Using Low-Cost Sensors to Determine the Effect of Ventilation on Indoor Air Quality Markers

Indoor air pollution can be detrimental to human health, leading to increased mortality rates. Inadequate ventilation can prevent escape of substances from within the home and lead to an accumulation of pollutants arising from internal sources (e.g., synthetic building materials, furnishings, personal care products, pesticides, and household cleaners). Due to the growing awareness of global warming and climate change, governments have applied pressure to motivate the building industry to provide more environmentally sustainable buildings. However, energy efficient buildings over the last decade have been shown to increase the concentration of some indoor pollutants.

Despite this rise in prominence of energy-efficient buildings globally, there remains a lack of evidence demonstrating the effects that mechanical ventilation has on indoor air quality (IAQ). In terms of indoor pollutants, the main benefit mechanical ventilation has over natural ventilation is the use of particulate matter (PM) filters in the supply duct. To improve understanding of the effects of mechanical ventilation against natural ventilation on indoor pollutant concentrations, this study analysed IAQ parameters in homes in New Zealand before and after installation of a positive pressure ventilation system (PPV).

A total of 15 New Zealand households were selected for this study, nine in Auckland and six in Hamilton. The average house size ranged between 120 and 273 m^2 in floorplan area, comprising three to four bedrooms, where possible, for standardisation. Participants were living in households with three to four occupants, including at least two adults. This study aimed to focus on a six-week period either side of PPV installation, during winter.

The study looked at various parameters which included: Particulate Matter (PM), Temperature, Relative Humidity (RH), and Carbon Dioxide (CO_2). The findings for these were as follows:

Indoor PM concentrations had reduced in the majority of the homes (86.7%) with reductions ranging from 52-91%, compared with pre-installation. As predicted, due to seasonal changes, external PM concentrations also decreased over the same timeframe. However, reductions externally were considerably smaller than internally, indicating that the internal reductions were aided by the PPV system. We have high confidence in the PM data due to the reliability of the sensors used. The sensors were verified through our own calibration as well as testing by AQ-SPEC against regulatory-grade equipment.

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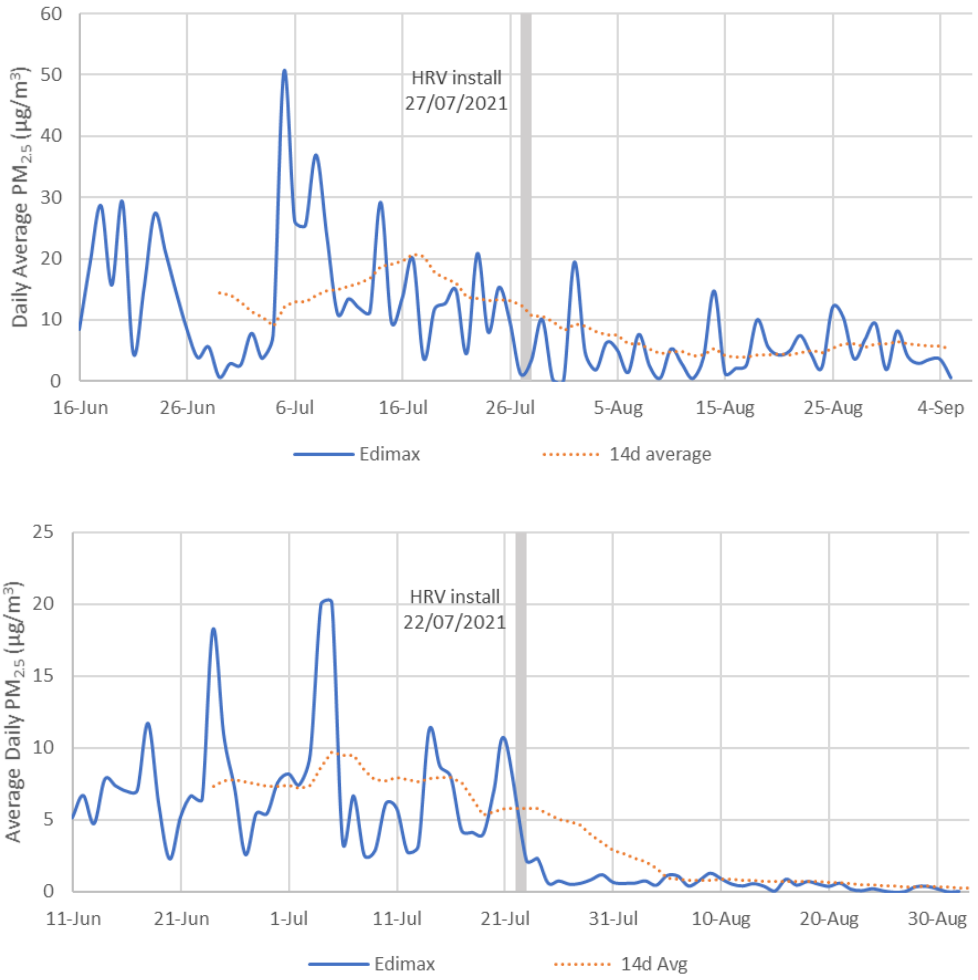

Typical indoor $PM_{2.5}$ profiles before/after PPV installation (House X (top), House Y (bottom))

Temperature - Indoor temperatures were found to increase between 0.2°C and 1.6°C following PPV installation for all but three houses. Whilst a small increase in temperature was expected, the magnitude of increase was less than expected. It is proposed that some of the expected increase may have been offset by a reduction in home heating needed to maintain comfortable living conditions.

RH - Levels were reduced following PPV installation for all but two houses (86.7%) by 4 to 14%.

CO_2 - Mean concentrations of CO_2 were found to decrease following PPV installation for all houses with the exception of two houses that showed no decrease, and two houses that showed an increase (by 3-10%). For the remaining houses, the decrease ranged between 1% and 26%.

In general, occupants found that they were more satisfied with the effectiveness of their current heating system, and generally found less extreme thermal sensations (i.e., very hot or very cold), post installation. Prior to PPV installation, the main reasons for discomfort experienced during cold weather were high humidity, drafts from windows and doors and the slow response of heating systems. During hot weather, reasons were high humidity, poor air movement and excessive sunlight.

When respondents were asked to rank five different aspects of IAQ (odour, humidity, air flow, dust and temperature) alongside overall IAQ, there was a significant increase in ranking post- PPV. Pre-installation, 57% of respondents believed their homes had an existing problem with IAQ, 40% did not, with the remainder uncertain. Post- installation, this has changed markedly to 7% of respondents

believed their homes had an existing problem with IAQ, 93% did not. The greatest changes in IAQ parameters observed by respondents during the winter season were caused by reductions in humidity.

Ranking of perceived IAQ and associated factors

	Pre HRV		Post-HRV
Parameters	Winter Mean rank (Std Dev)	Summer Mean rank (Std Dev)	Winter Mean rank (Std Dev)
Odour	3.5 (1.3)	4.2 (1.0)	4.5 (0.02)
Humidity	2.6 (1.2)	3.5 (1.2)	4.7 (0.01)
Air Flow	3.1 (1.2)	3.5 (1.4)	4.4 (0.03)
Dust	2.9 (1.1)	3.1 (1.2)	3.8 (0.03)
Temperature	2.8 (1.0)	2.9 (1.3)	4.4 (0.02)
Air quality	3.0 (1.0)	3.6 (1.2)	4.6 (0.02)

Rankings were provided on a scale of 1-5, where 1 = uncomfortable and 5 = comfortable

However, COVID-19 presented some clear challenges in terms of data collection and meant that the six-week period was pushed out into spring for some of the houses. Disruptions to logistics resulted in varying delays in timing and duration of the monitoring periods for different houses, with some houses being monitored over spring rather than winter. Technical issues with some of the sensors were identified mid-sampling period, and lockdown restrictions made servicing of faulty sensors difficult as access could not be gained to rectify these issues. Occupancy rates were likely to be higher than usual as a result of the COVID-19 lockdown. Therefore, the results of this study may not be representative of typical household inhabitation, and the potential impacts of seasonal variation need to be considered when interpreting the results and findings of this study.

Disclaimer

This report is based on academic research on indoor air quality conducted by Unitec's Environmental Solutions Research Centre. It presents results of research undertaken by Unitec institute of Technology on fifteen study houses with a mechanical ventilation system installed, which was provided by HRV. The report does not constitute a professional evaluation, assessment of quality or certification of the researched building or system but is aimed at increasing knowledge about indoor air quality in buildings with mechanical ventilation installed. The research team at Unitec acted independently when designing the methodology, executing the project and analysing the research results. This report may only be reproduced unaltered and in its entirety. References paraphrasing the research results in this report need to include a statement that this report was authored by Unitec's Environmental Solutions Research Centre.

Further information

If you require any further information or assistance for the interpretation of this report, please feel free to contact esrc@unitec.ac.nz.

References are provided on request.