Comparative Analysis of PM_{10}: Mairtown vs Robert Street, Whangārei Airshed

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Abbreviations / Glossary

Term	Meaning
AAQG	Ambient Air Quality Guidelines
Aerodynamic diameter	Particulate matters have irregular shape, and their behaviour in air is expressed in terms of the diameter of a spherical particle
Aerosol	Mixture of very small solid or liquid particles that can remain suspended in air from few minutes to many months depending on particle size and weight
Airshed	Also known as 'gazetted airshed.' Airshed is an 'air quality management area' (i.e. an area delineated by the regional council for the purposes of managing air quality)
Ambient air quality	General quality of the surrounding air, reflecting the cumulative effect of all activities, both anthropogenic and natural (this does not include air quality inside buildings)
Anthropogenic	Generated by human activities
BAM	Beta Attenuation Monitor
CO	Carbon Monoxide (an air pollutant)
Coarse particles	Particulate matter sized between 2.5µm ($PM_{2.5}$) and 10µm (PM_{10})
Fine particles	Particles less than 2.5µm in size ($PM_{2.5}$)
HAPINZ	Health and Air Pollution in New Zealand
IANZ	International Accreditation New Zealand
LAWA	Land Air Water Aotearoa (platform to share environmental data and information in New Zealand)
MfE	Ministry for the Environment
µm	Micrometre (one millionth of a metre)
MoH	Ministry of Health
NAAQG	National Ambient Air Quality Guidelines
NESAQ	National Environmental Standard for Air Quality
NIWA	National Institute of Water & Atmospheric Research
NRC	Northland Regional Council
NZTA	New Zealand Transport Authority
PCE	Parliamentary Commissioner for the Environment
PDP	Pattle Delamore Partners
PM	Particulate matter made up of various sizes
PM_{10}	Particulate matter less than 10µm in aerodynamic diameter
$PM_{2.5}$	A subset of PM_{10}, which is less than 2.5µm in aerodynamic diameter (also referred to as fine particulate)
RH	Relative Humidity
RMA	Resource Management Act
Sea salt	Particulate matter released to air through the action of wind and waves (also called marine aerosol)
Windblown dust	Particulate matter released from unsealed roads, construction sites, land use activities etc.
WHO	World Health Organisation
WSL	Watercare Services Limited

Executive Summary

Clear and clean air is essential for human health and the environment. Northland enjoys a high standard of air quality, thanks to the south-westerly wind, a relatively dispersed population, low vehicle density and few heavy industries. The quality of air we breathe is influenced by natural and human activities. The key issues affecting Northland's air quality are solid fuel burning for home heating, backyard burning, transport, industrial emissions, agrichemical application and dust from vehicles travelling on unsealed road or earthworks.

People with respiratory and heart disease, diabetes, the elderly, children, and pregnant women are more susceptible to the dangers of poor air quality. The World Health Organisation (WHO) 2021 estimates about seven million deaths annually are caused because of air pollution. Based on 2016 data, a Health and Air Pollution New Zealand study suggested that human-made air pollution causes around 98 premature deaths annually in Northland. The same report estimated the social cost from air pollution in Northland at $460 million each year.

Northland Regional Council (NRC) ensures that air quality in the region is maintained within the National Environmental Standards for Air Quality (NESAQ). To achieve compliance with the air quality standards, NRC adopted the Regional Plan for Northland (incorporating provisions for air, water, and soil resources) in part in 2023. The plan contains rules around activities that cause air pollution. NRC monitors compliance from discharge to air resource consents, investigates environmental incidents, and monitors the state of the region's air.

This report provides information on particulate matter monitoring conducted by NRC at its two air monitoring sites - Mairtown and Robert Street - in the Whangārei Airshed between August 2020 and October 2023.

Particulate Matter (PM_{10}) was continuously monitored using a beta attenuation monitor (BAM) at the Mairtown and Robert Street sites. Meteorological parameters were monitored at the Robert Street site using Vaisala. Particulate matter monitoring and meteorological monitoring methods comply with respective standards. This report assesses particulate monitoring results against the NESAQ and WHO 2021 guidelines.

Meteorological parameters temperature and humidity at the Robert Street site showed expected seasonal patterns. Temperature was high in summer and low in winter. Humidity showed the opposite effect, i.e. high in winter and low in summer. The windspeed and wind direction between 2021 and 2023 were found to be consistent, showing that most of the wind was coming from north and north-west with high frequency of low to moderate windspeeds. South-westerly wind was also consistent, and at a noticeably high windspeed compared to the north or north-west.

During the monitoring period, PM_{10} concentrations at both sites were compliant with both NESAQ and WHO guidelines, even though Mairtown PM_{10} concentrations were exceeded twice in 2022. One of the exceedances at Mairtown in 2022 was a result of vegetation burning near the monitoring site and was approved as an exceptional circumstance by the Minister for the Environment.

Comparison of PM_{10} monitoring data at the Mairtown and Robert Street sites indicated that the peak PM_{10} concentrations were somewhat higher at the residential Mairtown site, but overall, the two sites observed similar concentrations of particulate matter. Mairtown PM_{10} concentrations were found to be five percent higher than the Robert Street PM_{10} concentrations during the entire monitoring period and about seven percent higher during winter months.

PM_{10} concentrations at both sites peaked in the afternoon and again in the evening. Seasonal variation analysis showed distinct seasonal peak, with the highest concentrations recorded in the months of May, June, July, and August in Mairtown indicating that wood burners were the main source of PM_{10} at this site during winter. However, the same trend was not observed at Robert Street, which showed high concentrations in February, May, June, and July. The February peak was attributed to sea salt and windblown dust.

Correlation analysis between PM_{10} concentrations at Mairtown and Robert Street showed a strong to moderate relationship in 2021 and 2023 ($r^2 = 0.77$ & 0.67 respectively) and weak relationship in 2022 ($r^2 = 0.44$). The exception in 2022 was due to high concentration of PM_{10} because of exceptional circumstances on 25 May 2022 and one other exceedance on 19 June 2022. There was a moderate correlation of PM_{10} between sites ($r^2 = 0.55$) for the entire monitoring period.

Introduction

Ambient air quality is defined as the quality of surrounding air, reflecting the cumulative effect of human activities (industrial, commercial, domestic) and natural sources (MfE, 2009; Khanal & Naidu, 2022; NRC 2022). All living beings need air to survive and clean air is essential for the health of humans and the environment. Every day each person inhales about 14,000 litres of air (LAWA, 2021). Breathing clean air is fundamental to our wellbeing, allowing us to live healthy and active lives and many recreational, cultural, and economic activities are directly related to clean air and the sky (MfE, 2022; MfE, 2024). Breathing polluted air can adversely affect human health, increasing rates of cardiovascular and respiratory related hospitalisation (Barnett et al., 2006). The health effects of air pollution and public concern regarding the quality of air we breathe has started to increase in recent years as air pollution has become one of the leading environmental concerns in the world. In 2024, air pollution was identified as the second largest risk factor for early death globally, after high blood pressure (Health Effects Institute, 2024). The World Health Organisation estimates that about seven million deaths occur annually from breathing polluted air (WHO, 2021).

Air quality in Northland

Northland's air quality is dominated by the region's exposure to the prevailing south-westerly winds, which quickly disperses air pollutants. This, along with a relatively dispersed population, low vehicle density and sparse heavy industry means that Northland enjoys a high standard of natural air quality. However, a study based on 2016 data (Kuschel et al., 2022), suggested that anthropogenic air pollution caused about 98 premature deaths per year in Northland alone. It further estimated that the social cost from air pollution in Northland is approximately $460 million per year. Furthermore, Northland's air monitoring records suggested that on occasions pollutants approached or even exceeded the NESAQ. The NESAQ was established by the Ministry for the Environment (MfE) in 2004 to protect human health and the environment. These exceedances often occur under cool and calm conditions, during which air pollutants accumulate and increase to the levels that can be harmful to human health. Northland's air quality generally follows a seasonal trend, with the best air quality observed during the summer months and worst air quality in winter. Exceptions are dust, which is more of an issue during summer due to lower rainfall and PM_{10} in coastal locations such as the Marsden Point Airshed, the majority of which is sea salt. The key issues affecting air quality in Northland are:

- Solid fuel burning for home heating,
- Backyard burning,

- Agrichemical application,
- Transport and industrial emissions, and
- Dust from vehicles travelling on unsealed roads or other activities such as earthworks.

The Resource Management Act (RMA) 1991 requires Northland Regional Council (NRC) to manage air quality in Northland. There are five gazetted airsheds in Northland for air quality monitoring and management purposes:

- Kaitāia,
- Kerikeri,
- Whangārei,
- Marsden Point, and
- Dargaville.

Currently, NRC monitors particulate matter (PM) from its three permanent air monitoring stations in the Whangārei, Kaitāia and Dargaville airsheds. PM_{10} monitoring at the Kaitāia and Dargaville airsheds started in 2024. In addition, PM_{10} was monitored at the Marsden Point Airshed between 2013 and 2023.

In 2014, as an alternative to establishing permanent monitoring stations in unmonitored airsheds, NRC designed a trailer mounted Beta Attenuation Monitor (BAM) to measure PM_{10} that could be easily relocated from one airshed to another on an annual basis. NRC has monitored Kaitāia, Kerikeri, Dargaville, Kaikohe, and Kawakawa using this mobile monitor.

As part of the environmental monitoring network review, NRC engaged the National Institute of Water and Atmospheric Research (NIWA) to review council's historical and existing air monitoring and available modelling data for Northland and suggest a plan for particulate monitoring across Northland's five airsheds. In 2020 NIWA ranked Northland's five airsheds from potentially highest to lowest particulate concentrations in order of Whangārei, Kaitāia, Dargaville, Kerikeri and Marsden Point. NIWA recommended Mairtown or Whau Valley in the Whangārei Airshed would be a better location for particulate monitoring than the existing location at Robert Street. Monitoring at Mairtown to represent the Whangārei Airshed for particulate monitoring was also suggested by PDP (2022) along with Tikipunga South, Morningside, Sherwood Rise, and Grandfield Reserve.

As recommended by NIWA council relocated its mobile monitor to Mairtown, Whangārei. The initial plan was to monitor PM_{10} from Robert Street and Mairtown using a BAM for a reasonable period (at least two years) and compare results between the two sites before deciding to establish a permanent air monitoring station in Mairtown or any other places suggested by NIWA and PDP.

Objectives

The main objective of deploying an air monitor station at Mairtown was to check whether NRC's air monitoring station at Robert Street was a suitable compliance monitoring site for the Whangārei Airshed.

This report presents results of PM_{10} concentrations from Mairtown and Robert Street in the Whangārei Airshed between August 2020 and October 2023. The report compares PM_{10} concentrations between the two sites and assesses the results against the NESAQ and WHO 2021 guidelines. Based on results from both sites the report discusses whether it is appropriate to establish a new permanent air monitoring station in Mairtown as recommended by NIWA and PDP.

Particulate Matter (PM_{10})

Particulate matter is a collective term used to describe very small solid or liquid particles such as dust, fumes, smoke and mist or fog (Khanal, 2003; MfE & Stats NZ, 2021). Particulate matter with an aerodynamic diameter of less than 10 microns (µm) is referred as PM_{10} Figure 1.

Research has shown that PM_{10} are small enough to be inhaled. However, finer particles ($PM_{2.5}$) are a better indicator of health impacts across the population than PM_{10} (Khanal, 2003; PCE, 2015; MfE & Stat NZ, 2018; Zoran, 2020). PM_{10} and $PM_{2.5}$ originate from both natural sources (e.g., windblown dust, forest fires, sea salt), and anthropogenic sources (e.g., automobile exhaust, solid fuel burning) (Khanal, 2003; NRC, 2015).

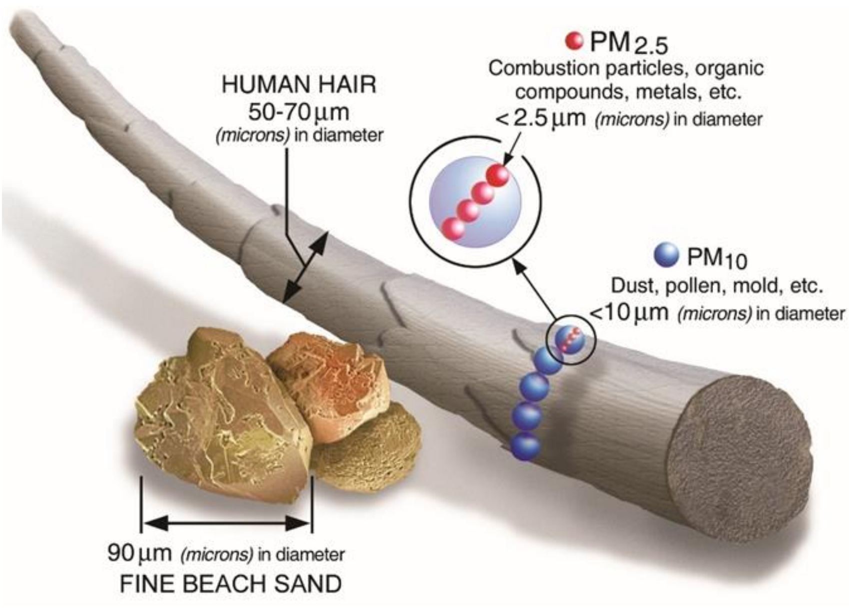

Figure 1 : Particulate matter 10 µm (PM_{10}) size (USEPA, 2024)

When inhaled, particulate matter can be deposited in various parts of human respiratory system Figure). Coarse particles (also called thoracic particulates) 2.5 to 10 micron in diameter deposit mainly in the upper airways and $PM_{2.5}$ deposit in the lower respiratory tract in small airways and alveoli (Zoran, 2020).

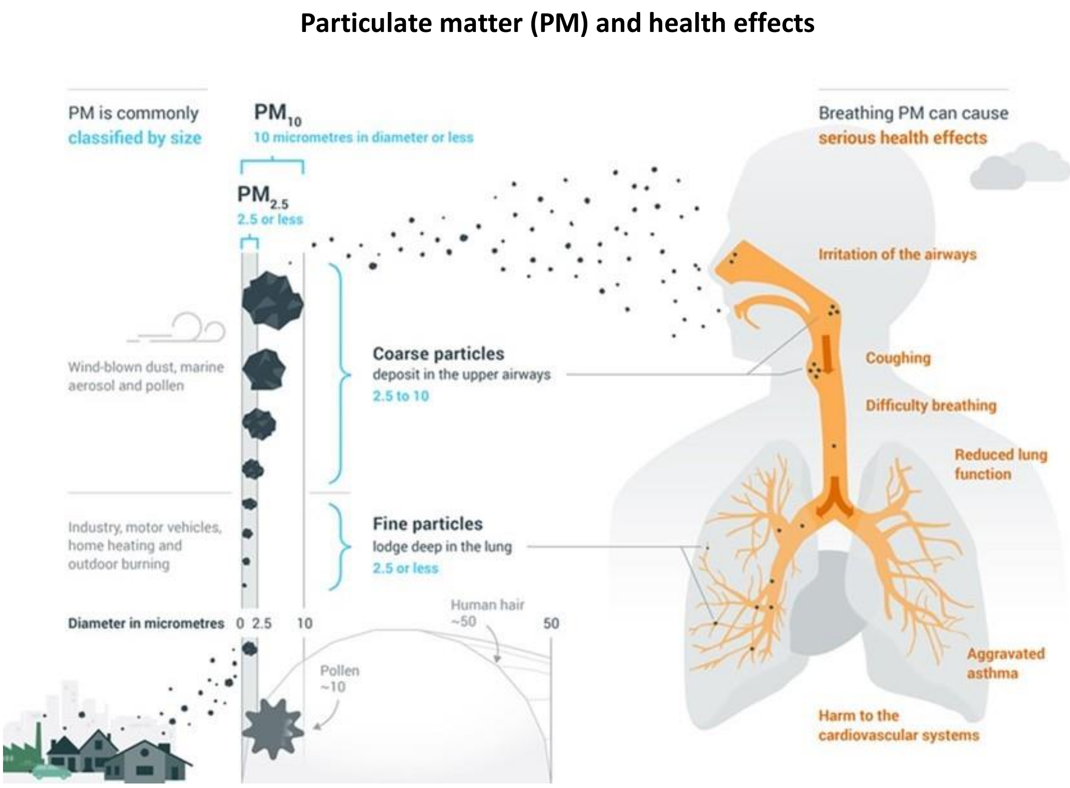

Figure 2: Deposition of particulate matter in different size fraction on the respiratory tract (http://ecan.govt.nz)

Symptoms of exposure to particulate matter at less severe levels start from shortness of breath, coughing, chest pain etc., but at severe levels this can lead to heart attack, stroke, and premature deaths (Khanal, 2003; Beer, 2010; MfE & Stats NZ, 2021; WHO, 2021; Boamponsem, 2022). Recent epidemiological studies have linked air pollution, especially $PM_{2.5}$, to dementia and other brain disorders (Cory-Slechta, et al 2023 & Nature, 2025).

Elderly people with existing respiratory disease such as asthma, chronic obstructive pulmonary disease, and bronchitis, those with cardiovascular disease, those with infections such as pneumonia and children are most susceptible to impacts of the particulate matter (Beer, 2010; MfE & Stats NZ, 2021; Boamponsem, 2022). Particulate matter exposure increases mortality, hospital admissions and emergency department visits (Kuschel, et al 2022).

In the Whangārei Airshed, domestic wood burning contributes 45% and 54% to the annual emissions of PM_{10} and $PM_{2.5}$, respectively (PDP, 2021). However, contribution from domestic wood burning increases to 71% and 78% of PM_{10} and $PM_{2.5}$ respectively during winter months (PDP, 2021; Bluett et al., 2022).

Transport is the second largest contributor of PM_{10} and $PM_{2.5}$ in Whangārei followed by industrial emissions and backyard burning. During other seasons, emissions from motor vehicles, crustal matter and marine aerosol were primary sources (Davy et al., 2014) and a noticeable contribution of sea salt to PM_{10} collected from Water Street, central Whangārei, was also found.

Methodology

Monitoring Method

PM_{10} was monitored using Beta Attenuation Monitors (BAM) model Thermo FH62 at both sites. The instrument continuously draws ambient air (16.7 litres per minute) into a 10-micron size selective inlet which separates particles with an aerodynamic diameter above and below 10 µm. The ambient PM is then drawn down onto a heated sample tube to reduce moisture in particulate matter and reduce the relative humidity. Ambient PM_{10} from the sampling tube gets deposited on a glass fibre filter tape, which is located between the detector and a beta source. Beta beams pass through the filter tape and the deposited PM_{10}. As the mass of PM_{10} increases on the filter tape, the beta count is reduced. The relationship between the decrease in beta count and particulate mass is computed and a continuous “real time” concentration ($\mu g/m^3$) of particulate is measured. The measured concentration is then used to calculate 24-hour averages, in accordance with MfE’s NESAQ guidelines. The PM_{10} concentration is calculated to standard temperature ($0^{\circ}C$) and pressure (1 atmosphere). BAM operates with a full-scale measurement range of 0 to 10,000 $\mu g/m^3$.

Watercare Services Limited (WSL) manages NRC’s air quality instrument maintenance, calibrations, and data management. They use Envitech Conserve for downloading data at 10-minute intervals, and Envista Air Resource Manager as their data management and reporting tool. All monitoring data is stored and processed in accordance with MfE’s Good Practice Guide (MfE, 2009b).

Averages (10-minute intervals) of PM_{10} are aggregated to hourly averages where there is at least 75% data capture. Daily averages are calculated every 24 hours at midnight for the preceding 24 hours (00:10 to 24:00 hours) and require at least 18 hours of data for each 24-hour period to be included in the dataset. PM_{10} values are rounded up to the nearest whole number for reporting purposes as per the MfE Good Practice Guide.

NRC's monitoring methods, pollutants and instrument details are described in Table 1.

Table 1: Methods for sampling and analysis of ambient air

Pollutant	Standard	Details	Instrument
PM_{10}	AS/NZS 3580.9.11 - 2016	Determination of suspended particulate matter - PM_{10} beta attenuation monitors	BAM FH62
Meteorology	AS 3580.14 – 2014	Meteorology monitoring for ambient air quality monitoring applications	Vaisala
Siting	AS/NZS 3580.1.1 - 2016	Guide to siting air monitoring equipment	

The majority of graphs presented in this report are produced using Microsoft Excel and some using the Openair R package. Hilltop Hydro was used to produce monthly and daily averages of data.

Monitoring Site Locations

Whangārei Airshed

Whangārei is the largest urban centre in the Northland region. The Whangārei Airshed covers an area of about 62 km^2 (covering most of Whangārei city), which has a population of 56,800 as of June 2024 (StatsNZ, 2024). Whangārei has the highest density of wood burners in use in Northland (NIWA, 2020) and has the highest traffic counts from the NZTA counters in Northland (NZTA, 2020).

Robert Street

NRC is operating a long-term ambient monitoring station in central Whangārei within a commercial area at 88 Robert Street. The site currently measures PM_{10}, $PM_{2.5}$, and meteorology, and has been in operation since the late 1990s.

Mairtown

NRC established a second temporary ambient air monitoring site in Mairtown at 31 Princes Street in August 2020 in order to provide monitoring data to assess the effects of domestic wood burners in the winter and compare results obtained between the two sites (Robert Street and Mairtown). NRC's mobile BAM was used at this site. Site metadata for the Robert Street and Mairtown sites is presented in Appendix 1 and 2. The location of both sites is shown in Figure 3.

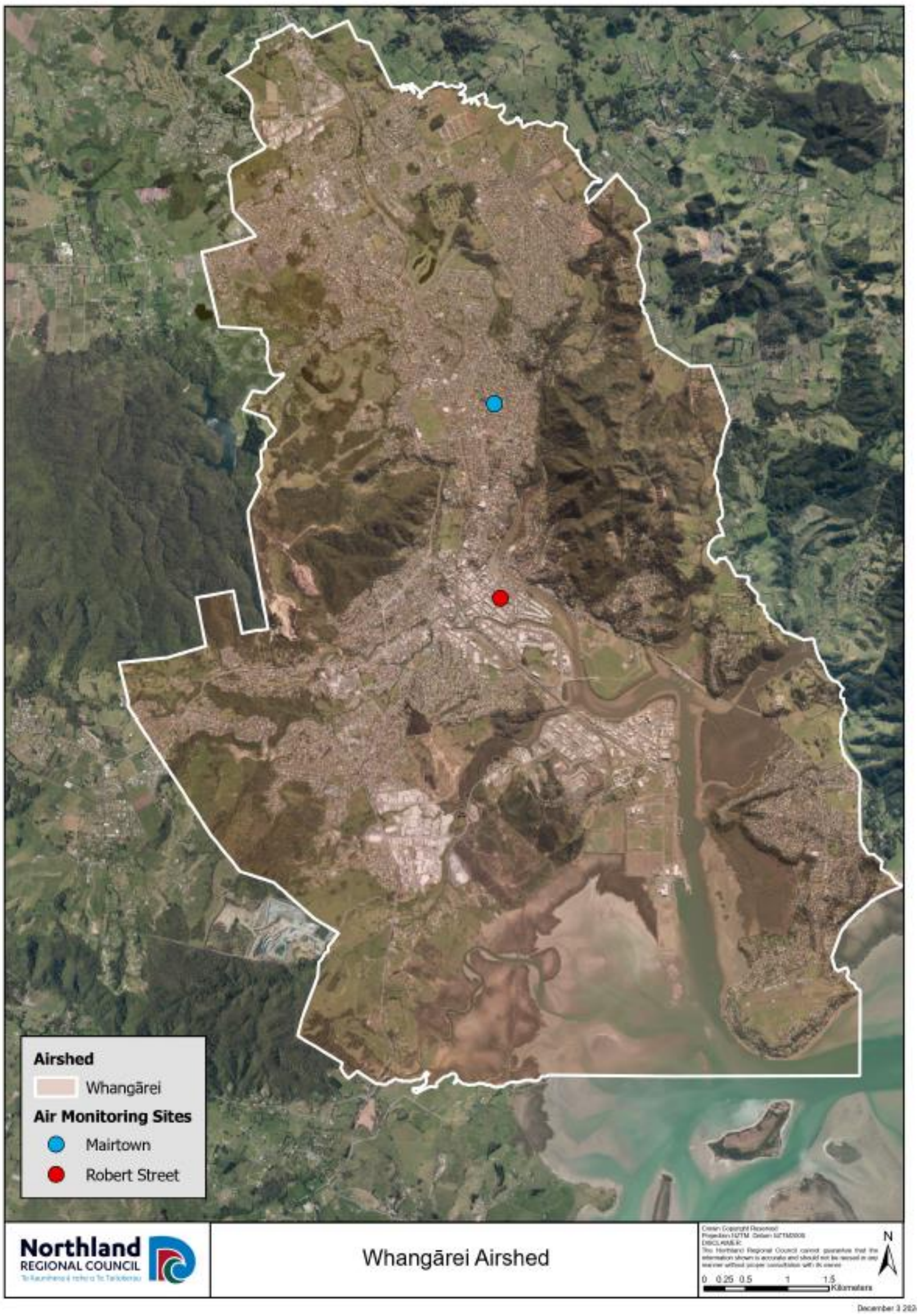

Figure 3 : Whangārei Airshed showing two monitoring sites

Results and Discussion

Robert Street

Meteorological monitoring

It is useful to collect meteorological data along with air pollutants as air quality and meteorological parameters are closely linked. Meteorological parameters such as temperature, windspeed, wind direction, and relative humidity play a vital role in pollutant formation, transportation, dispersion, and chemical reactions between air pollutants (Habeebullah et al., 2014). Air pollutant concentrations show typical diurnal, weekly, seasonal, and annual cycles because of change in meteorological conditions and emission sources over the period.

Both meteorological parameters and PM_{10} were monitored at Robert Street, but only PM_{10} was monitored at Mairtown. However, meteorological data from Robert Street was used to produce pollution rose graphs for Mairtown, believing that the meteorological parameters would not differ much between the two sites. It is well understood that this was not going to be an accurate prediction but would be useful to get a rough idea on possible source areas of PM_{10} at both sites.

Ambient temperature

Monthly ambient temperature records from Robert Street (2021 - 2023) followed an expected seasonal pattern of temperature variation as shown in Figure 4.

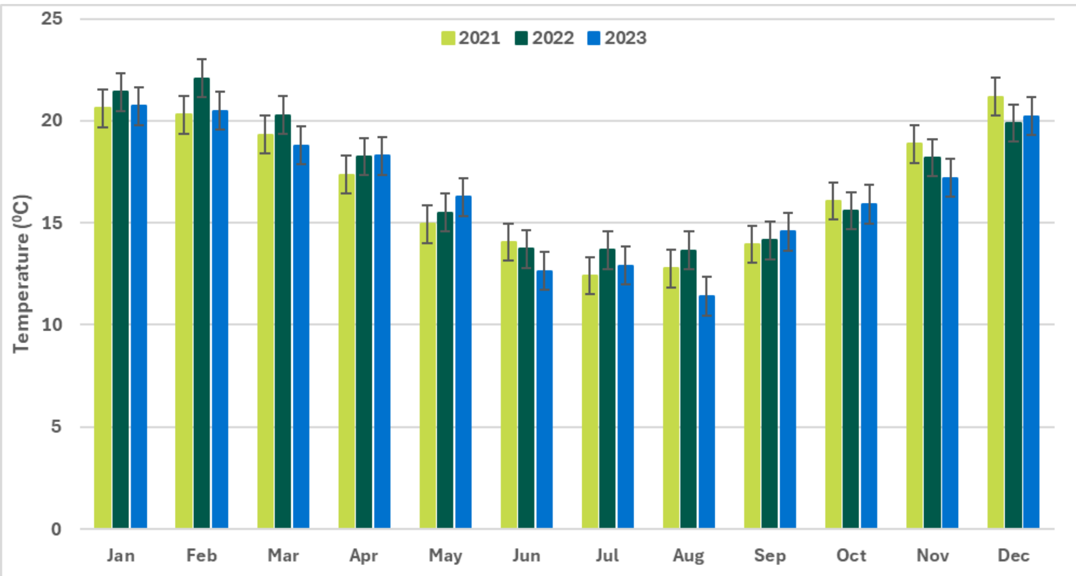

Figure 4: Monthly average ambient temperature at Robert Street (2021 – 2023)

The temperature is higher in summer months (December, January, and February) and lower in winter months (June, July, and August). Error bars shown are standard errors of monthly averages. Annual average temperature increased to 17.2˚C (±3.19) in 2022 from 16.8˚C (±3.19) in 2021 and slightly decreased to 16.6˚C (±3.22) in 2023.

Relative Humidity (RH)

Monthly relative humidity at Robert Street followed an expected seasonal pattern for each year (2021 – 2023) - higher in winter months and lower in summer months as per Figure 5.

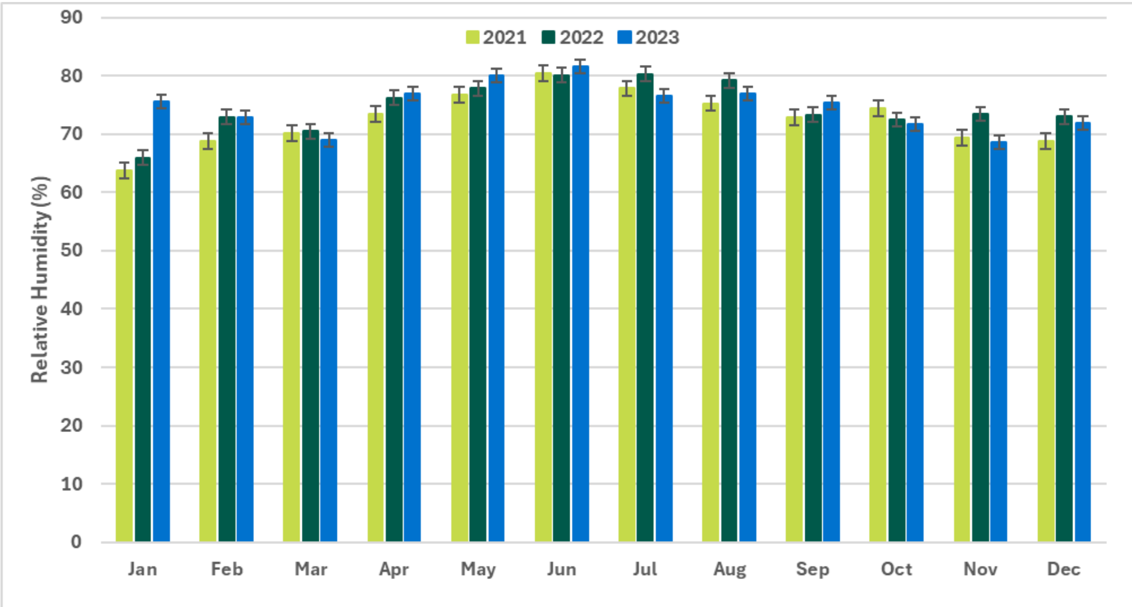

Figure 5: Monthly averages of relative humidity at Robert Street

Annual average RH ranged from 72.6% (± 4.6) to 74.74% (± 4.06), showing an increase of 2.9% from 2021 to 2023.

Windspeed and wind direction

Windspeed plays a vital role in accumulation or dispersal of air pollutants. Similarly, wind direction is useful in understanding which direction air pollutants are originating from at each monitoring station. The relative frequency and speed of winds from different directions for 2021 to 2023 is shown in Figure 6.

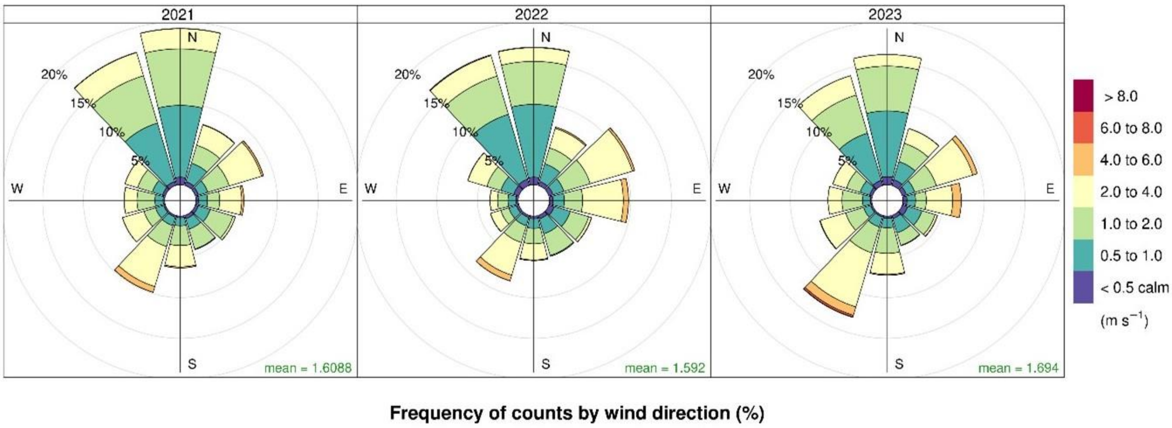

Figure 6: Wind rose showing wind direction and windspeed at Robert Street (2021 - 2023)

The windspeed and wind direction between 2021 and 2023 were consistent, showing that most of the wind was coming from north and north-west with high frequency of low to moderate windspeeds. South-westerly wind was also consistent over this time, and it is noticeable that high windspeed is from the south-west compared to the north or north-west. The average windspeed shows consistency between years.

Particulate Matter (PM_{10})

Hourly PM_{10}

There is no hourly standard for PM_{10} in New Zealand, therefore, this report is using MfE suggested trigger levels of 150 µg/m^3 for PM_{10} from dusty sources (MfE, 2016; Metcalfe & Wickham, 2019). The main purpose of hourly threshold of PM_{10} is to manage dusty environments on time and to avoid exceedance of longer time-averages (Metcalfe & Wickham, 2019). The hourly box plots of PM_{10} at Robert Street and Mairtown during the monitoring period are presented in Figure 7 below.

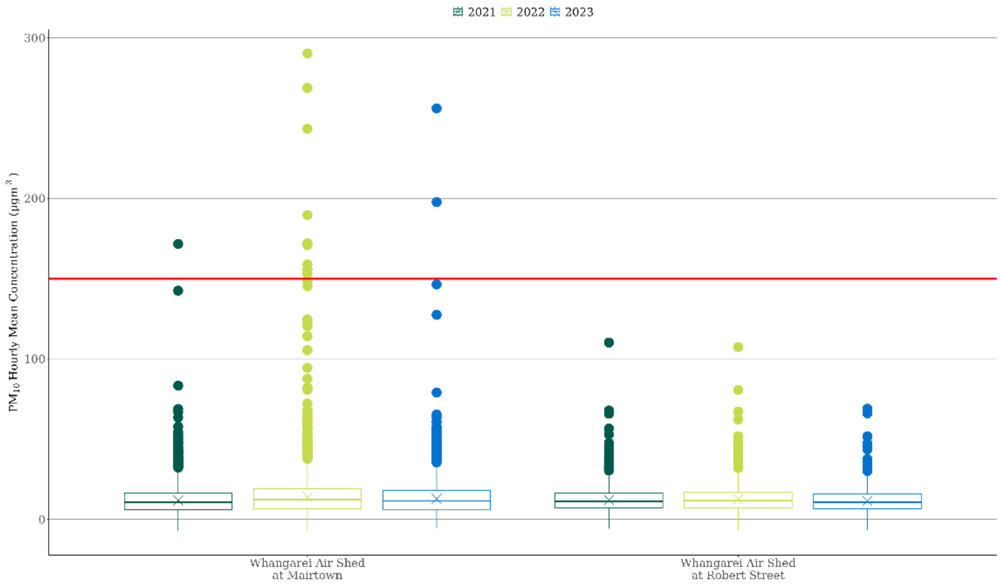

Figure 7: Box plots of hourly PM_{10} concentration at Robert Street) and Mairtown (2021-2023)

In box plots, boxes represent the 25th (bottom of the box) and 75th (top of the box) percentile, central line through the box is the median, bars outside the box (whiskers) represent the 1.5x interquartile range, and x markers are the means, and circles are outliers (Boamponsem, 2022).

The hourly averages of PM_{10} concentration are higher than MfE's trigger level on several occasions, especially at Mairtown, but it is important to note that hourly spikes are normal and could be influenced by a short-lived source near the monitoring station. Figure 7 and Table 2 clearly show that hourly and daily concentrations, including mean, median, lower, and upper percentiles at Mairtown are higher than the Robert Street concentrations.

Table 2: Summary statistics of daily PM_{10} concentrations (µg/m^3) at Mairtown and Robert Street

Year	2021		2022		2023	
Site	Mairtown	Robert Street	Mairtown	Robert Street	Mairtown	Robert Street
Annual mean	12	12	14	13	13	12
Maximum	26	24	81	29	33	25
Minimum	2	3	4	3	3	4
Median	11	11	13	12	12	11
Std deviation	3.94	3.83	6.21	4.22	4.78	4.11
99th percentile	22.68	22.89	37.26	27.31	25.25	23.19
75th percentile	13.91	14.25	16.09	14.83	16.01	13.73
25th percentile	9.08	9.44	10.68	10.09	9.97	8.70
No. > 50 (µg/m^3)	0	0	2*	0	0	0
Data capture %	99.72	96.16	96.71	99.45	77.85	99.66

**One exceedance was approved as an exceptional circumstance and one exceedance is permitted in a 12-month period*

Daily PM_{10}

Daily PM_{10} concentrations measured at Mairtown and Robert Street between 2021 and 2023 is presented in Table 2 and daily PM_{10} concentrations are shown in Figure 8 below.

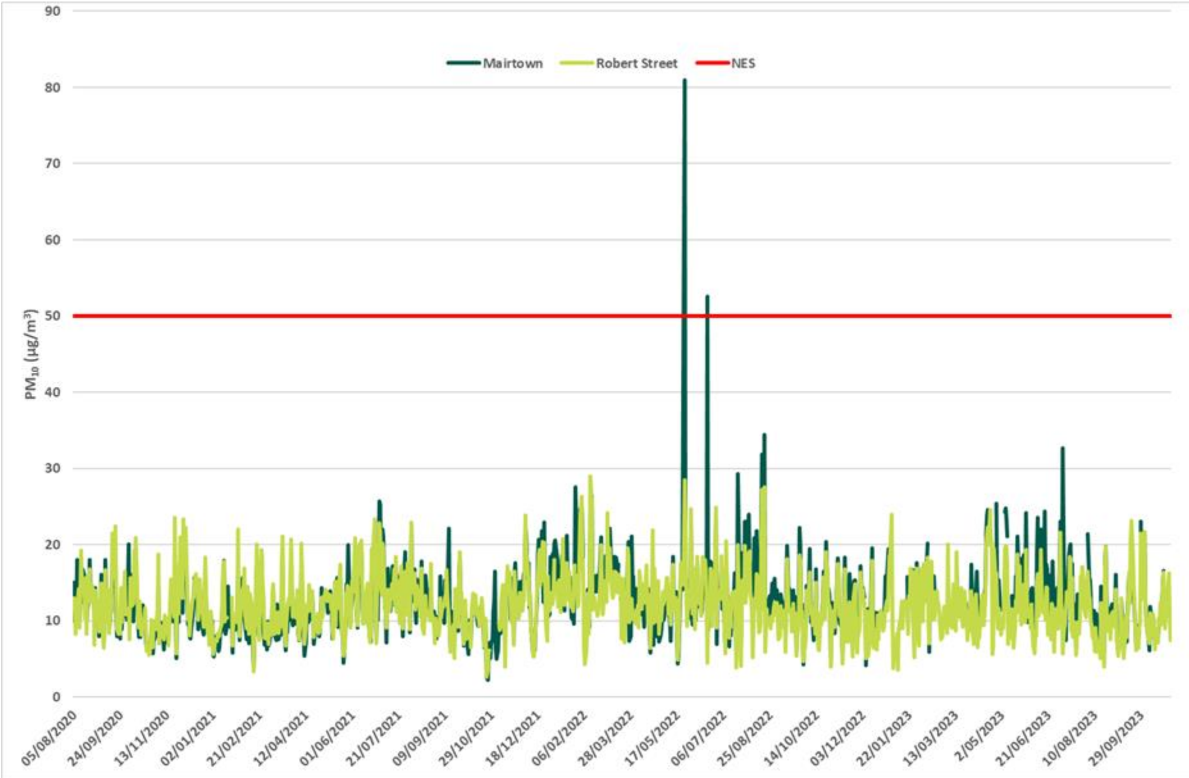

Figure 8: Daily PM_{10} concentration at Mairtown and Robert Street (2021 – 2023)

Results presented in Table 2 and Figure 8 confirm compliance with the NESAQ at both sites. However, in 2022 Mairtown PM_{10} concentrations exceeded NESAQ on two occasions. PM_{10} exceedance on 25 May 2022 was attributed to a large vegetation fire at Paranui Valley Road between 24 and 26 May 2022 (shown in cover photo). PM_{10} concentration was found to be elevated on that day at Robert Street as well but was within the NESAQ level (50 µg/m^3). NRC made an application to the Minister for Environment under NESAQ Regulation 16A to consider that the exceedance on 25 May 2022 was an Exceptional Circumstance. The Minister agreed with the evidence provided that the PM_{10} concentration on 25 May 2022 was caused by exceptional circumstances and approved the application. This approval avoided the Whangārei Airshed being classed as a “polluted airshed.” The Ministry’s approval letter is provided as Appendix 3.

The second exceedance of daily PM_{10} concentration at Mairtown was recorded on 19 June 2022 (53 µg/m^3). On that day PM_{10} concentrations significantly peaked in the early hours of morning with stable concentration in the afternoon as shown in Figure 9.

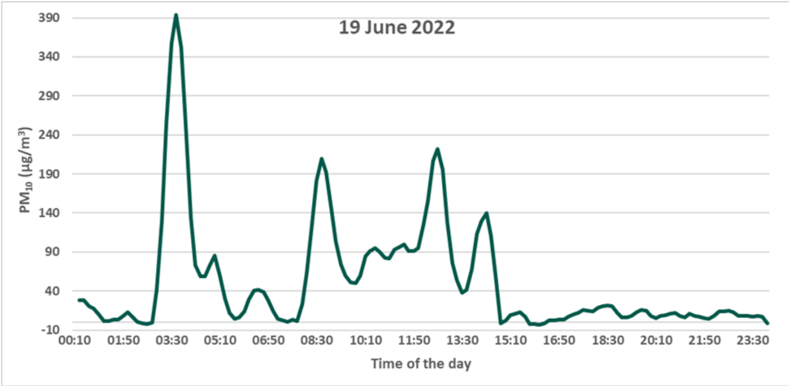

Figure 9: Continuous PM₁₀ concentration on 19 June 2022, the day second highest PM₁₀ concentration was recorded at Mairtown

Robert Street meteorological data showed that wind was flowing from the south and southeast for most of the day. The daily average temperature was recorded at 15˚C, a warm day for winter, and windspeed was recorded lower than expected for that time of the year at 1m/s. Low windspeed provides perfect conditions for air pollutants to accumulate and increase the overall concentration (Caldwell, 2019; MfE & Stats NZ, 2021). PM_{10} concentrations at Robert Street on 19 June 2022 were only 4µg/m^3, which indicates that the Mairtown concentration was affected by a local source.

To investigate the high concentration of PM_{10} on 19 June 2022 further, pollution roses are useful. In this case we used Robert Street meteorological data to produce pollution roses for both sites and these are shown in Figure 10.

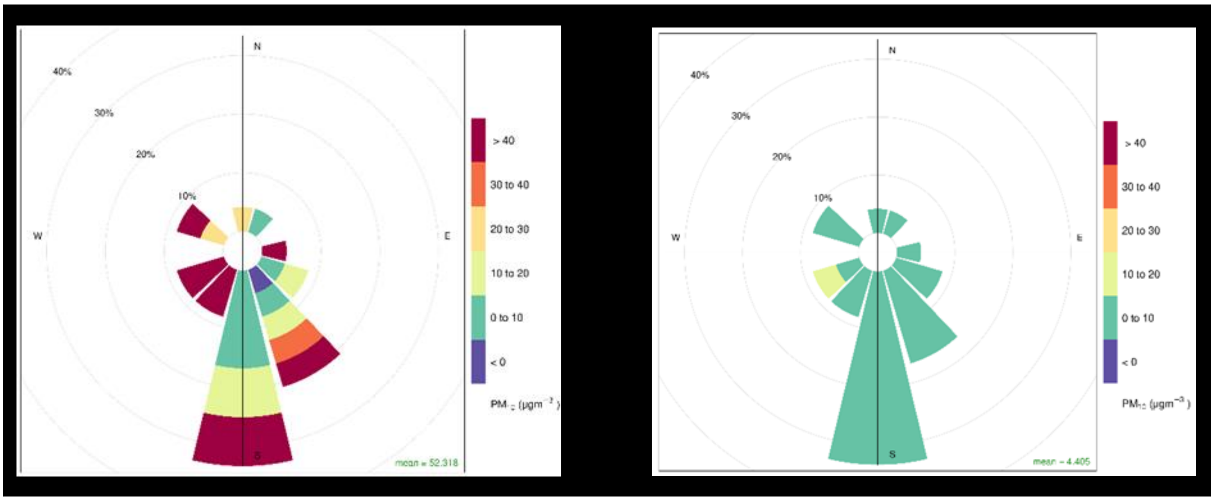

Figure 10: Pollution roses for Mairtown (left) and Robert Street (right) on 19 June 2022

Figure 10 shows that high PM_{10} concentrations were recorded when wind was blowing from the south and south-east. High concentrations were also recorded from south-west and north-westerly winds. Low concentrations were recorded when the wind was from the north, north-east and majority of north-west. The pollution rose for Robert Street showed similarities in wind directions, but PM_{10} concentrations recorded were significantly lower than Mairtown. This confirms that the source of PM_{10} at Mairtown on 19 June 2022 was near the monitor and was somewhere north or north-west from Robert Street.

Diurnal and seasonal variations

Diurnal variations of PM_{10} at both sites during the whole monitoring period and during winter only are presented in Figure 11 and Figure 12, respectively.

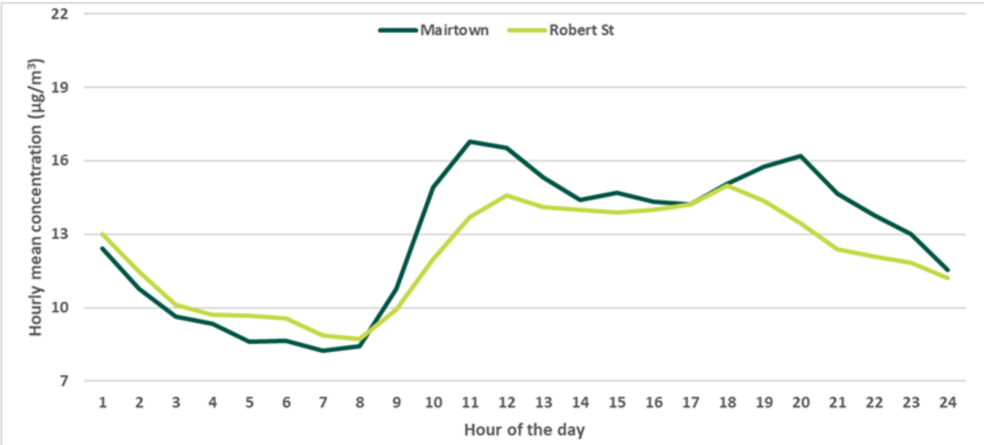

Figure 11: Variation in hourly PM_{10} concentration at Mairtown and Robert Street

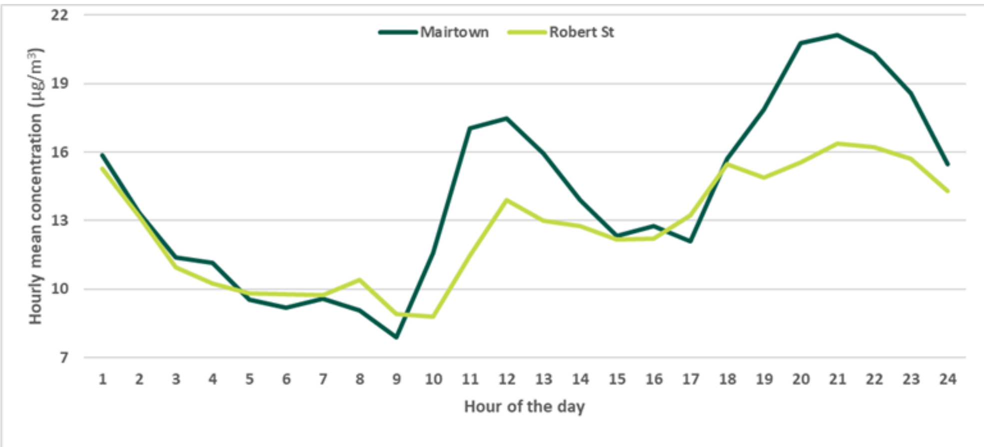

Figure 12: Winter variation in hourly PM_{10} concentration at Mairtown and Robert Street

Both figures have two peaks, one around midday and a similar peak in the evening. However, the evening peak during winter is higher than the midday peak. Overall diurnal peaks show PM_{10} concentrations start to increase just before midday and then again around 1800 hours. Winter peaks stayed for a longer period in the evening. This is a typical trend found in New Zealand towns where solid fuel burning for home heating is the primary source of particulate matter during winter months. Another reason for higher evening peaks is a more stable atmosphere in the evening than in the afternoon. Secondary peaks between 1100 and 1400 hours are mainly attributed to daytime human activities such as vehicle, industries, and backyard burning, among others. Similar observations were made by Boamponsem (2022) and LAWA (2021).

Figures 11 and 12 show that PM_{10} concentrations in Mairtown were higher than Robert Street during most hours of the day. Higher evening peaks during winter at Mairtown over Robert Street suggested that the Mairtown area had a higher density of wood burners than the Robert Street site as previously estimated and suggested (NIWA, 2020; PDP, 2021; Wilton, 2007).

Monthly averages are useful to understand seasonal variations in PM_{10} concentrations. Monitoring results show increase in PM_{10} in May, June, July, and August (Figure 13) at Mairtown, whereas the PM_{10} concentrations at Robert Street only showed a slight increase during winter.

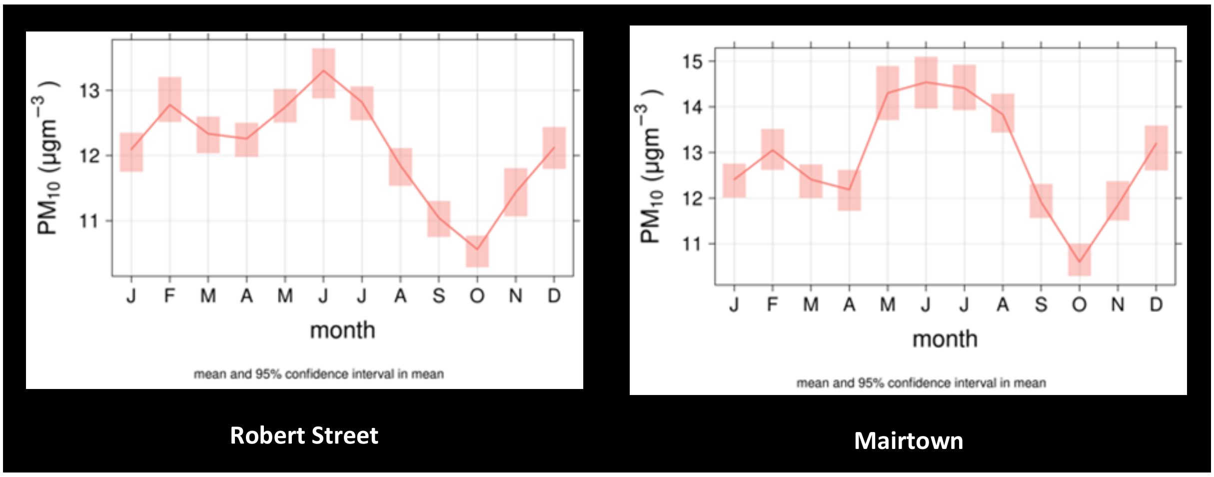

Figure 13 : Monthly variation in PM_{10} concentration at Mairtown and Robert Street

Winter increases are likely caused by emissions from domestic home heating. However, PM_{10} concentration during summer months suggested non-domestic heating sources of PM_{10}, and it was believed to be from natural sources such as sea salt and windblown dust (Davy et al., 2014) as the Robert Street monitoring station is located a few hundred meters from Whangārei town basin marina.

Diurnal and monthly variations explained in the above paragraphs are further broken down into seasonal level and presented in Figure 14 and 15. These Figures suggest similar patterns between two sites. However, difference between winter and summer peak is high at the Mairtown site. The lowest concentrations were recorded in spring at both sites similar results were reported by Khanal & Naidu (2022).

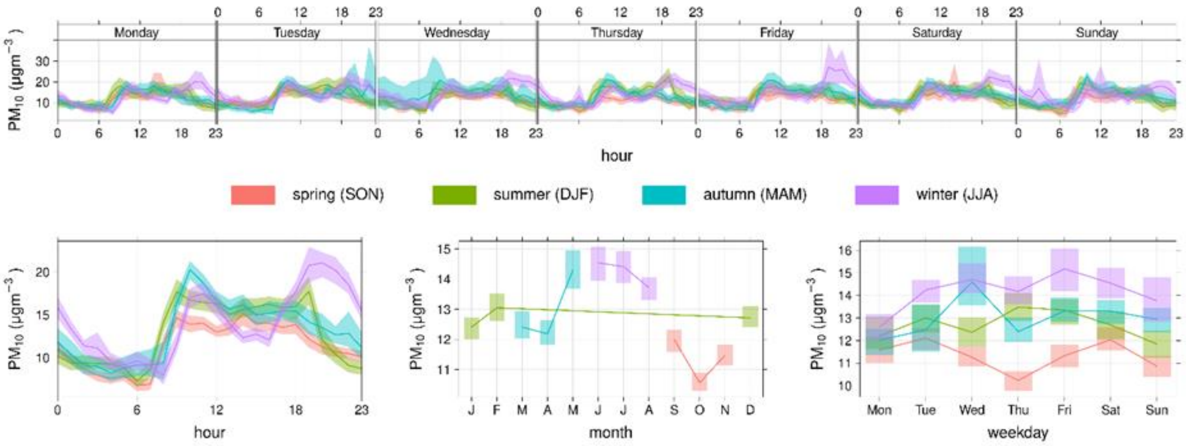

Figure 14: PM_{10} time variation plots for Mairtown

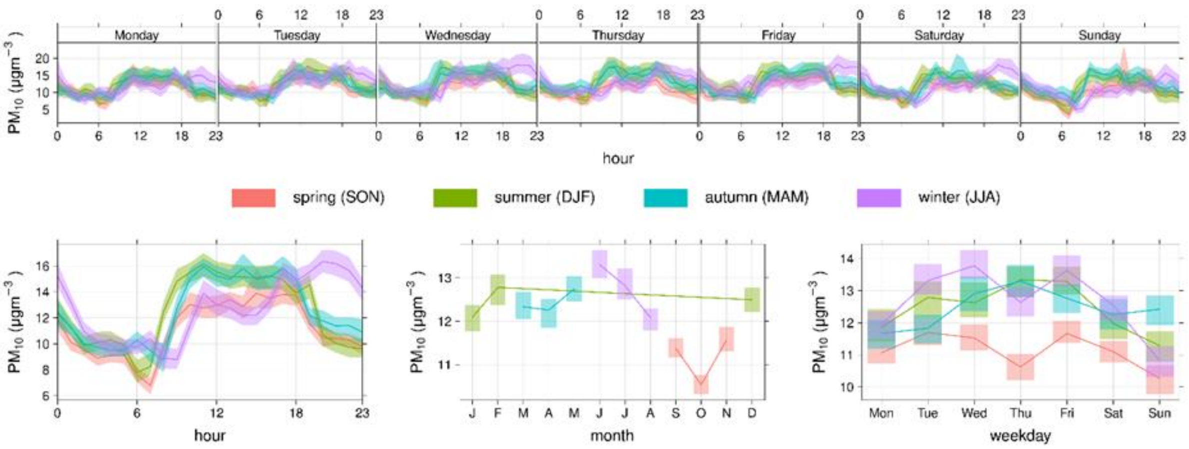

Figure 15 : PM_{10} time variation plots for Robert Street

Figures 14 and 15 show PM_{10} concentrations during different season by hour and day of the week, hour of the day, month of the year and day of the week. Shaded area shows the 95% confidence intervals for the means. PM_{10} concentrations at both sites on weekends were lower than the weekdays while workday concentrations were higher due to increased traffic and industrial emissions. Diurnal peaks during winter were distinct from other seasons in the evening, however, the winter midday peak was smaller than autumn and summer peaks at both sites. Detailed individual graphs of Figures 14 and 15 is given in Appendix 4 & 5, respectively.

PM_{10} Pollution roses

Meteorological conditions such as windspeed and wind direction influence the concentration of air pollutants (Habeebullah et al., 2014). Pollution roses are useful tools to show emission sources of pollutants and dependence of pollutants on windspeed and wind direction. As expected, PM_{10} concentrations were highest in winter, followed by autumn, summer and the lowest in spring (Figure 16 and 17) at both sites. However, the difference between seasons was smaller at Robert Street than the difference observed at Mairtown. Seasonal PM_{10} concentrations were higher at Mairtown than Robert Street in all seasons (Figure 17).

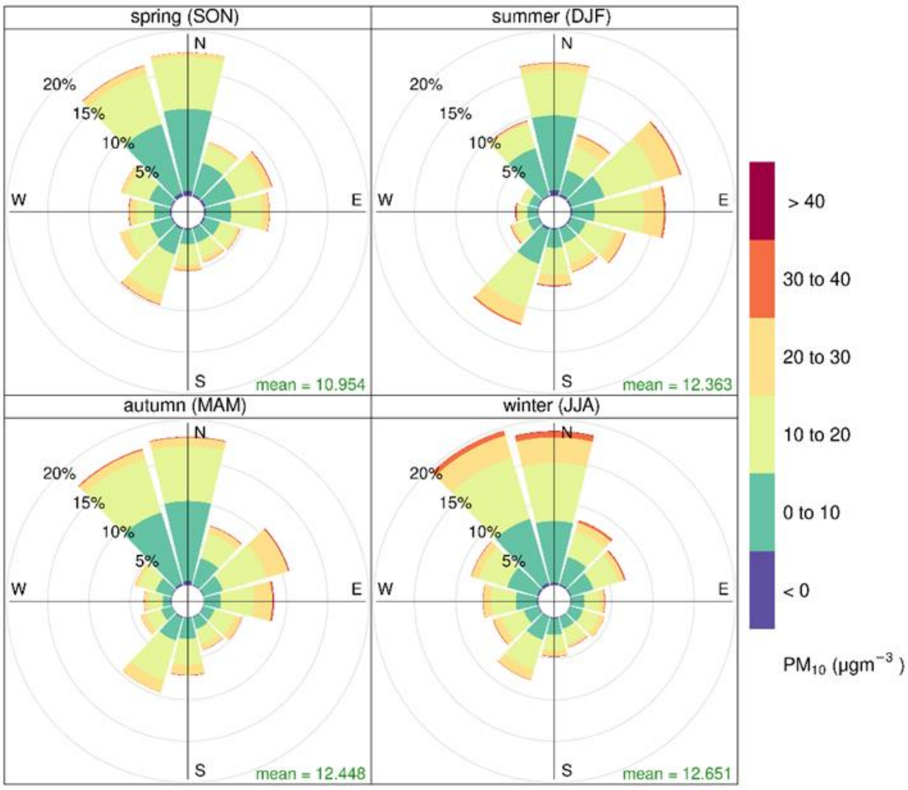

Figure 16: Seasonal PM_{10} pollution roses for Robert Street

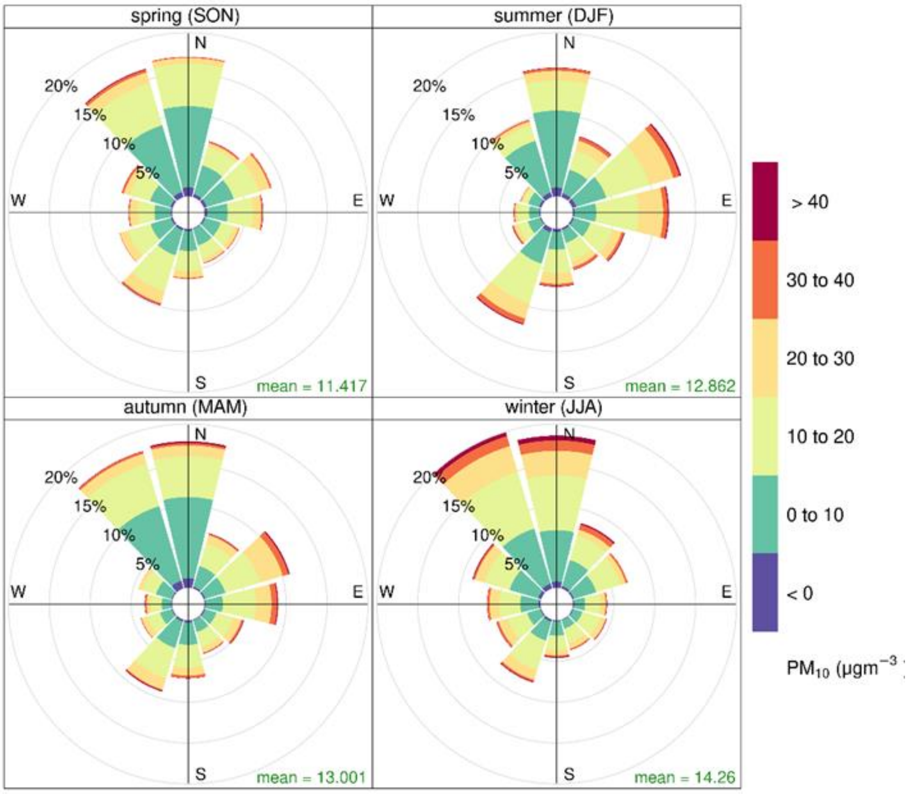

Figure 17: Seasonal PM_{10} pollution roses for Mairtown

The highest PM_{10} concentrations at both stations were mainly sourced from north and north-west in all seasons except summer, which was dominated by north and north-east winds when concentrations were high.

Relationship between Mairtown and Robert Street results

Correlation analysis between two sets of data is the best way to check whether the results have any relationship. Correlation value indicates how one variable tends to change when another variable changes. The relationship between PM_{10} concentrations at Mairtown and Robert Street is shown by scatterplots presented in Figure 18.

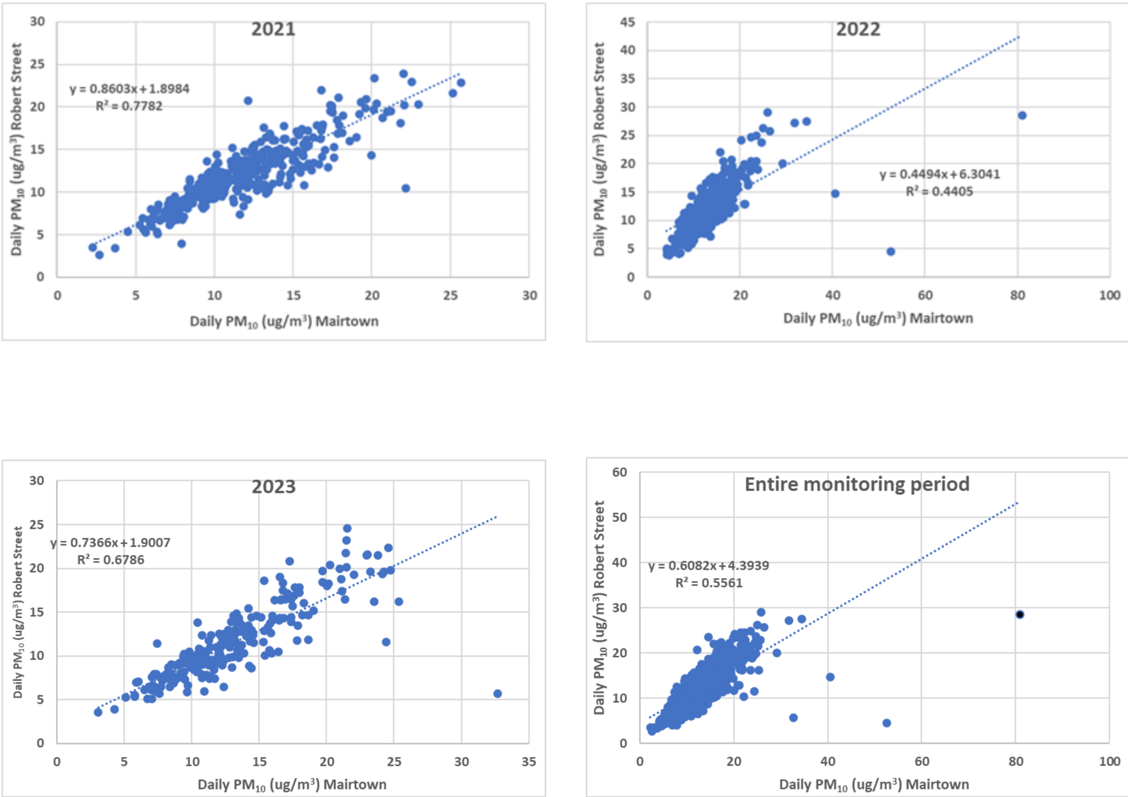

Figure 18: Relationship between daily average PM_{10} concentration between Mairtown and Robert Street

The plots are divided as overall plot and annual plots. Correlation values in Figure 18 show a strong to moderate relationship between sites in 2021 and 2023 (r^2 = 0.77 and 0.67 respectively) and a weak relationship in 2022 (r^2 = 0.44). The exception in 2022 was due to high concentrations of PM_{10} because of exceptional circumstances and one other exceedance at the Mairtown. There was a moderate correlation (r^2 = 0.55) for the entire monitoring period.

Conclusions

Northland Regional Council is responsible for managing air quality in the region under the RMA 1991. This report included comparative analysis of PM_{10} monitoring results between the Mairtown and Robert Street sites in order to understand whether NRC's long term air monitoring station is the right location for air monitoring under the NESAQ. Mairtown monitoring was established as recommended by NIWA (2020) and supported by PDP (2022). This report assessed results against NESAQ and WHO guidelines.

Key findings

- PM_{10} concentrations at both sites were compliant with NESAQ.
- Mairtown PM_{10} concentrations exceeded both NESAQ and WHO guidelines twice in 2022.
- One of the exceedances at Mairtown was a result of vegetation burning near the monitoring site and was approved as an exceptional circumstance by the Minister for the Environment.
- Comparison of PM_{10} monitoring data at the Mairtown and Robert Street sites indicated that the peak PM_{10} concentrations were somewhat higher at the Mairtown site, but overall, the two sites observed similar concentrations of particulate matter.
- Mairtown PM_{10} concentrations were found to be five percent higher than the Robert Street PM_{10} concentrations during the entire monitoring period and about seven percent higher during the winter months.

Seasonal and diurnal patterns

- PM_{10} concentrations at both sites peaked in the afternoon and again in the evening.
- PM_{10} concentrations at both sites increased from Wednesday and Friday.
- Seasonal variation analysis showed distinct seasonal peaks, with the highest concentrations recorded in the months of May, June, July, and August in Mairtown. However, the same trend was not observed at Robert Street, which showed high concentrations in February, May, June, and July.

Correlation analysis

- Correlation analysis between PM_{10} concentrations at the Mairtown and Robert Street sites shows a strong to moderate relationship.

Recommendations

Mairtown monitoring was established as per the recommendation by NIWA 2020. Following the NIWA report NRC engaged PDP to conduct an air dispersion model for the Whangārei Airshed. The model predicted relatively high concentrations of both PM_{10} and $PM_{2.5}$ at Tikipunga South, Morningside, Glenfield Reserve, Mairtown and Sherwood Rise. The difference in predicted concentrations of PM_{10} and $PM_{2.5}$ for each of these locations was not significant. The reason PDP suggested Mairtown as a suitable air monitoring site was because NRC had already started monitoring at that site. Otherwise, any of the sites recommended were equally suitable.

Comparative analysis of three years of PM_{10} monitoring data found that PM_{10} concentrations at Mairtown were higher than Robert Street by seven percent during winter, which is less than the 20 percent uncertainty of PDP model predictions. NRC also conducted PM_{10} monitoring at Tikipunga South using an environmental beta attenuation monitor (EBAM) in winter 2023. PM_{10} concentrations at the Tikipunga site were less than the concentrations of PM_{10} at Mairtown. During winter, low windspeed occurred with similar frequency from all directions, suggesting that a centrally located monitoring site would be more frequently impacted by high particulate concentrations than a site located more towards one end of the airshed boundary.

After the completion of the Environmental Monitoring Network Review in 2021, efforts were made to find a suitable air monitoring site within the Mairtown area, but NRC were unable to find a site that met the requirements of AS/NZS 3580.1.1:2007 Part 1.1 Guide to Sitting Air Monitoring Equipment. The search continued, along with nearby areas. There is no public space in Mairtown and it is not appropriate to establish a permanent monitoring station on private property. A couple of businesses in the area were contacted, but a positive response was not received.

On the other hand, the Robert Street monitoring site was established in the late 1990s. The site was selected due to convenience such as security, power supply etc. as it was the council office premise. Continuous PM_{10} monitoring started in 2006. Should NRC relocate this monitoring station to Mairtown or any other areas suggested, continuity of long-term air monitoring for the Whangārei Airshed would be lost. Data analysis such as trend analysis for the airshed would not be possible using data from old and new sites. A new monitoring location would begin a new era of air monitoring for the airshed.

The current monitoring site is in an area of low density of wood burners, but close to traffic, commercial and some industrial emission sources. Monitoring at Mairtown or Whau Valley will cover emission from wood burners and traffic. In terms of finding a perfect air monitoring site as per the NESAQ, Whangārei is a challenging airshed. The airshed could be divided into four to five different air catchment areas, e.g.:

- area south of Morningside Hill;
- City Centre;
- North of Regent up to Kamo East;
- Kamo West ; and
- Three Mile Bush and Springs Flat.

These areas have different source types and have the potential to have elevate particulate concentrations. The Robert Street site is just as suitable for monitoring as the site is not far from residential areas such as Avenues and Morningside to capture emissions from wood burners and has a high density of traffic and commercial emissions.

Therefore, it would be wise to run a screen monitoring campaign involving a network of low-cost sensors to determine a perfect monitoring site for the Whangārei Airshed. Until that time, monitoring from the existing site at Robert Street is recommended.

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Appendices

Appendix 1: Whangārei Airshed ambient air monitoring - Robert Street metadata

Monitoring site metadata	
Indicators monitored	CO, SO_2, PM_{10} and $PM_{2.5}$. CO and SO_2 monitoring discontinued from 2016.
Site code	104977
Location ID	LOC.300837
IRIS ID	REG.802714
Site title	Whangārei
Address	88 Robert Street, Whangārei
Region	Northland
Map reference	Q07305-074
Site coordinates	E1719769 N6045549 (NZTM)
Latitude	-35.7267287
Longitude	174.3242521
Equipment owner	Northland Regional Council
Landowner's detail	Northland Regional Council, Tel: 0800 002 004
Equipment housing	Shed
Housing environment	Air conditioned 25 °C
Monitoring objective	• Sustainably manage air quality in the Whangārei Airshed • Measure NES air quality compliance • Ensure public health is protected and amenity values are maintained • Assess airshed capacity • Measure the effectiveness of the Air Quality Plan for Northland
Site category	Residential
Scale of representation	Neighbourhood
Air conditioner service provider contact details	Airzone Limited, Whangārei Phone: 09 438 9880
Photograph of the site	Street map and photo shown on the following pages
Meteorological variables measured	Windspeed, wind direction, ambient and room temperature, humidity, pressure, rainfall etc.
Meteorological data operator	Northland Regional Council
Location of meteorological site	Onsite at 4.5 meters above ground level
Meteorological data information	Northland Regional Council
Regional and local meteorological characteristics	Monitoring site is located in a flat terrain, close to the town basin. Mild, humid, and windy conditions are common in Whangārei. Winter is mild. Predominant wind direction for Whangārei is from the south-west and north-west. Strong south-westerly winds dominate during spring and summer, whereas lighter winds from

Monitoring site metadata	
	north-west dominate during autumn. Mostly calm conditions during autumn and winter. Average ambient temperature remains between 10°C and 12°C.

Contaminant metadata	
Contaminant	PM_{10} and $PM_{2.5}$, SO_2 and CO
Data owner	NRC
Instrument	Thermo BAMFH62 and Thermo BAM5014i
Period of operation	PM_{10} High volume sampler 1996 - 2003, PM_{10} BAM 2006 ongoing $PM_{2.5}$ August 2016 ongoing CO and SO_2 July 2010 – July 2016
Method	PM_{10} in accordance with AS 3580.9.11 – 2016: Determination of suspended particulate matter - PM_{10} beta attenuation monitors. $PM_{2.5}$ measurements are conducted in accordance with AS/NZS 3580.9.12 – 2013: Determination of suspended particulate matter – $PM_{2.5}$ beta attenuation monitors and AS/NZS 3580.9.11 – 2016.
Data logging	Watercare Services
Sampling height	Inlet height 3 meters
Calibration frequency	Every three months
Percent of valid data	Meeting the NES air quality standard since 2010

Air monitoring shed at Robert Street, Whangārei

Robert St, air monitoring site

Appendix 2: Whangārei Airshed ambient air monitoring - Mairtown metadata

Monitoring site metadata	
Indicators monitored	PM_{10}
Location ID	LOC.329442
IRIS ID	REG.852439.01
Site title	Whangārei Airshed Mairtown
Address	31 Princes Street
Region	Northland
Site coordinates	E1719714 N6047916 (NZTM)
Latitude	-35.705429
Longitude	174.323327
Equipment owner	Northland Regional Council
Landowner's detail	Residential private house
Equipment housing	Mobile shed
Housing environment	Air-conditioned 25°C
Monitoring objective	• Sustainably manage air quality in the Whangārei Airshed • Compare results between two sites • Measure NES air quality compliance • Ensure public health is protected and amenity values are maintained • Assess airshed capacity • Measure the effectiveness of the Air Quality Plan for Northland
Site category	Residential
Scale of representation	Neighbourhood
Air conditioner service provider contact details	Airzone Limited, Whangārei Phone: 09 438 9880
Photograph of the site	Street map and photo shown on the following pages
Site topography	The local topography sets Whangārei on the Whangārei Harbour in a valley with hills to the east and west. The monitoring station is on the elevated area of Whangārei, in Mairtown, north of the main city.
Site location	The NRC air quality monitoring station was located at 31 Princes Street, Mairtown, in front of the house at the address in the eastern end of the yard. The site was 10m east of the house, 10m north-west of Princes Street, 300m north-east of Kamo Road, 370 m north-east of the Kensington Shops, 590m west of the Hātea River, and 1km east of State Highway 1. Neighbouring houses have chimneys.
Location of meteorological site	Onsite at 4.5 meters above ground level

Contaminant metadata	
Contaminant	Particulate Matter as PM_{10} – according to AS/NZS 3580.9.11–2016 'Determination of suspended particulate matter – PM_{10} beta attenuation monitors' using a Thermo model FH62-C14 Beta Attenuation Monitor (BAM). The BAM operates with a full-scale measurement range of 0-10,000 $\mu g/m^3$. Watercare is accredited by IANZ for this method. The estimated relative expanded uncertainty of measurement at the 95% confidence interval for PM_{10} was 5.0% of the 24-hour reading. Reported data have not been interpreted using this value.
Data owner	Northland Regional Council
Instrument	Thermo BAMFH62
Period of operation	August 2020 ongoing
Method	PM_{10} in accordance with AS 3580.9.11 – 2016: Determination of suspended particulate matter - PM_{10} beta attenuation monitors.
Data logging	Data was logged onsite and downloaded at regular intervals during the day via a router to Watercare's data management and reporting software. Subsequently, the data were checked daily, validated and reported in line with the Good Practice Guide. All data are stored as time ending averages and at New Zealand Standard Time (NZST). Pollutants reported as $\mu g/m^3$ are calculated to standard temperature (0°C) and pressure (1atm).
Sampling height	Inlet height three meters
Calibration frequency	Every three months
Percent of valid data	Meeting the NES air quality standard since 2020

Air monitoring site at Mairtown, Whangārei

Mairtown site map

Appendix 3: MfE exceptional circumstance letter

Hon Phil Twyford

MP for Te Atatū

Minister for Disarmament and Arms Control
Minister of State for Trade and Export Growth
Associate Minister for the Environment
Associate Minister of Immigration

22 November 2022 PT03814

Michael Payne
Policy Specialist
Northland Regional Council
Private Bag 9021
Te Mai
Whangārei 0143

Dear Michael Payne

Application under the National Environmental Standards for Air Quality – Regulation 16A Exceptional Circumstances

Thank you for your application for a decision under regulation 16A of the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (NES-AQ) that the exceedance of the particulate matter standard in the Whangārei airshed on 25 May 2022 was caused by exceptional circumstances. I am responding as the matter falls within my portfolio of responsibilities as Associate Minister for the Environment.

I have considered your application and the evidence you have provided about the exceedance recorded by the Mairtown Monitoring Station on 25 May 2022.

Based on the evidence, I am satisfied that the exceedance was caused by exceptional circumstances, beyond the reasonable control of the Northland Regional Council. As such, I have decided to approve your application under section 16A of the NES-AQ.

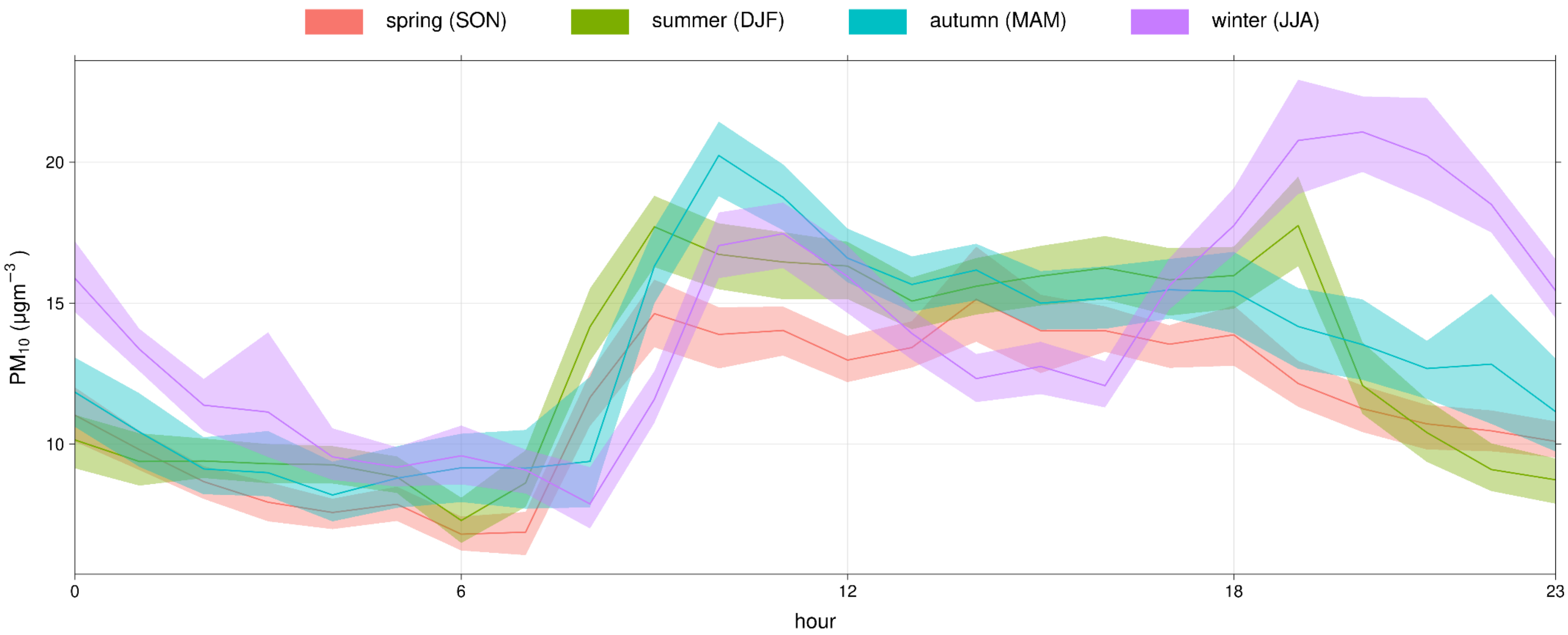
Yours sincerely

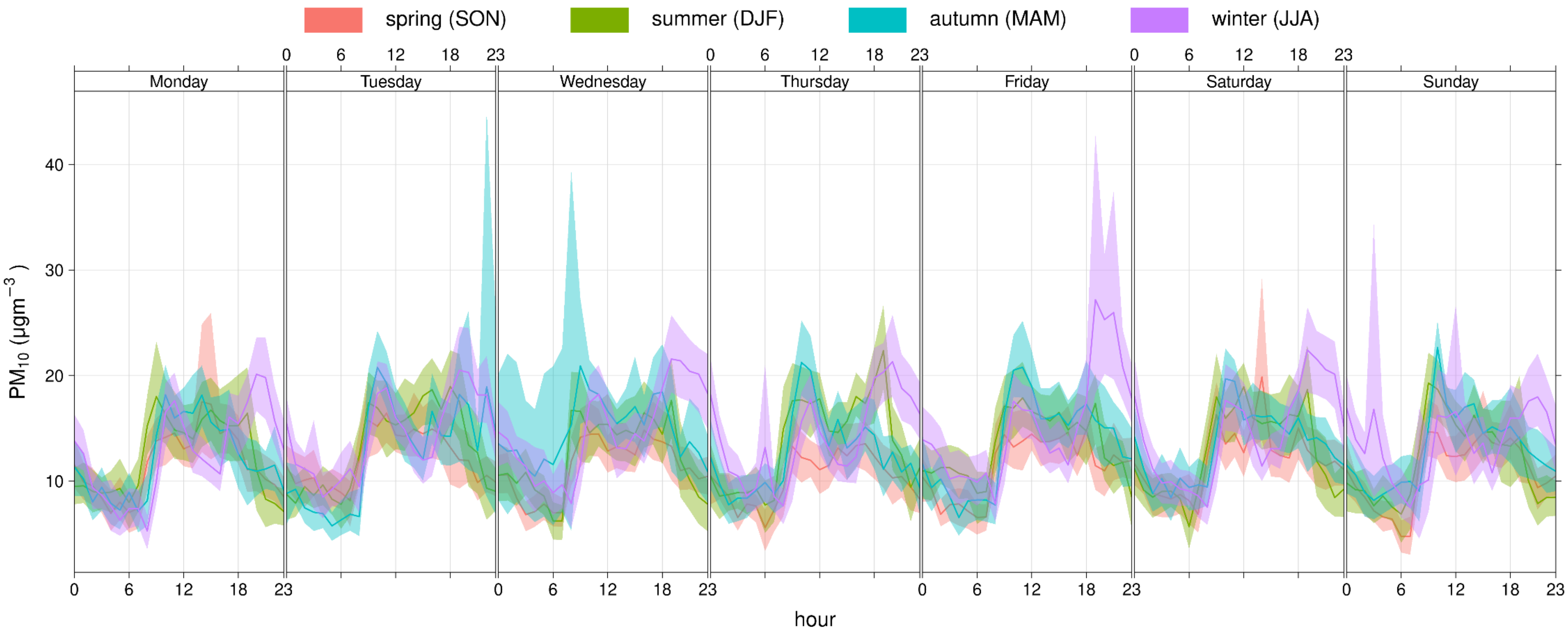
Hon Phil Twyford

Associate Minister for the Environment

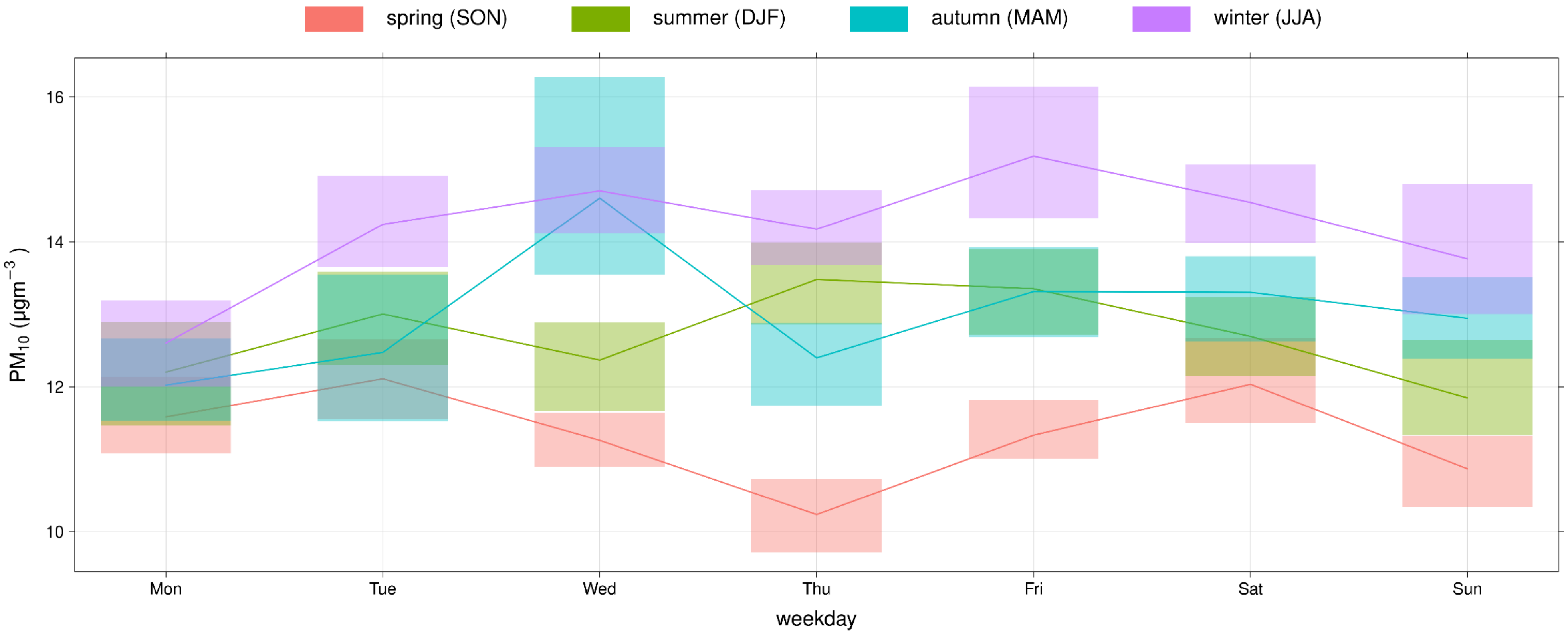
Private Bag 18041, Parliament Buildings, Wellington 6160, New Zealand
+64 4 817 8704 | ptwyford@ministers.govt.nz | beehive.govt.nz

Appendix 4: Mairtown time variation plots



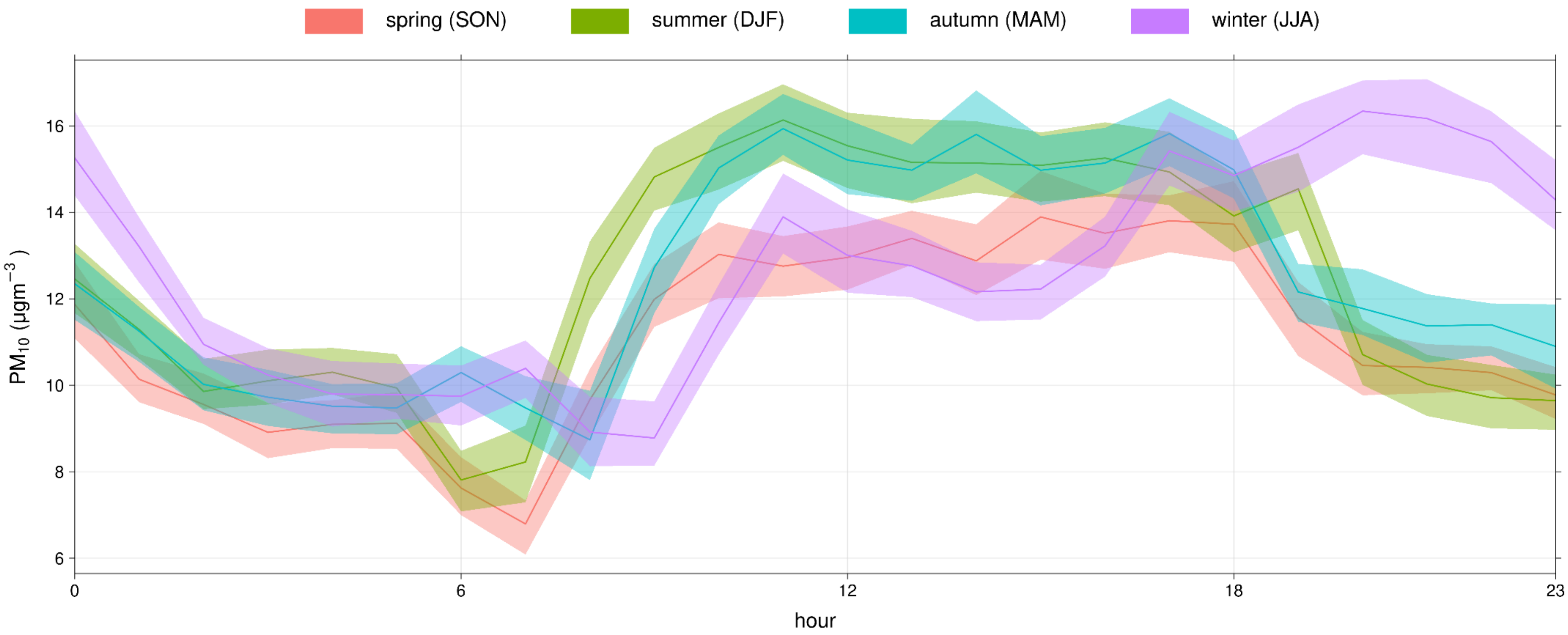


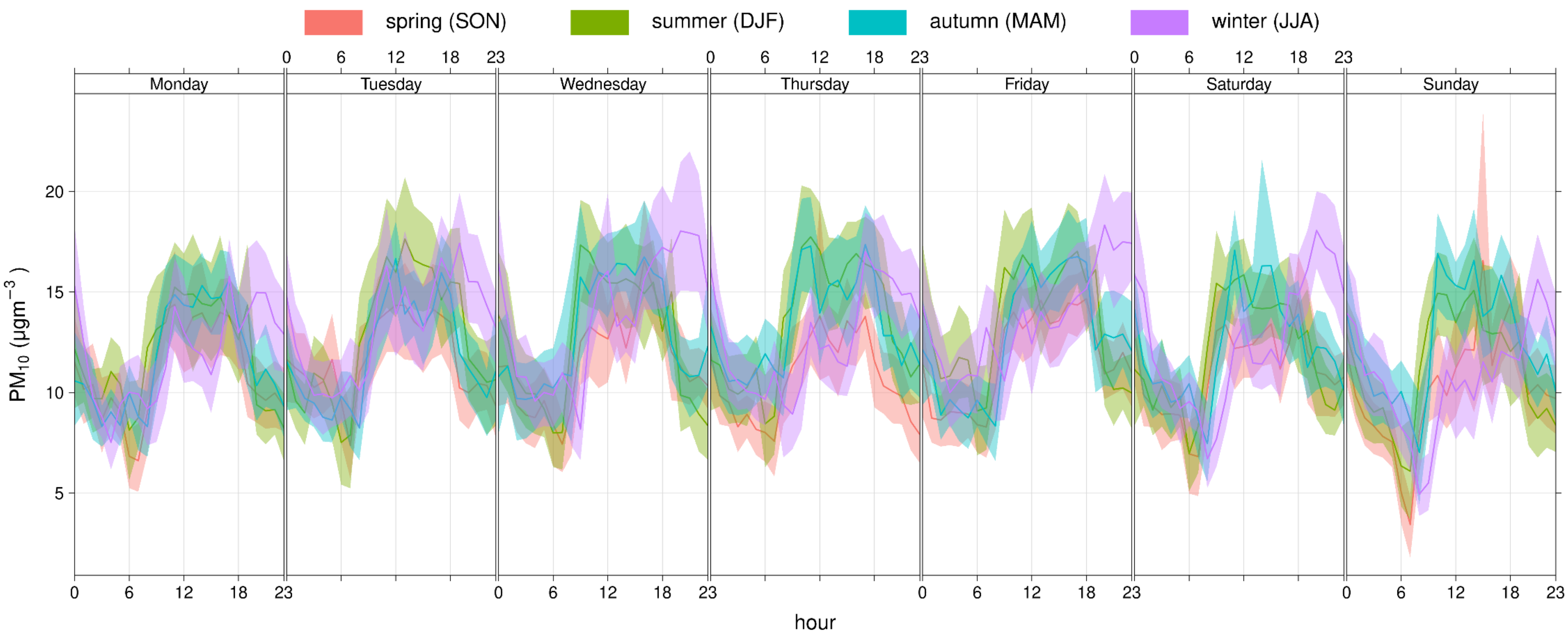
spring (SON)
summer (DJF)
autumn (MAM)
winter (JJA)
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
PM10 (μgm−3)
hour
0
6
12
18
23
10
20
30
40



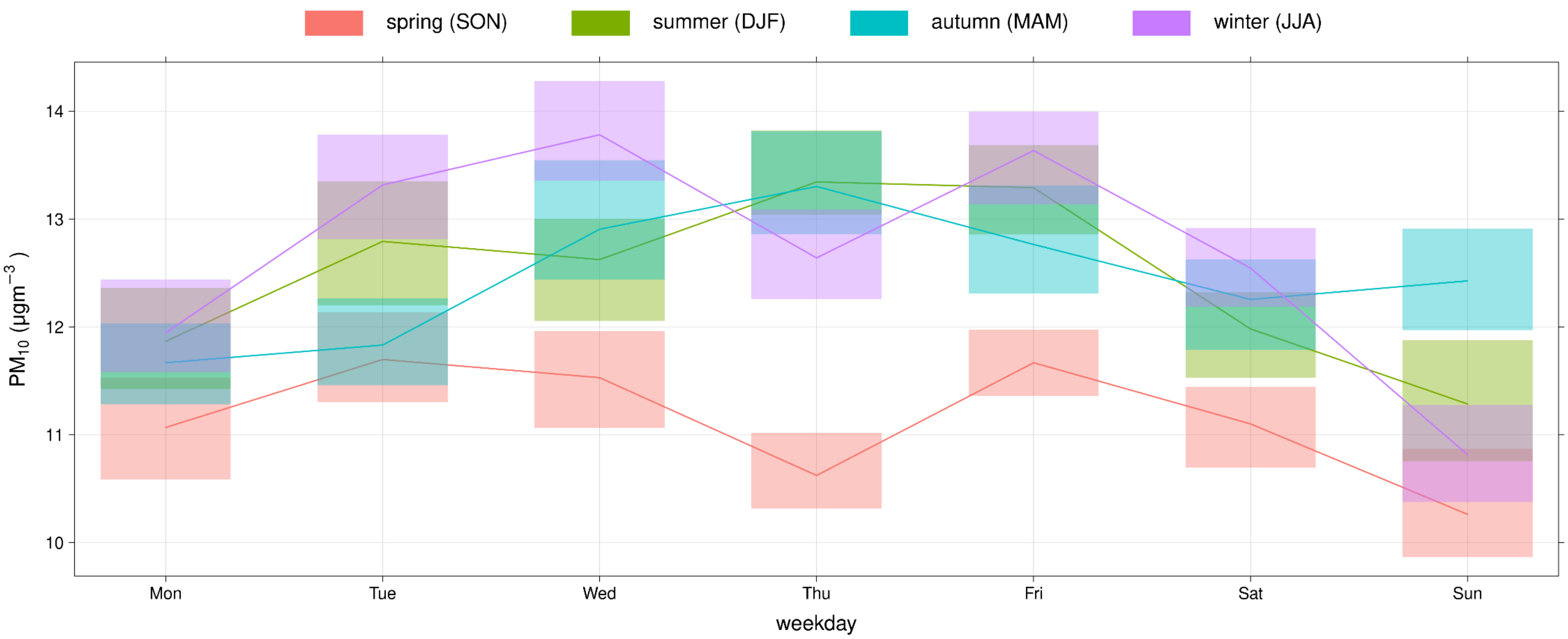
spring (SON)
summer (DJF)
autumn (MAM)
winter (JJA)
PM_{10} (μgm^{-3})
16
14
12
10
Mon
Tue
Wed
Thu
Fri
Sat
Sun
weekday

Appendix 5: Robert Street time variation plots





spring (SON)
summer (DJF)
autumn (MAM)
winter (JJA)
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
PM10 (μgm−3)
hour


spring (SON)
summer (DJF)
autumn (MAM)
winter (JJA)
PM_{10} (μgm^{-3})
14
13
12
11
10
Mon
Tue
Wed
Thu
Fri
Sat
Sun
weekday

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Northland REGIONAL COUNCIL

Te Kaunihera ā rohe o Te Taitokerau