An overview of indoor air contaminants in New Zealand schools

Excess moisture and contaminants in the air of New Zealand classrooms affects the health and wellbeing of students and teachers. Understanding what is wrong with the air quality and how ventilation can improve it will help make New Zealand schools healthier and more comfortable to learn and work in.

Indoor air quality in schools is important:

- Children spend a large proportion of time at school.
- Children are more vulnerable to contaminants than adults. They breathe faster and their lungs are proportionally larger, so contaminants become more concentrated in their bodies.
- Classrooms are typically more crowded than houses or offices.
- Schools are often exposed to traffic pollution from busy roads.
- International studies show that poor classroom ventilation impacts children's health, school attendance and academic achievement.

This Research Now covers the findings of a number of studies into New Zealand classroom air quality and two Building Research Levy-funded projects in particular:

- A study in October 2016 of a Wellington primary school classroom that is typical of many - a 1970s single-storey weatherboard building with windows on both sides (Bennett et al., 2019).
- A 2017 project assessing lower-cost remote monitoring technology SKOMOBO (SKOol MOnitoring BOx). Trials took place in four Auckland classrooms and then expanded to 28 classrooms in 10 schools in Hawke's Bay, Christchurch and Dunedin (see Research Now: Indoor air quality #5).

School buildings were tested for excess moisture levels and contaminants including:

- biological contaminants such as fungi, bacteria and dust mites
- volatile organic compounds (VOCs)
- gases such as carbon dioxide (CO_2)
- particulates.

MOISTURE

Excess moisture is the most pressing problem with indoor air quality. Many studies show links between damp rooms and respiratory/allergy illnesses. Humidity levels of 40-60% are recommended for optimum comfort. As relative humidity increases above 60%, airborne pathogens such as bacteria increase.

In the Wellington classroom during school hours, relative humidity was an average 61% - at the high end of the recommended range.

Figures just over 60% were common in Hawke's Bay classrooms too, with a few over 70% and one classroom reaching 86% relative humidity. This does not provide a pleasant learning environment.

Humidity rates were comfortable in Christchurch and Dunedin schools, within 40-60%, although one Christchurch classroom recorded a winter weekly average of 81%. High humidity rates indicate that windows are not being opened.

BIOLOGICAL CONTAMINANTS

Biological contaminants such as moulds and dust mites are more common in damp buildings. NZS 4303:1990 *Ventilation for acceptable indoor air quality* recommends relative humidity no greater than 60% specifically to minimise levels of biological contaminants.

The faecal waste of dust mites causes problems for people with asthma, but dust mite levels in schools may not be high. As part of the

He Kura Asthma Study funded by the Health Research Council and the University of Otago, researchers collected floor dust samples from 136 classrooms in 12 primary schools. Dust mite allergens were found in nearly all classrooms but none at a level that could cause illness.

A quarter of the classroom carpets had high enough levels of cat dander (most likely carried in on the clothing of children who had cats at home) to potentially cause breathing problems in children allergic to cats.

VOCs

Volatile organic compounds (VOCs) are organic chemicals given off as gases from some solids and liquids. They are found in many solvents and cleaning fluids, paints, coatings, adhesives and other products. They can be emitted by new furnishings. VOCs can irritate eyes, nose and throat, cause headaches/nausea and potentially even damage internal organs. VOC emissions are of particular concern in new or recently redecorated/refurbished buildings.

There has been limited work measuring VOCs in New Zealand schools, but research in New Zealand houses indicates that, even with active ventilation, VOC emissions from new furnishings or new decoration may take several days to fall to safe levels. For more details, see Research Now: Indoor air quality #1 *An overview of indoor air contaminants in New Zealand houses*.

GASES

Breathing in high levels of carbon dioxide (CO_2) can result in headaches, tiredness and more frequent illness. Nitrogen oxides (NO_x) produced from burning gas and from car exhausts can also have an impact, irritating the airways of many people. These gases can cause more severe reactions in people with asthma.

CO_2 levels are frequently used as a proxy to estimate the stuffiness in classrooms and measure the effectiveness of ventilation. NZS 4303:1990 recommends ventilation that results in CO_2 levels below 1,000 parts per million (ppm). In new school buildings, the Ministry of Education requires that the average concentration should not exceed 1,500 ppm.

Some classrooms comply while others don't:

- Inside the Wellington classroom, the CO_2 average concentration in school hours was almost 900 ppm.
- In the Auckland schools of the SKOMOBO trial, CO_2 in one classroom exceeded 1,000 ppm for 66% of school time and 1,500 ppm for 40% of the day in winter. In spring, CO_2 rates were mostly below 1,000 ppm.
- In Hawke's Bay, weekly average CO_2 measurements were consistently over 1,000 ppm year round. Students in one classroom experienced high CO_2 levels the whole year, with summer levels around 2,000 ppm. Windows were not being opened.
- In Christchurch, over half of the averages were above 1,200 ppm, with one room reaching 2,800 ppm in winter and another 3,800 ppm in autumn. In one classroom, students were exposed to CO_2 levels of 2,000-3,000 ppm for a whole week in winter. In another, CO_2 levels were above 2,000 ppm for most of the year.
- In Dunedin, 53% of the weekly averages were below (or around) 1,000 ppm. No students were exposed to CO_2 above 2,000 ppm.

These CO_2 concentrations are unlikely to be a significant health risk but are more likely to have a temporary impact on performance.

NO_2 levels in the Wellington classroom were higher in class time than evenings and weekends but unlikely to pose health problems.

PARTICULATES

Particulates are tiny pieces of matter. Two sizes are commonly tested for. PM_{10} particulates (defined as coarse) are 10 micrometres or less in diameter, and $PM_{2.5}$ particulates (defined as fine) are less than 2.5 micrometres in diameter. Human hairs average 100 micrometres across.

High levels of particulates, especially PM_{10}, can irritate the eyes and throat. People with breathing conditions may experience an increase in symptoms. The smaller $PM_{2.5}$ particles can be a bigger threat because they can reach deep into the lungs. Particulates have a chronic health impact and cause a high loss of so-called 'disability-adjusted life years'.

In the Wellington classroom, indoor averages for $PM_{2.5}$ and PM_{10} were significantly higher in school hours. Indoor concentrations of PM_{10} were significantly higher than concentrations in outdoor air. The PM_{10} particulates were mostly soil, possibly brought in on children's shoes and then resuspended as children moved around the classroom. Over half of the indoor $PM_{2.5}$ particulates were from the infiltration of motor vehicle emissions from the busy road outside. The findings from this study are likely to be applicable to many other schools.

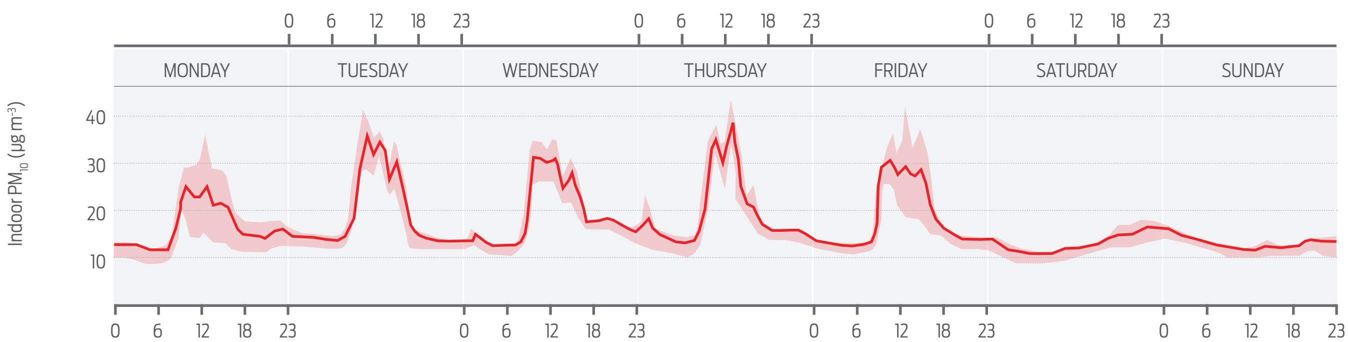

Figure 1. The level of PM_{10} particulates in the Wellington classroom was much higher during school hours. (The shaded areas are the 95% confidence interval in mean concentrations.) (Source: Bennett et al., 2019)

In the Auckland classrooms of the SKOMOBO trial, $PM_{2.5}$ and PM_{10} levels were higher in winter than spring, reflecting less opening of windows on colder days. A large open-plan classroom with 70 students had a consistently higher level of particulates than other classrooms, explained by a higher level of activity resuspending more dust.

The World Health Organization specifies that the annual mean concentration of $PM_{2.5}$ and PM_{10} should not exceed 10 μg/m³ and 20 μg/m³. The 24-hour concentrations of $PM_{2.5}$ and PM_{10} should not exceed 25 μg/m³ and 50 μg/m³.

Of the 28 classrooms in Hawke's Bay, Christchurch and Dunedin, only one classroom had a problem, breaching the level for $PM_{2.5}$ almost 10% of the time. This same classroom breached the PM_{10} level for almost 4% of school time in winter.

VENTILATION

NZS 4303:1990 recommends ventilation with outdoor air of 8 litres per second per person for classrooms and auditoriums.

In the Wellington classroom, the average rate measured was 6.6 litres/second, meeting the guideline in the standard only 38% of the time. This is similar to figures recorded in other schools.

Most New Zealand classrooms depend entirely on ventilation from opening windows, but this happens infrequently, particularly in winter. A 2015 survey of 20 low-decile and 20 high-decile Auckland schools found that only 38% of teachers opened windows in teaching time. Security concerns and outdoor noise were given as the reasons for keeping windows closed.

In 2017, a survey of 33 teachers from nine schools in Hawke's Bay, Christchurch and Dunedin found that, while almost 80% agreed that ventilation created a comfortable classroom environment, only 25% said they opened windows each time they taught a class. Noise and wind were the main reasons for not opening windows.

SUMMARY

Ventilation of school classrooms typically relies on windows being opened, but this is not happening often enough to provide effective ventilation. CO_2 rates are often above recommended levels in many classrooms, and humidity levels are sometimes too high. Dust mite allergens and particulates may not be a widespread problem. (The sample size of classrooms was too low to have a high confidence interval in the results, so what was found in this area should not be assumed to be true for the whole classroom stock.)

Researchers looking at indoor air contaminants in schools recommend:

- entry mats to capture dust/dirt before it is brought inside
- daily vacuuming with well-maintained vacuum cleaners with HEPA filters
- improved ventilation, including behavioural changes around window opening
- hard floor surfaces rather than carpet
- low-VOC building materials
- considering the proximity of main roads when building new schools.

Following the success of the SKOMOBO platform, new work includes:

- an interactive product, SKOMOBO PLUS, which displays real-time indoor air quality data using facial expressions rather than numbers to represent good or poor conditions
- a set of air quality educational activities (a 2018 Unlocking Curious Minds Project and 2019 MBIE-funded projects) that engage with students as 'young scientists'.

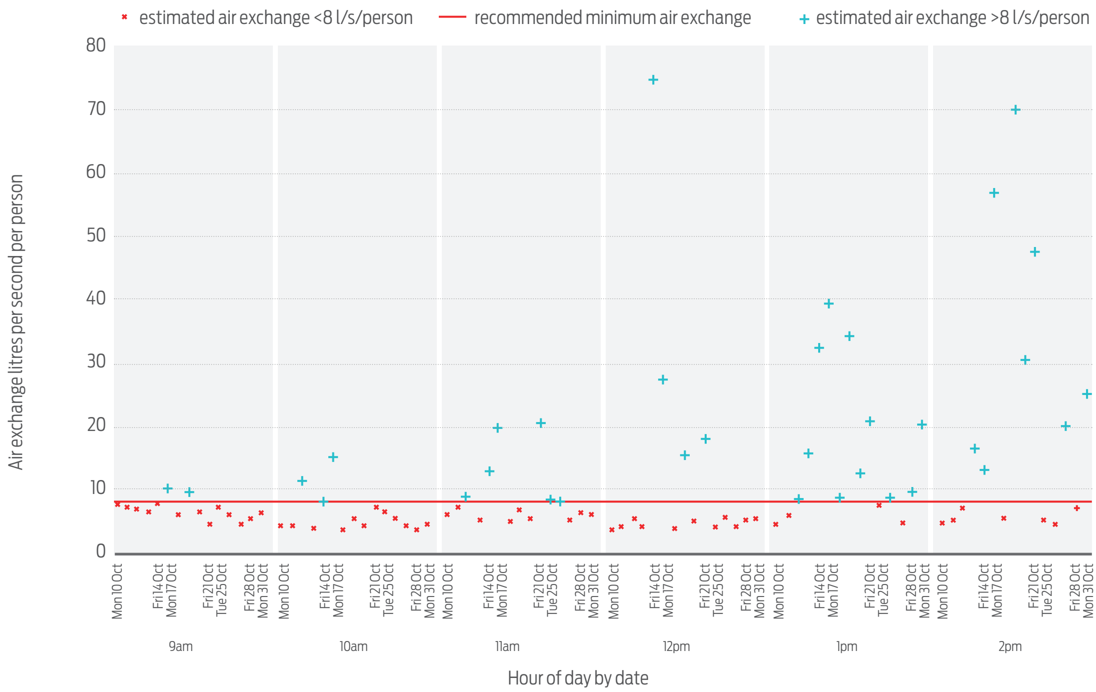

Figure 2. Ventilation rates in the Wellington classroom calculated by using measures of CO_2. The number of days the ventilation rate fell below the recommended level of 8 litres per second per person (the red line) is clear. (Source: Bennett et al., 2019)

Ministry of Education requirements

The Ministry of Education (MoE) has performance requirements for new school buildings. Older buildings being renovated must comply "as near to the guidelines as reasonably practicable". A substantial upgrade should meet all or most requirements and recommendations.

Wherever practical, MoE prefers non-mechanical ventilation, provided this meets minimum requirements for controlling contaminants and stable temperatures.

Rooms where natural ventilation is difficult - rooms with deep plans, no cross-ventilation or complex shapes with airflow dead spots - must have additional supply/exhaust systems.

Where natural ventilation is not available, schools must install a mechanical ventilation system with filters to provide the minimum flow rates from NZS 4303:1990 or AS 1668.2-2012 *Mechanical ventilation in buildings*.

In cold climates where opening windows would create discomfort, MoE recommends that schools consider heat recovery or mixed-mode ventilation.

MoE expects that summer CO_2 levels will vary approximately 400-1,000 ppm over the day. At any time of year, the average concentration should not exceed 1,500 ppm at seated head height (1,200 mm) during teaching hours. Peak concentration should not exceed 3,000 ppm. There must be a CO_2 monitor with a display in each learning space to help staff and students to manage CO_2 by opening windows.

Building components/materials must fall below the maximum allowable VOC content or VOC emission rates as prescribed by the New Zealand Green Building Council (NZGBC) or a NZGBC-recognised eco-label or indoor air quality scheme.

More information

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

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

Research Now: Indoor air quality #4 *Project: Indoor air quality in New Zealand homes and garages*

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*

Bennett, J., Davy, P., Trompetter, B., Wang, Y., Pierse, N., Boulic, M., Phipps, R. & Howden-Chapman, P. (2019). Sources of indoor air pollution at a New Zealand urban primary school; a case study. *Atmospheric Pollution Research*, 10(2), 435-444.