Sources of air pollution in ~~NZ~~ Wellington homes

and the impact of ventilation/infiltration

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GNS SCIENCE
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Analysis of Indoor Air Pollution and Sources

Context:

- **Examining indoor air pollutants useful for exposure analysis, health impacts and air quality management**
  - **We spend 80-90% of our time in built environments**
  - **What we are exposed to indoors highly relevant from a health and epidemiology perspective**
- **Key questions:**
  - **What are the primary sources of PM pollution in our homes?**
  - **What commonalities are there across different homes?**
  - **What is the interaction between indoor and outside (ambient) air quality?**

Analysis of Indoor Air Pollution and Sources

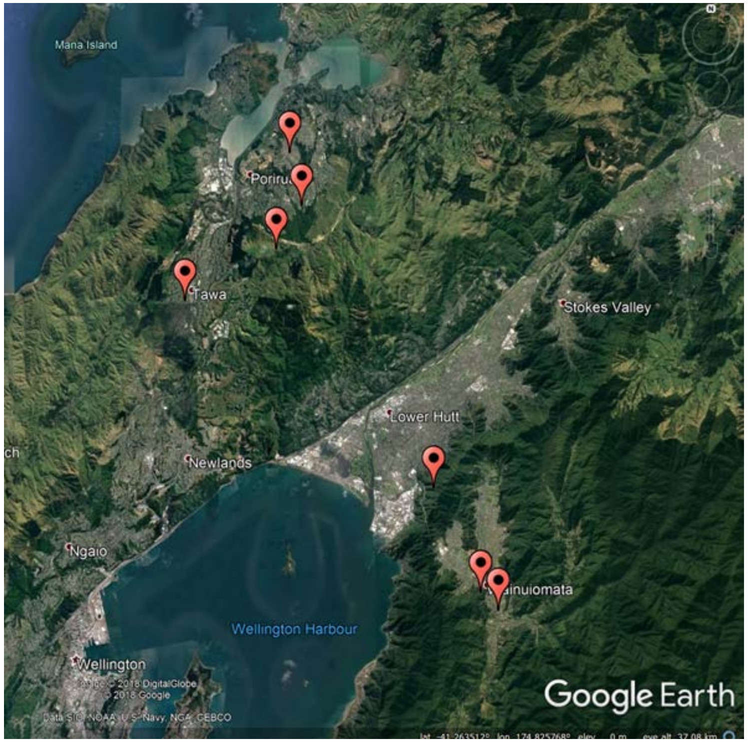
Outline:

- Location and houses studied
- Indoor air pollutants and sources
- Warm, dry homes?
- Impact of occupancy and ventilation
- Infiltration of outdoor pollutants indoors
- Summary

Study homes

A selection of homes was sought that would represent the range of NZ building stock:

- old and new homes
- including state houses
- homes with inbuilt garages



Seven houses chosen from

Porirua through to Wainuiomata

- Built 1948 to 2014
- 2 with internal garages
- 15 days monitoring in each house
- None were immediately adjacent busy roads

	House 1	House 2	House 3	House 4	House 5	House 6	House 7
Suburb, City	Waiwhetu, Lower Hutt	Tawa, Wellington	Cannons Creek, Porirua	Papakowhai, Poriura	Cannons Creek, Porirua	Wainuiomata, Lower Hutt	Wainuiomata, Lower Hutt
House type	Modern	State house	State house	New	State house	State house	New
Storeys (not incl garage)	2	1	1	2	1	1	1
Bedrooms	4	3	4	3	4	2	2
Age	1980	1948	1965	2014	1977	1956	2011
Floor Area (m^2)	260	130	140	178	110	90	100
Land (m^2)	863	445	1078	523	615	809	294
Roof	iron/slate	Concrete tiles	Concrete tiles	iron	iron	iron	Decromastic tiles
Cladding	Wood	Brick	weatherboard	plaster Styrofoam	Wood	weatherboard	brick
Windows	Wood/ aluminium	wood	wood	Aluminium	Aluminium	Aluminium + wooden	Aluminium (double glazed)
Heating (Lounge)	Wood burner	Wood burner	Heat pump	Wood burner	Wood burner and or heat pump	Electric oil heater	Heat pump
Lounge Floor covering	Carpet	Wood/mat	Carpet	Wood	Carpet	Carpet	Carpet
Stove	Gas	Electric	Electric	Gas (LPG)	Electric	Electric	Electric
Insulation - roof	yes	40-50%	yes	yes	yes	yes	yes
Insulation - floor	yes	no	yes	yes	yes	yes	yes
Insulation - walls	yes	yes	?	yes	no	?	yes
Smokers?	none	none	none	none	none	none	yes
Pets	Cat (chickens outside)	none	none	cat	none	dog (outside)	birds in the garage
Total house occupants	2 adults 3 children	2 adults 3 children	2 adults 5 children	2 adults 2 children	2 adults 5 children	2 adults 3 children	2 adults
Bedroom 1	1 child	1 woman, 1 baby	1 child	1 child	2 children	2 children	2 adults
Bedroom 2	1 child	1 adult, 1 child	3 children	1 child	1 child	2 adults, 1 baby	no occupants
Notes				take off shoes at the door		take off shoes at the door	

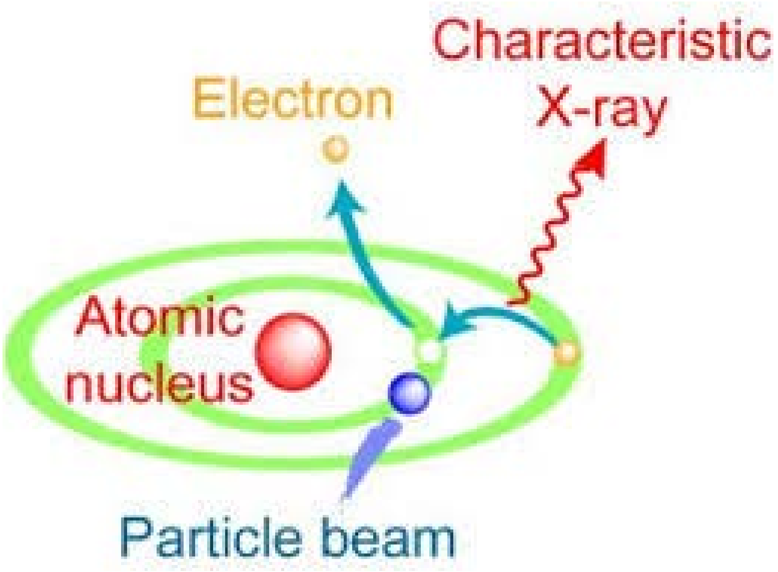
Monitoring set-up

Outside	Lounge (+ Garage)	Bedrooms
PM_{10} monitor (EBAM)	PM_{10} monitor (DustTrak)	CO_2, CO, Temp, RH (QTrak,)
$PM_{10-2.5}$ 2hr samples (Streaker)	$PM_{10-2.5}$ 2hr samples (Streaker)	
$PM_{2.5}$ 2hr samples (Streaker)	$PM_{2.5}$ 2hr samples (Streaker)	
Temp (EBAM)	CO_2, CO, VOC, Temp, RH (QTrak,)	



Particulate matter elemental composition by ion beam analysis (IBA)

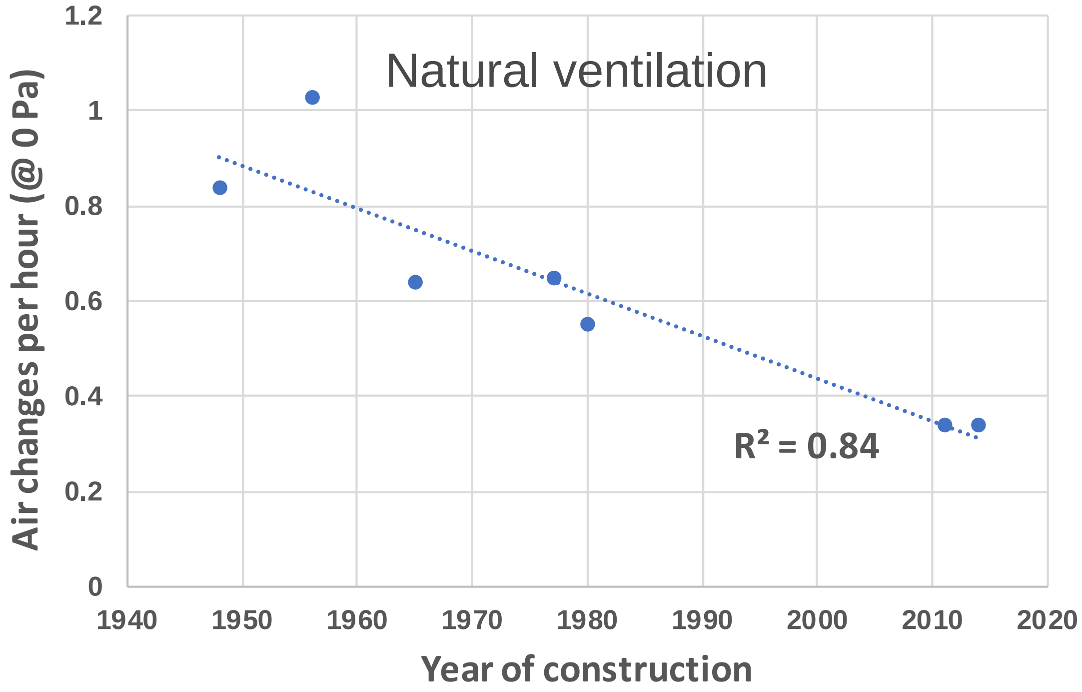
- **Elemental concentrations determined from atomic interactions with PM on filters**
  - Elements Na to U (plus H for IBA)
  - Rapid, non-destructive



- **Black carbon (soot) by light reflection (i.e. a separate measurement)**

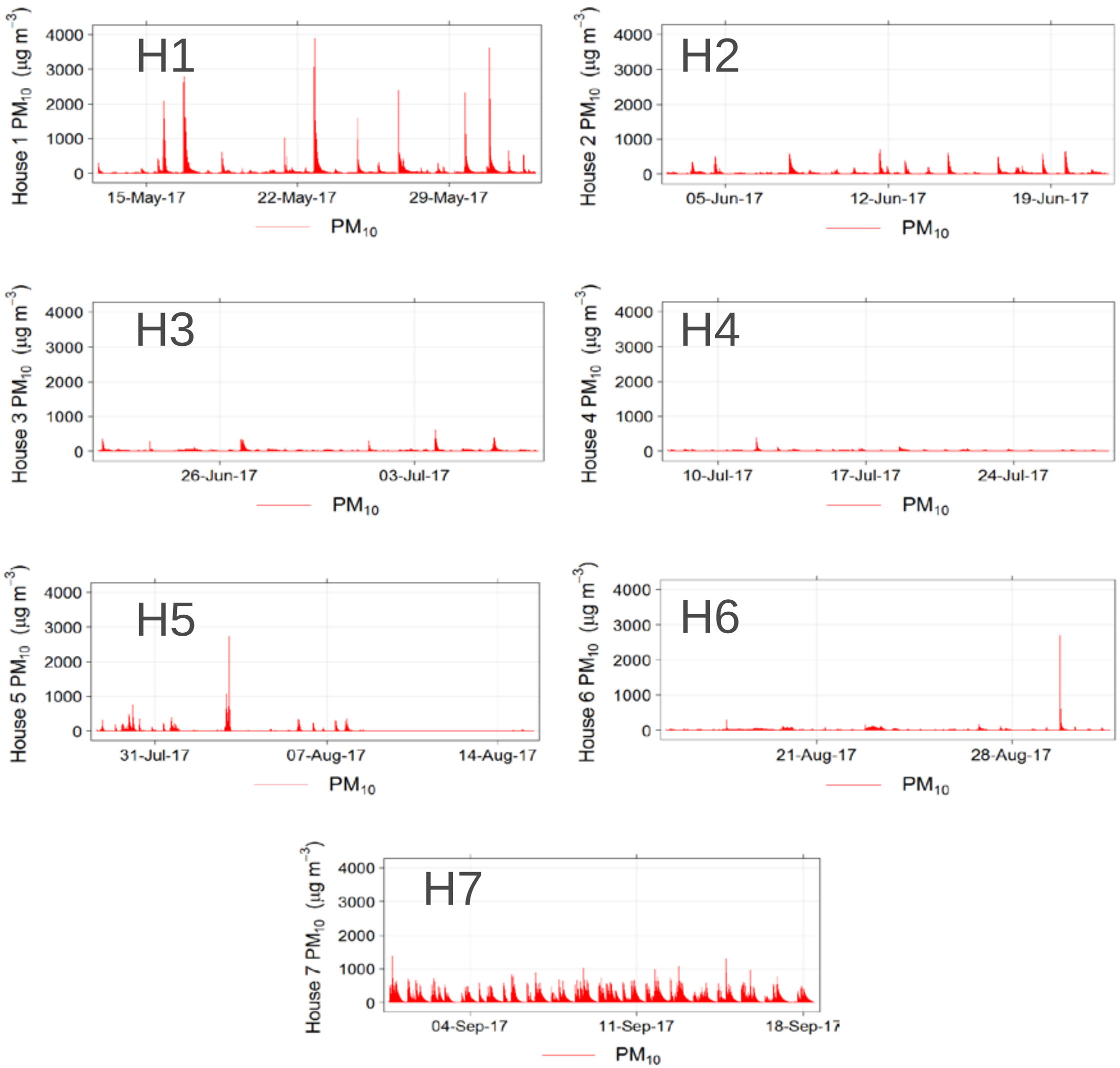
House ventilation rates

- Older houses have higher natural ventilation rates (i.e. they are ‘leakier’)
- Most likely due to construction materials and tightness of fit for windows and doors



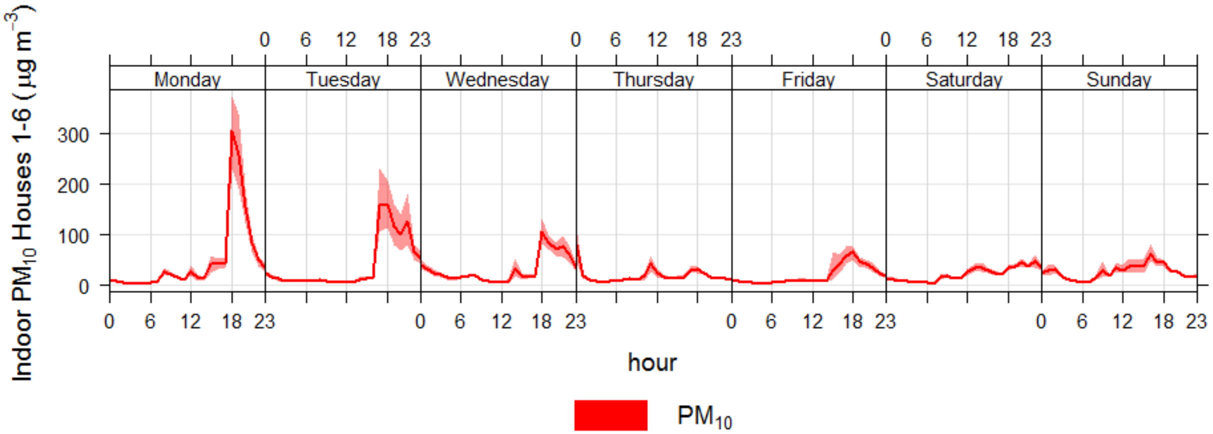
PM_{10} (fine particle) concentrations Indoors

- **Interesting pattern of extreme peaks in each house over the monitoring period**
- **Variability in peak concentrations across houses**

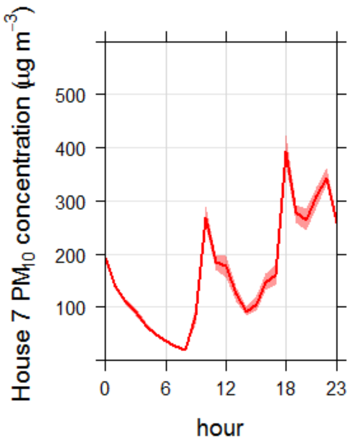


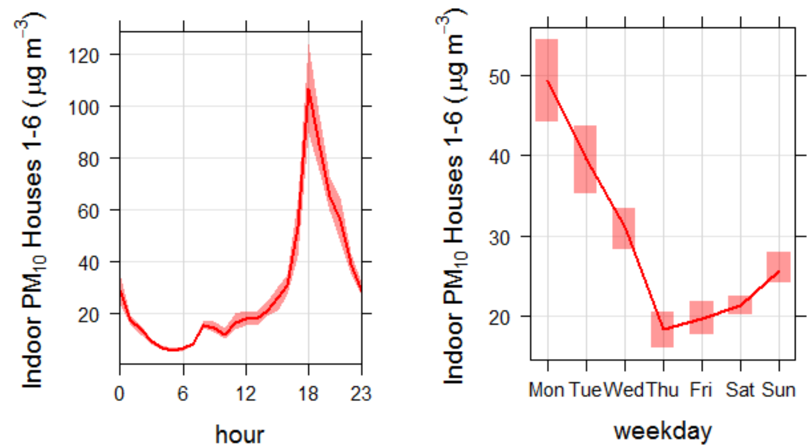
PM$_{10}$ (fine particle) concentrations Indoors

- **Temporal variation was surprisingly regular across houses (1 to 6)**



- **Smoking has a significant influence (H 7)**

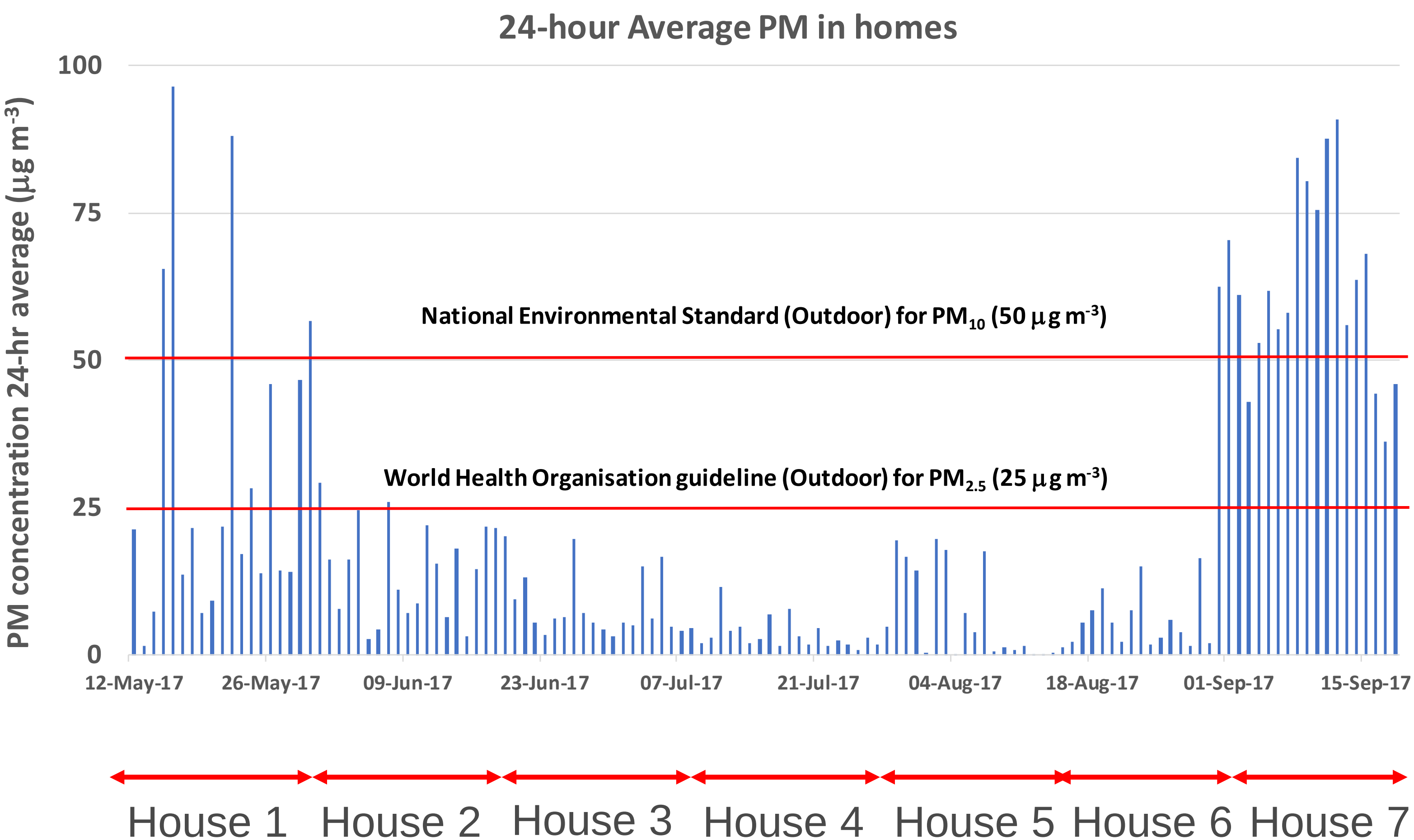




mean and 95% confidence interval in mean

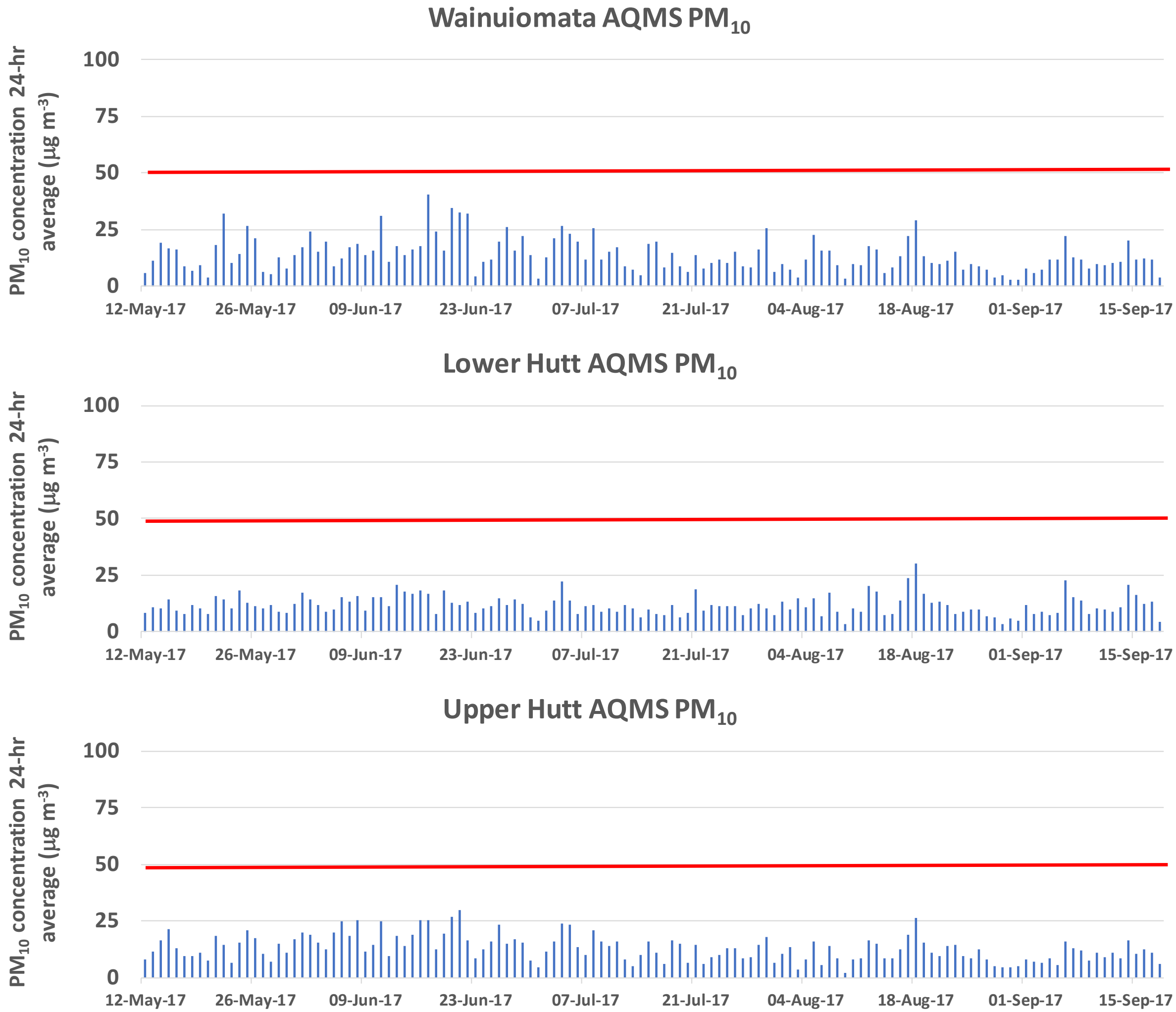
PM_{10} (fine particle) concentrations Indoors

Graph shows indoor concentrations compared to the outdoor PM_{10} National Environmental Standard



PM_{10} (fine particle) concentrations Outdoors

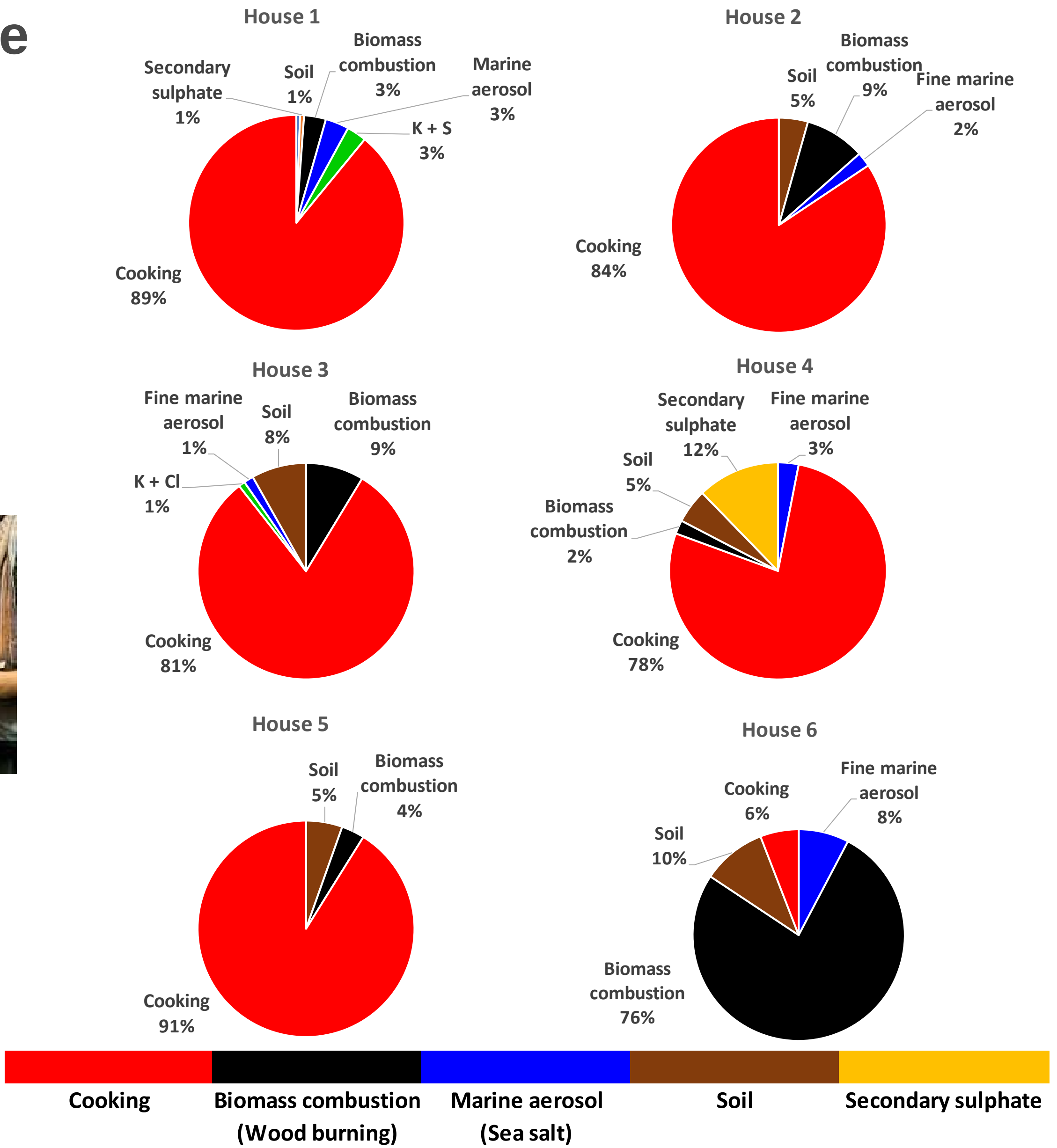
Graph shows concentrations at Wellington Regional Council air quality monitoring stations (outdoor) for the same time period



PM_{10} Source types and contributions indoors

- Differentiation of source by compositional and time-series analyses
- Cooking emissions the primary source of peak PM in houses (1 to 5) and dominates overall average

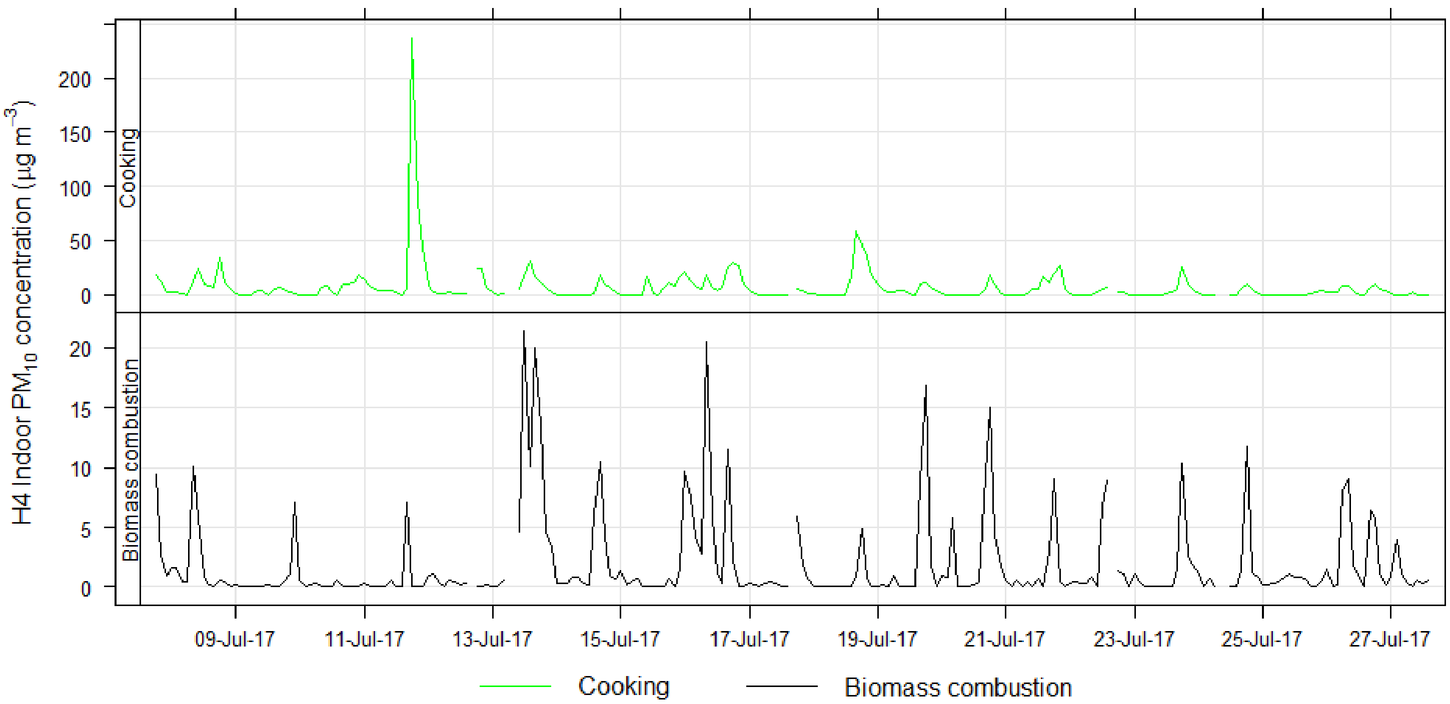
- House 6 mainly had evening meals with family nearby
- House 7 equipment malfunction in lounge

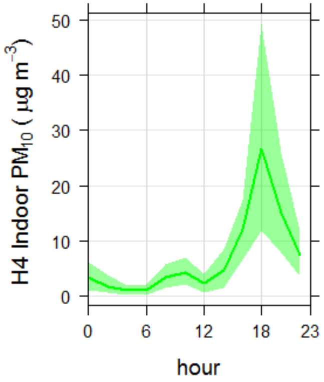


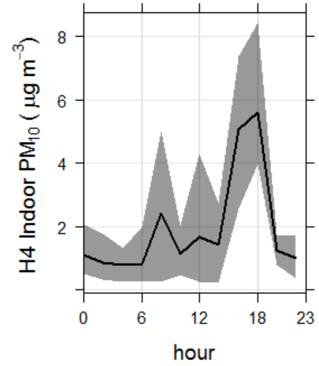
Biomass combustion in houses with wood burners

House 4 (built 2014) example:

- Wood burner the main source of heating and in regular use
- Cooking probably mostly defined by frying (maybe roasting)…

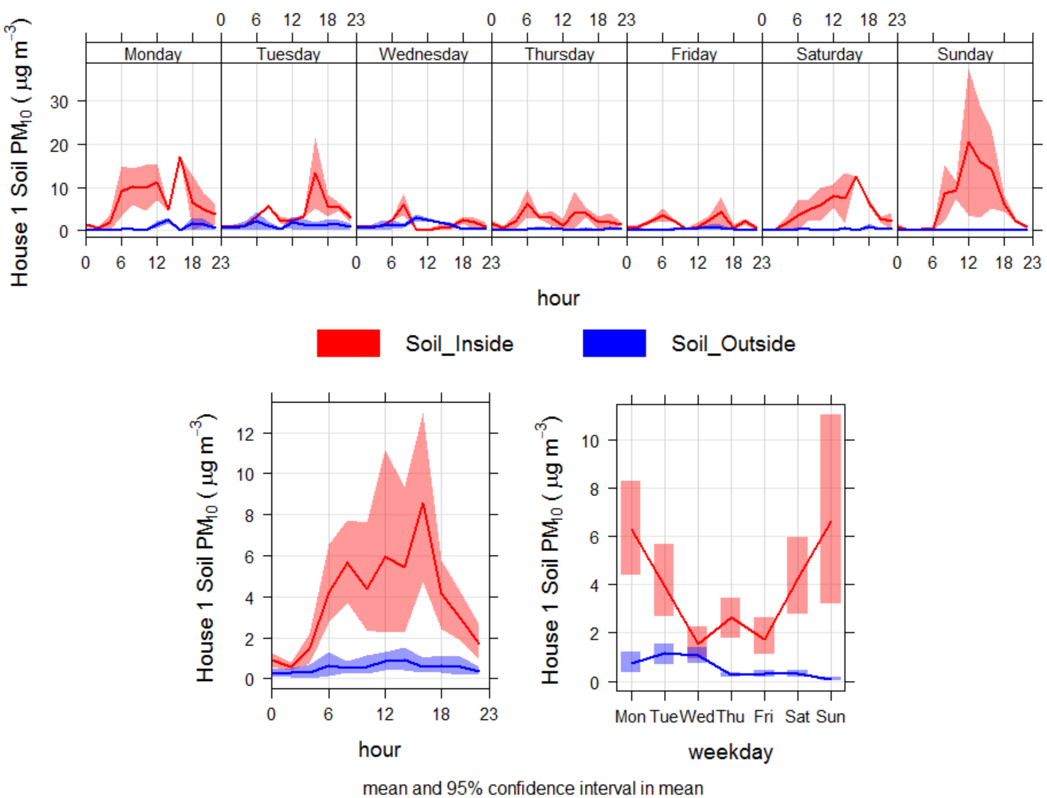






Crustal matter indoors

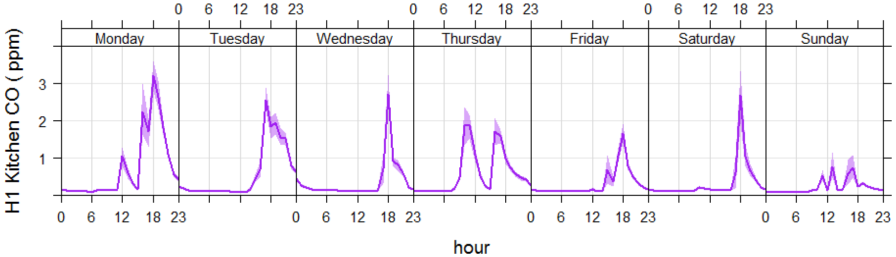
- **Soil indoors due to resuspension by movement of people (*cf* classrooms) or activities such as sweeping or vacuuming**
- **Generally coarse particle ($PM_{10-2.5}$ [Si] >> $PM_{2.5}$ [Si])**
- **Not related to outdoor crustal matter concentrations**

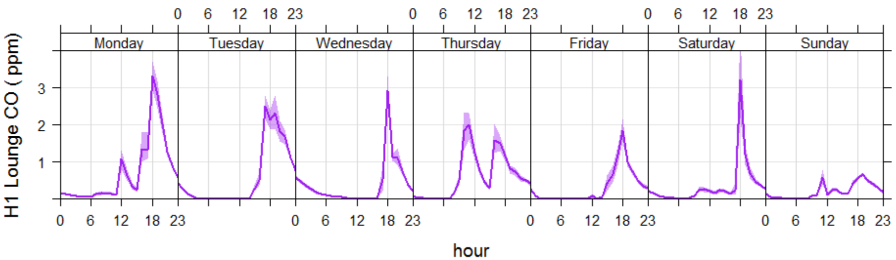


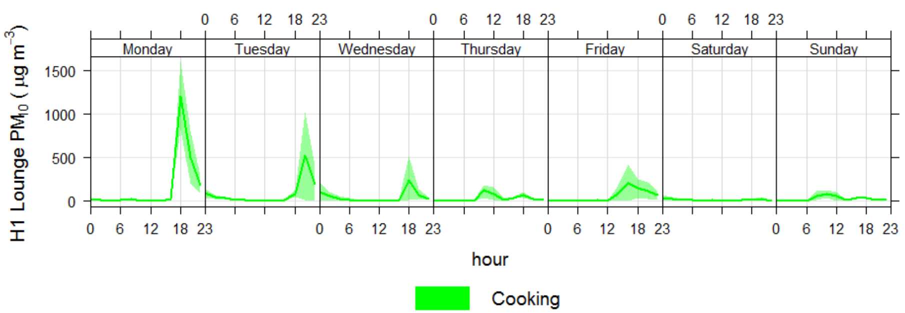
Indoor carbon monoxide

- **Main influence appeared to be use of gas appliances or motor vehicles for the houses with internal garages**

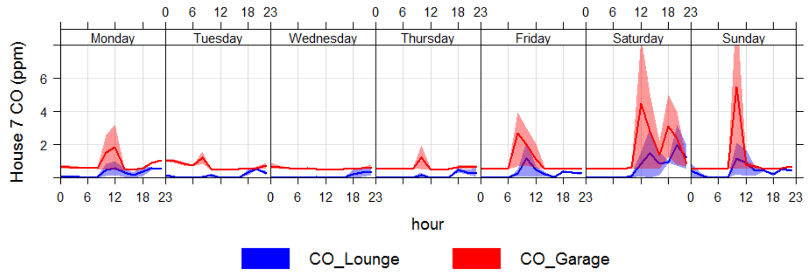
House 1 gas hob in kitchen







House 7 internal garage



WHO Guidelines for CO:

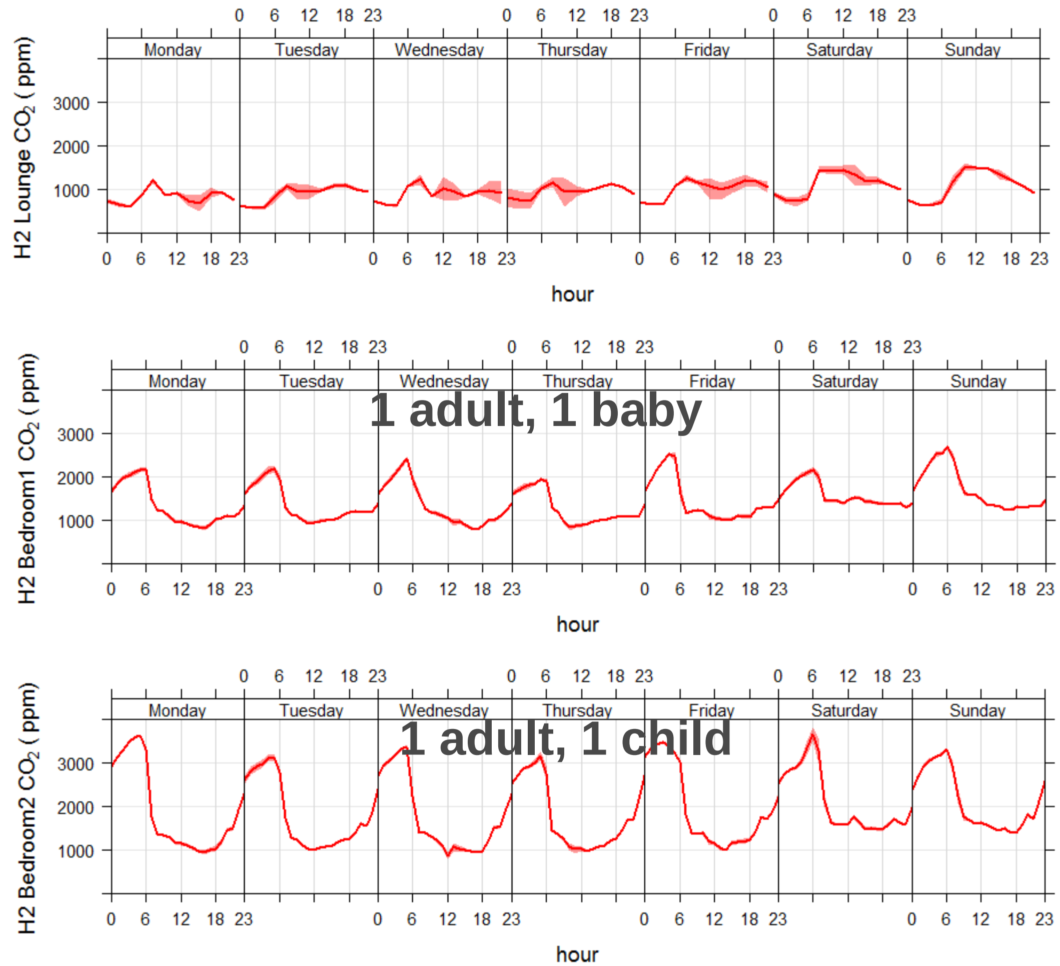
- **100 mg/m^3 (90 ppm) for 15 minutes**
- **60 mg/m^3 (50 ppm) for 30 minutes**
- **30 mg/m^3 (25 ppm) for 1 hour**
- **10 mg/m^3 (10 ppm) for 8 hours**

Ventilation rates - Indoor carbon dioxide

CO_2 indoors is an indicator of occupancy and ventilation rates:

- **Toxicity > 10,000 ppm,**
- **Health and cognition effects >1500 ppm**
- **'Stuffiness' > 1000 ppm**

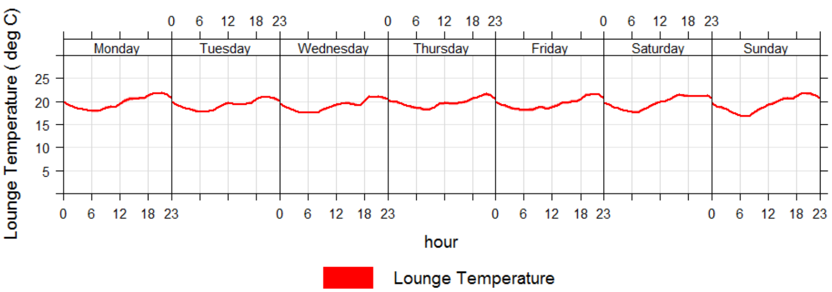
The peak night-time CO_2 pattern in bedrooms was consistent across all houses

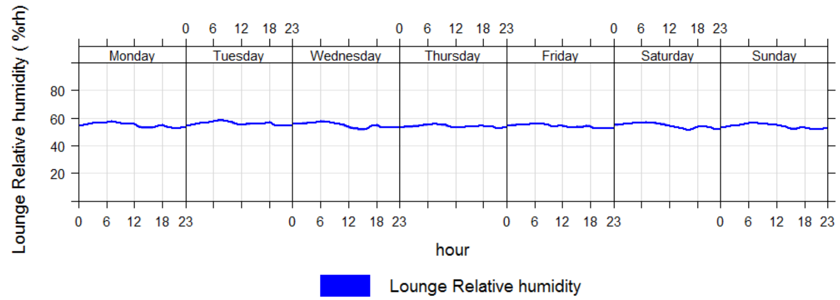


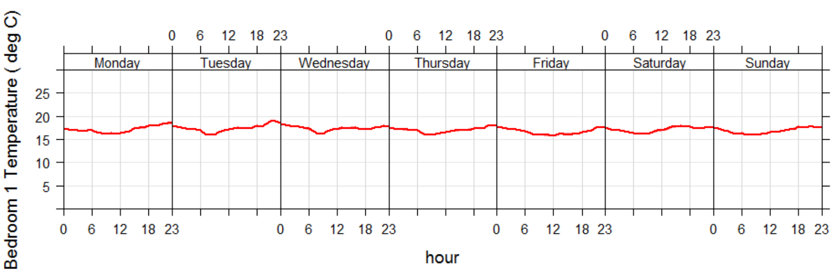
(atmospheric background ≈ 400 ppm↑)

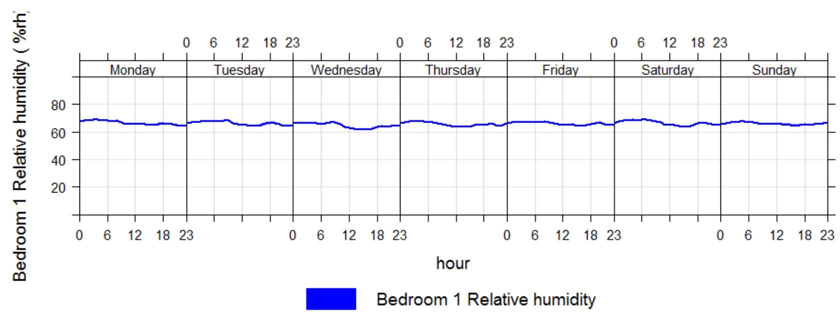
Warm, dry homes?
Indoor temperature and relative humidity

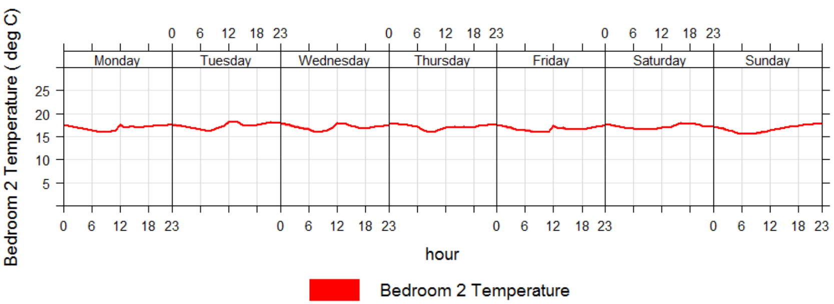
- **Temperature in bedrooms lower than lounge – expected**
- **Relative humidity and temperature appear within acceptable bounds**
  - **These were houses that had interventions (insulation, heating)**

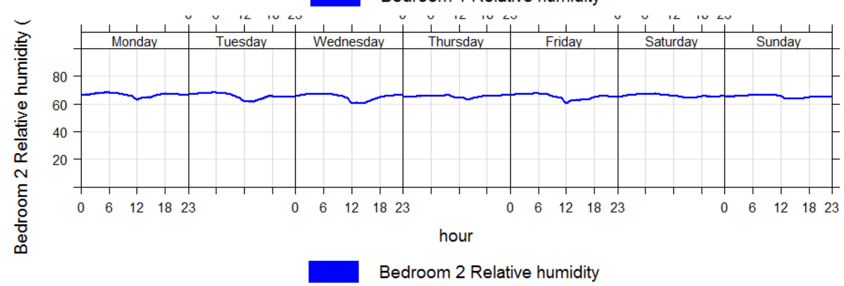








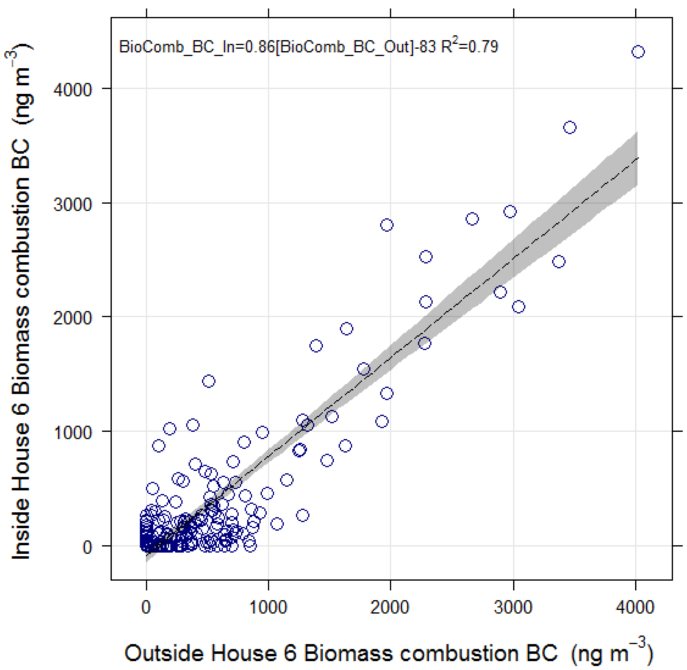


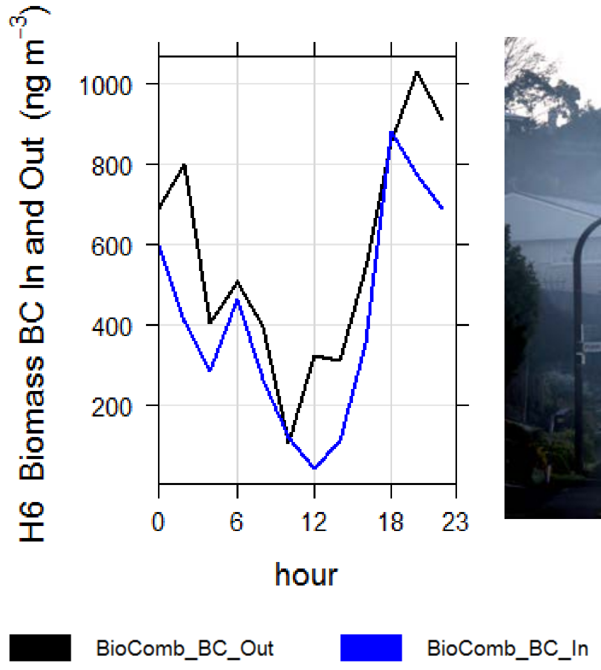


Infiltration of outdoor sources to indoors

House 6:

- Ex state house, built in 1956, no wood burner
- Located on Wainuiomata valley floor
- Highest natural ventilation rate
- Inside pollutant concentrations were similar to outdoor
- Diurnal concentration pattern typical of urban wood burning





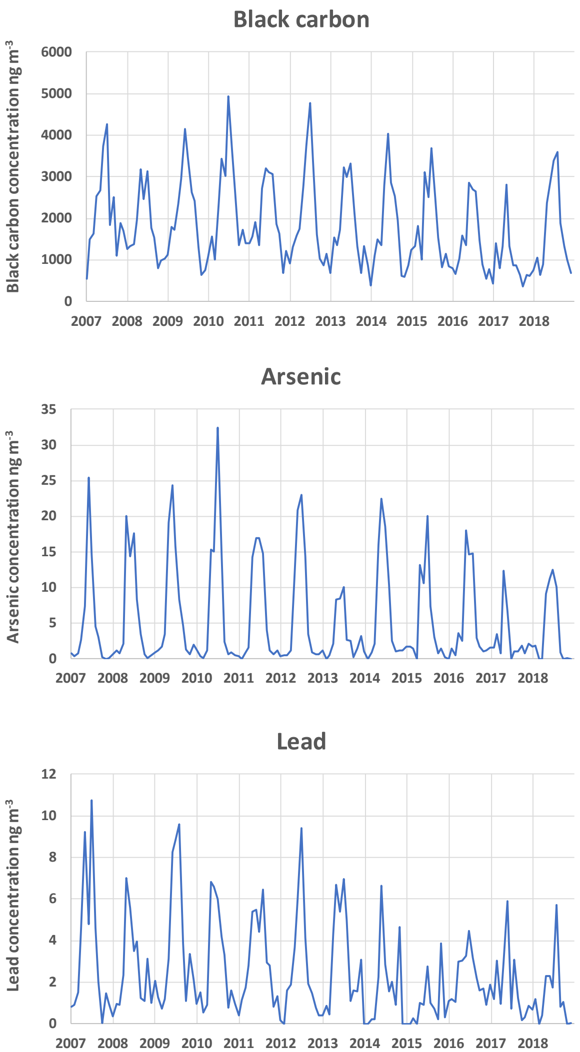
Infiltration of outdoor pollutants to indoors

Wood burning for home heating – a neighbourly impact

Across NZ we see outdoor pollutant concentrations associated with winter home heating:

- **Black carbon (soot) is a product of fuel combustion**
- **Arsenic is from burning treated timber (off-cuts/waste)**
- **Lead is from burning old painted timber (pre-1970s paint contained lead)**

Implications for indoor air quality for passive (infiltration) and active (people doing the burning) exposure to these pollutants

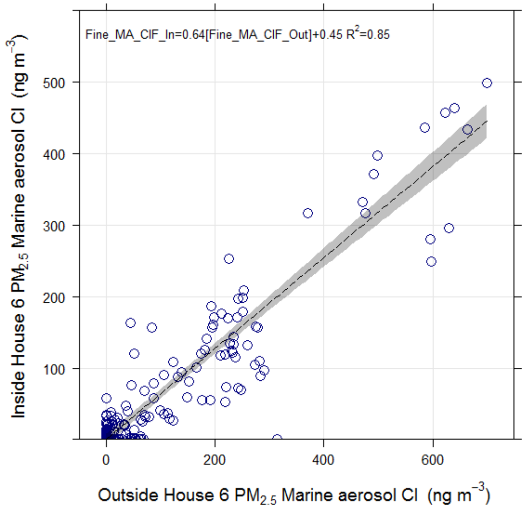


Infiltration of outdoor sources to indoors
Size matters!

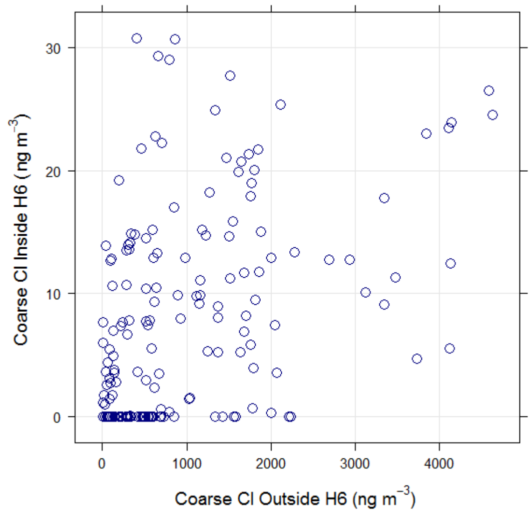
Marine aerosol (sea salt) ubiquitous outside at all sites

- Outdoor coarse marine aerosol fraction concentration >> fine
- Only the fine fraction was detected indoors
- Ratio varied from approx 1/3 to 2/3 outdoor concentrations
- Illustrates the relative infiltration by particle size (and ⇨ source)
- Ultrafine particles unimpeded (wood burning, motor vehicles etc)

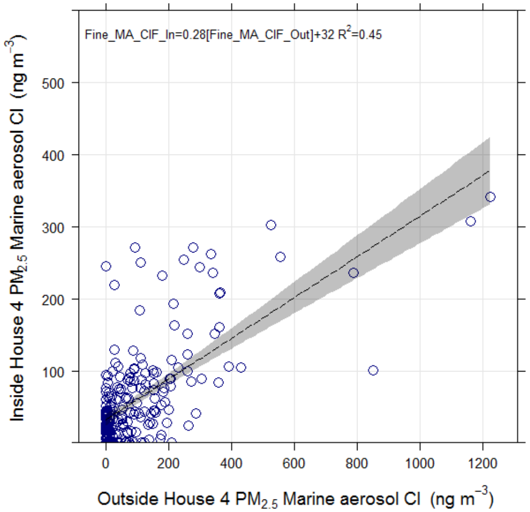
H6 Fine marine aerosol inside vs outside



H6 Coarse marine aerosol inside vs outside



H4 Fine marine aerosol inside vs outside



Summary and implications

- Indoor PM mainly $PM_{2.5}$
- Cooking can dominate indoor PM
- Wood burners leak PM indoors
- Outside $PM_{2.5}$ infiltrates indoors $\Rightarrow$ implications for buildings in polluted urban atmospheres
- Indoor exposure to PM higher than outdoors $\Rightarrow$ implications for health and epidemiology
- Inadequately ventilated (bed)rooms can reach high CO_2 levels $\Rightarrow$ implications for health?

Importance of building design for indoor air quality as well as ventilation, temperature, moisture control…..

Thanks for your attention!

Acknowledgements

- Thanks to the home occupants for suffering the imposition!
- Otago University *He Kainga Oranga*, Sustainability Trust and Tu Kotahi Māori Asthma Trust for assistance with locating homes
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