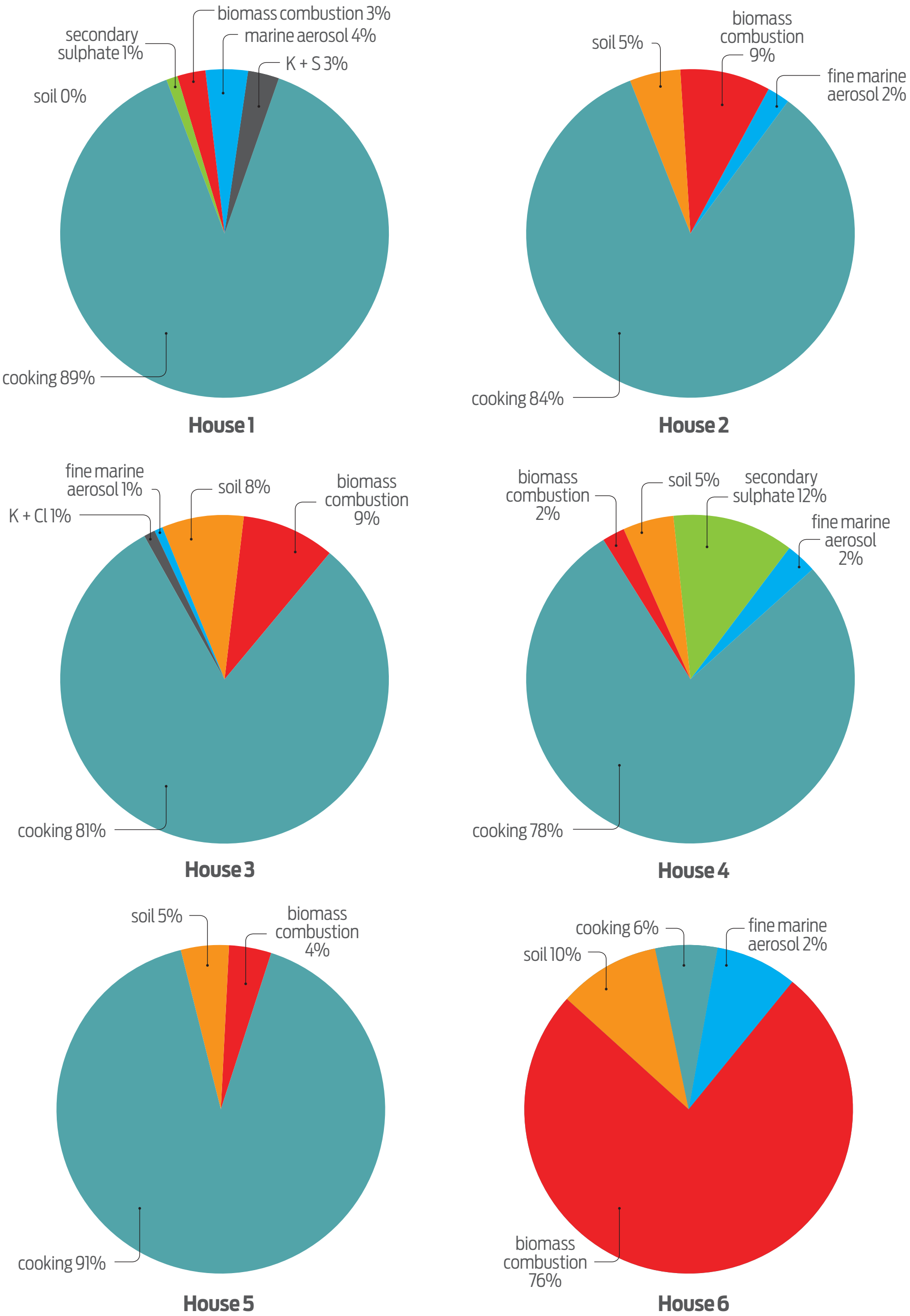

Figure 1. Sources of PM_{10} concentrations in Houses 1–6 showing the dominance of the cooking source except for House 6 (where the family ate at another house). Houses 1, 2, 4 and 5 all used wood burners for space heating.

PARTICULATES

$PM_{2.5}$ (fine) particulates are less than 2.5 micrometres in diameter and PM_{10} (coarse) particulates are 10 micrometres or less - one-tenth the thickness of a human hair. High levels of PM_{10} can irritate the eyes and throat, but finer $PM_{2.5}$ particles can be a bigger threat because they can reach deep into the lungs.

Peak PM_{10} concentrations were largely driven by cooking activities in almost all the houses (Figure 1). For the houses with wood burners (Houses 1, 2, 4, 5), combustion emissions from the appliances leaked into the indoor air. In some cases, traces of arsenic were found, indicating that treated wood was being burned. Indoor concentrations were unrelated to outdoor concentrations due to differing concentration and activity profiles. Soil particles found in the air were due to resuspension by activity such as sweeping or vacuuming.

The common outdoor sources of particulate matter at all sites were wood burners (monitoring was done in the winter) and marine aerosol (sea salt), quantities of the latter depending on weather patterns and wind speed (Figure 2). In most cases, the smallest particles essentially infiltrated the houses unchecked (concentration indoors ≈ concentration outdoors).

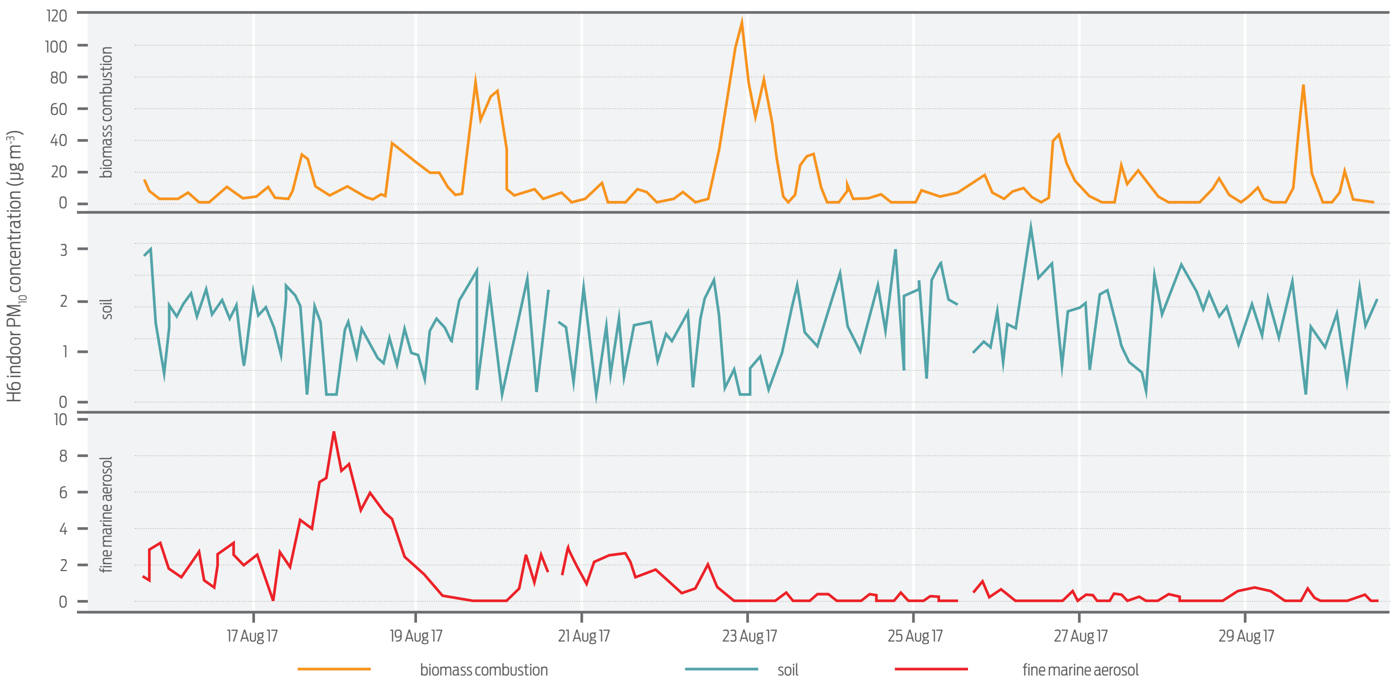

Figure 2. The chart of particulates shows (from the top) the times a wood burner was lit, the continuous presence of soil (dust) and salt particles peaking due to wind/weather patterns.

House 6, built in 1956, was the least airtight house and had the highest natural ventilation rate. As there was no wood burner, the indoor concentrations of ultrafine wood smoke particles that mirrored outdoor concentrations indicated significant infiltration from outdoor pollution sources.

House 7, built in 2011, also had a significant concentration of PM_{10} in the lounge but no wood burner. Smoking indoors may have been the primary source of those concentrations.

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More information

Research Now: Indoor air quality #1 *An overview of indoor air contaminants in New Zealand houses*

Research Now: Indoor air quality #2 *An overview of indoor air contaminants in New Zealand schools*

Research Now: Indoor air quality #3 *The impact of ventilation in New Zealand houses*

Research Now: Indoor air quality #5 *Project: Using a low-cost sensor platform to explore the indoor environment in New Zealand schools*

Research Now: Indoor air quality #6 *Project: Indoor air pollution at a New Zealand urban primary school*