Murchison and Motueka $PM_{2.5}$ monitoring network

May-September 2023

report for:

Tasman District Council

21 February 2024

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Mote Limited would also like to thank the landowners/occupiers in Murchison and who kindly agreed to host an air quality monitoring during this monitoring campaign. Their assistance and patience during the installation and instrument removal is gratefully acknowledged.

Revision History

No.	Date	Author(s)	Reviewer(s)	Details
1	21 Nov 2023	**Paul Baynham**	**Dr. Brett Wells**	V1.0 Draft report completed
2	22 Nov 2023	**Paul Baynham**		V1.1 Revised draft sent to client
3	21 Feb 2024	**Paul Baynham**		V1.2 Revised draft following review by TDC

CONTENTS

1.0 EXECUTIVE SUMMARY

3 air quality monitors (‘dustmotes’) and 1 meteorological monitor were deployed around Murchison between 25 May and 14 September 2023 as part of a high-resolution air quality monitoring network evaluating the effect and source of $PM_{2.5}$ concentrations in Murchison. The three selected sites included a site north of Waller Street (Murchison North) and second site on Hampden Street (Murchison central) and a third site off Fairfax street (Murchison South).

The investigation found that while emissions from domestic home heating did result in an increase in $PM_{2.5}$ concentrations during winter inversion conditions, peak concentrations at all three sites remained below the 2020 Ministry for the Environment’s proposed 24-hour average National Environmental Standard for $PM_{2.5}$ of 25 µg/m^3.

The highest peak 24-hour average $PM_{2.5}$ concentration of 18.4 µg/m^3 was recorded at Murchison south, while the Murchison central site recorded the highest $PM_{2.5}$ average for the study period of 9 µg/m^3. The Murchison North site exhibited the lowest overall concentrations of $PM_{2.5}$ during the study.

In 2021 the World Health Organisation (WHO) published the “WHO global air quality guidelines”. These health-based guidelines take into consideration the scientific evidence which has accumulated since the previous guidelines were published in 2005. While traditionally, New Zealand air quality guidelines have maintained consistency with the WHO global air quality guidelines, it is unclear whether the Ministry for the Environment intends to do so on this occasion. Of relevance to this study is the recommended 24-hour $PM_{2.5}$ guideline of 15 µg/m^3 which allow for up to 3 exceedances per year. Based on the 2023 monitoring data, only one site – Murchison central would not comply with the World Health Organisation 24-hour $PM_{2.5}$ guideline.

Wind speeds during the study remained low throughout the winter study period. The meteorological monitoring station displayed clear evidence of cold flow drainage under light winds which appeared to be the dominant dispersive mechanism at night.

A dustmote was also co-located at Ledger Goodman Park, Motueka, alongside a TDC monitoring instrument (Partisol). The monitoring station at Motueka also exceeded the WHO guideline and recorded a total of 22 days above 15 µg/m^3.

2.0 PROJECT OUTLINE

Mote Limited were contacted by Tasman District Council in February 2023 regarding potential ambient air quality monitoring networks for the Murchison community. The objective of the study was to understand if there are air quality issues in Murchison that may require ongoing monitoring and management.

The focus of the investigation was to assess the concentration of airborne particulate matter (the term of a mixture of solid particles and liquid droplets found in the air). The particulate size fraction of interest included particles with an aerodynamic diameter of 2.5 microns or less ($PM_{2.5}$). The outputs of the study compared peak 24-hour average $PM_{2.5}$ concentrations with the proposed 2020 Ministry for the Environment Standard for $PM_{2.5}$ of 25 µg/m^3 (24-hour) and the 2021 World Health Guideline for $PM_{2.5}$ of 15 µg/m^3 (24-hour).

On 4 May 2023, 4 continuous particulate monitoring instruments were co-located with a Partisol in Motueka for a period of 19 days. This was to establish the relationship between the nephelometers and the National Environmental Standard compliant monitoring device (Thermo Scientific Partisol) operated by Tasman District Council. On 24 May 2023 three of the instruments were transferred to various locations in and around Murchison. One nephelometer remained colocated in Motueka for the Winter period (until 12 September 2023)

The network was intended to be deployed for a three-month period to coincide with cooler winter weather when temperature inversions reduce the amount of atmospheric dispersion which can result in an increase in particulate concentrations.

2.1 Project location

Murchison is a small settlement in the Tasman District of New Zealand's South Island situated approximately 110 kilometers south-west of Richmond via State Highway 6. At the time of the 2018 census, Murchison had a population of 606 people in approximately 222 households.

The township is situated in a valley near the confluence of the Matakitaki and Buller Rivers and is bounded by elevated mountain ranges to the North and South.

A location map identifying the area can be seen in **Figure 1** over the page.

Murchison study area location map

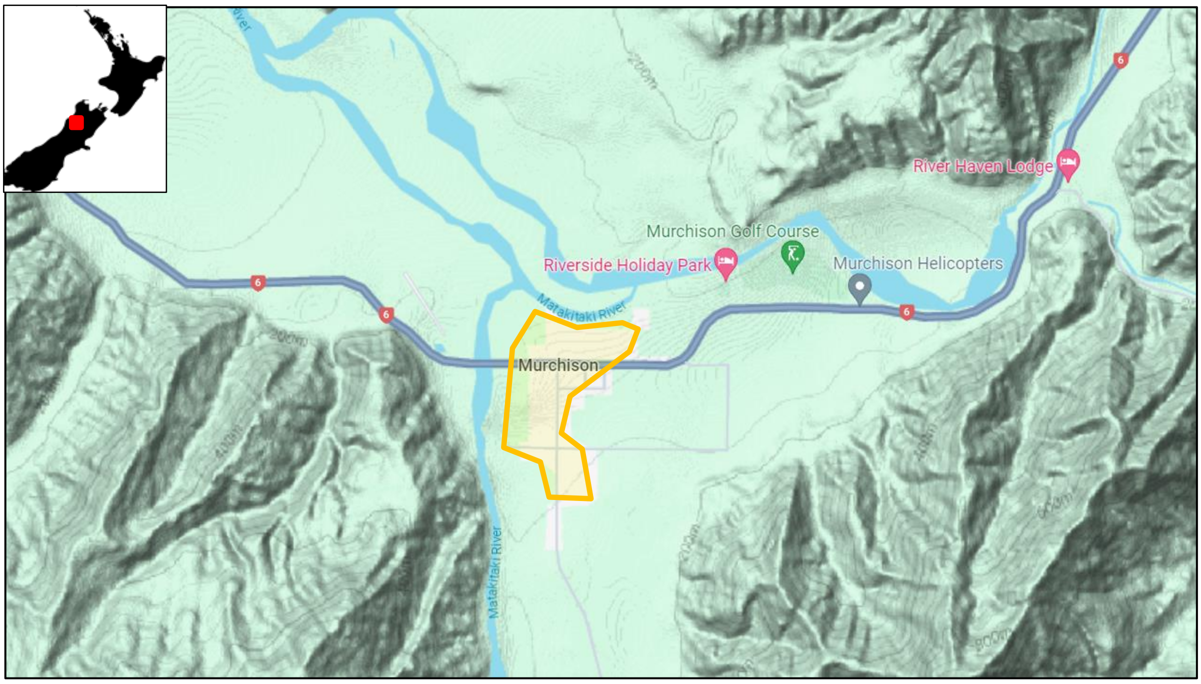


Figure 1: Location map of the study areas (highlighted yellow), Tasman District, New Zealand

Within Murchison, a total of three monitors were deployed. These monitors were positioned near the north, centre and southern sections of the town. In addition, a meteorological monitor was also deployed at the northern section to collect wind speed and direction data during the investigation.

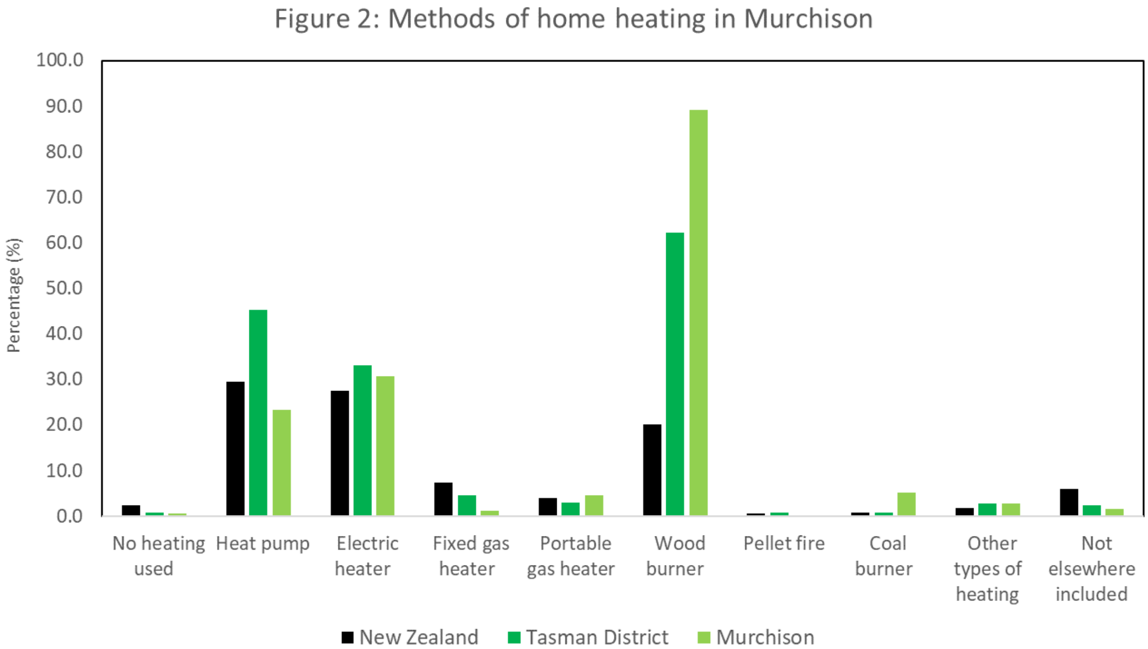


Figure 2: Graph displaying the proportion of different home heating methods in Murchison compared with the New Zealand average based upon the 2018 Census data. Note that some households contain more than one heating type and/or multifuel burners.

The Murchison community has a much higher proportion of wood burners (89.2%) than other parts of Tasman District or New Zealand (62% and 20%) as shown in **Figure 2** above.[1]

2.2.1 Particle Instrument Selection

One primary instrument was selected - an optical nephelometer (known as 'dustmotes'). The instrument is a Met One ES642 near-forward nephelometer which was coupled with a programmable modem.

The ES642 produces 1 second data which was collated to produce 1-minute averaged data. The ES642 unit contains an inlet heater which was controlled using a set point of 35% relative humidity. Sample flow rates of 2 litres per minute were calibrated using a DryCal defender immediately following installation of the instrumentation. The flow rates were confirmed at the conclusion of the project and were all found to be within 5% of the original flow rates.

Temperature, pressure, and relative humidity sensors were also calibrated using Vaisala HMT330 and HM70 meters following installation to ensure accurate flow measurement.

The instruments store data locally if cellular transmission is disrupted. When cellular connectivity is restored, then data transmission will recommence with older data transmitted first.

Figure 3: Photograph of one of the ES642 units being installed in Murchison.

All instruments were co-located at Motueka alongside the TDC partisol for an initial 19-day period. The location was Goodman Ledger Park, Motueka, which TDC has been using as a

[1] Source 2018 New Zealand census.

temporary monitoring site in recent years. The purpose of this co-location was firstly, to ensure that the optical nephelometers are producing consistent data prior to their respective field deployment locations (degree of precision). The second purpose is to enable the optical concentration data to be corrected to gravimetric equivalent (degree of accuracy).

Following the 19-day co-location, the data from each of the units was adjusted using a linear correction factor to ensure consistent measurements during the monitoring campaign and to verify that the instrumental concentrations were comparable during the initial 12-day deployment. This was performed by calculating an average concentration during the co-location and comparing this with combined average value of all instruments over the same period.

The gain on each instrument was then adjusted and the instrumental data checked to verify that the values where within +/-2 µg/m^3. A comparison of the instruments confirmed that the 24-hour average values were within tolerable thresholds.

Standard practice is to replace any instruments which fail to meet this requirement, however following gain adjustments, all optical nephelometers met the required degree of precision (24-hour average +/-2 µg/m^3).

Figure 4 displays the corrected instrumental concentrations for each of the monitors used during the deployment.

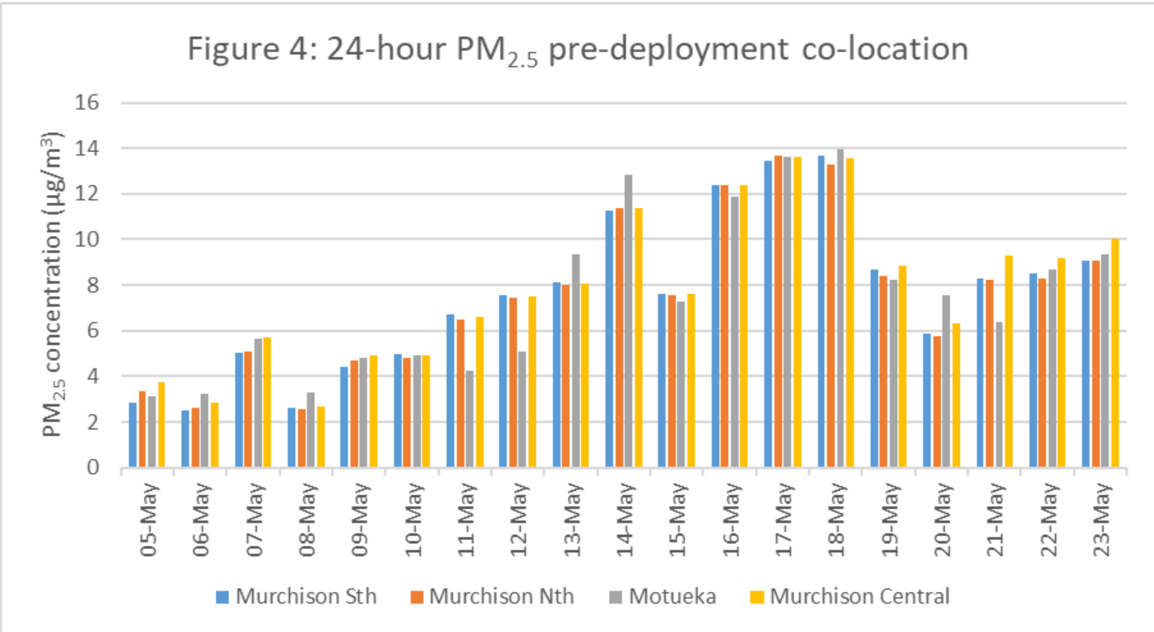


Figure 4: comparison of 24-hour average concentrations for the 4 $PM_{2.5}$ instruments co-located in Motueka (5 May – 23 May).

The second part of the co-location process involves applying a linear correction factor to correct the optical concentrations to gravimetric equivalent. This is normally achieved by either sampling the optical particles onto a filter (e.g. MetOne ESampler), calculating the optical correction factor and applying linearly across the sampling period or as in this case, using filter based results from a co-located instrument.

The correction factor recognises that two different instrumental techniques are used by the instruments (Gravimetric vs Optical). Essentially, the optical devices measure the number of particles during a given period of time and then convert this to a concentration by making an assumption around particle density(ρ). Investigations in other parts of New Zealand have established that $PM_{2.5}$ particle density assumptions can vary ($0.8>\rho>2.2$) between sites.

As the particle size decreases, there is generally better agreement between optical nephelometers and gravimetric instruments. There are several reasons, for this, however if one considers the formulae to calculate the volume of a sphere:

$$V = \frac{4}{3}\pi r^3$$

It is apparent that the cubic radius has a significant effect on particle volume. Therefore, it follows that as the particle size decreases, the particle volume and the effect of particle density becomes less significant.

2.2.2 Meteorological Instrument Selection

One meteorological wind speed and direction sensor was deployed at the Murchison north site. The sensor consists of a Gill Windsonic 60 ultrasonic wind speed and direction sensors which was mounted on a pole which extended 900mm above the roofline of the adjacent building. The device was aligned to true north during installation. The instruments were factory calibrated prior to deployment with the reported accuracy of the wind speed and wind direction being +/- 2% and +/-2º respectively.

The ultrasonic anemometers collect data at 1 second intervals (u & v vectors). The meridional and zonal components are then converted to 1 minute average data using vector averaging. The 1-minute average data has the same timestamp as the associated ES642 data to enable direct comparison.

2.3 Site Selection

The Tasman District Council identified their preferred locations during the pre-planning phase of the deployment in conjunction with Mote Limited. All instruments were mains powered with RCD trip devices installed in the event of any electrical earth fault developing.

All instruments were generally positioned between 2 and 3 metres above ground level where possible and the wind speed and direction sensor was positioned 1.0 meter above the adjoining nephelometer.

A location map depicting the location of the instruments is shown in **Figure 5**.

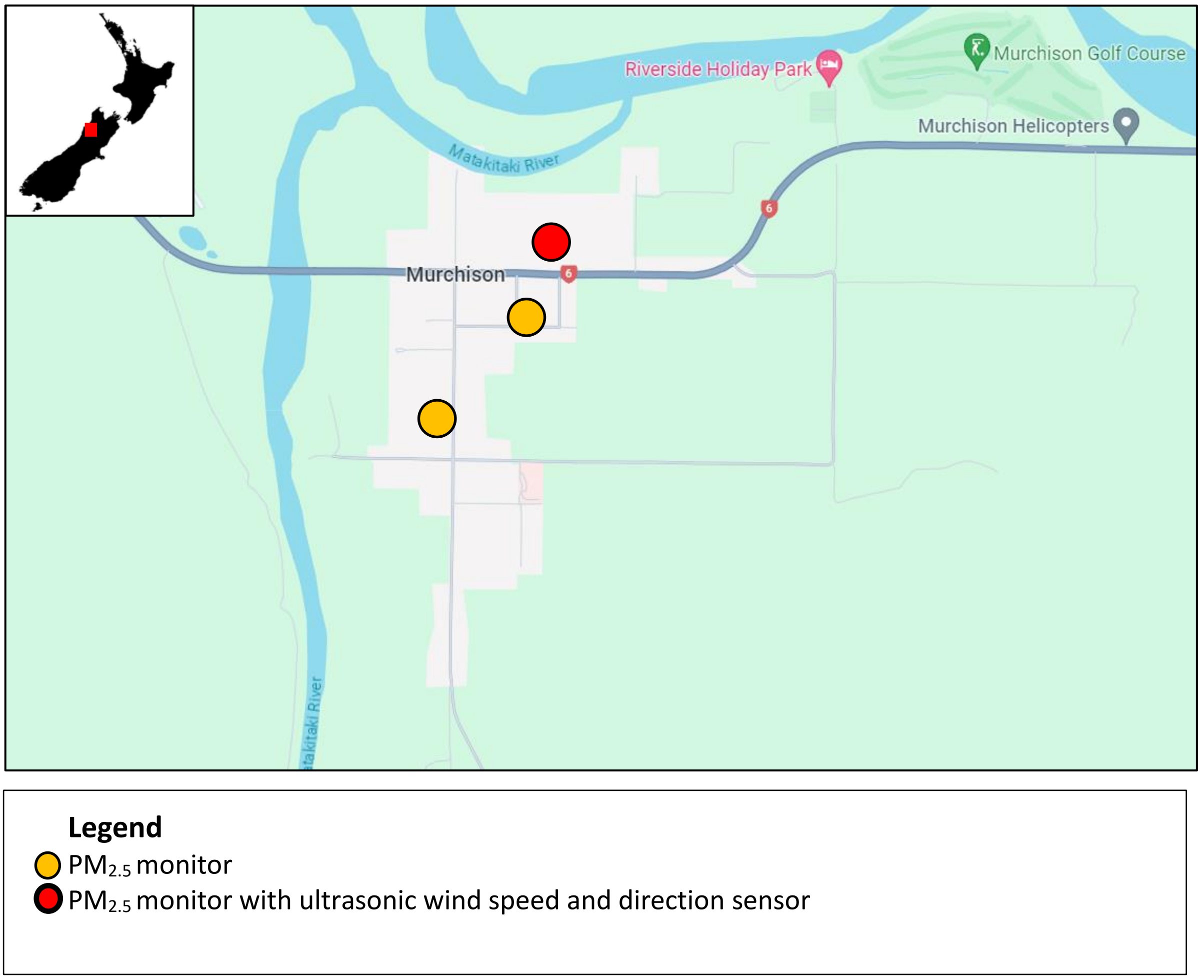


Figure 5: Location map of $PM_{2.5}$ monitors in Murchison during the 2023 winter monitoring campaign.

3.0 RESULTS

Landowners/occupiers who provided approval to house an instrument were given a food voucher for a local supermarket upon the initial installation along with a second food voucher when the instrument was removed.

These vouchers were provided to compensate the landowners and occupiers for the inconvenience of having an instrument on their property and also in recognition of the small amount of electricity consumed by the device while it was operational.

3.1 Data capture rate

On 24 May 2023, the 3 Dustmotes and meteorological sensor were installed at their designated monitoring locations in Murchison. These devices operated continuously until 14 September when the southern monitor was powered off. The remaining monitors at Murchison central and Murchison north sites continued operating until 19 September when the remaining units were decommissioned. The three units were then transported back to Motueka and co-located alongside the Partisol from 20 September through to 3 October.

The overall data capture rate for the investigation was 97.9%. Intermittent power issues that were experienced at the Murchison central site resulted in some data loss. Periodic instrument calibration and servicing also resulted in some data loss. Total data capture rates are shown in **Table 1** below.

Table 1: Instrument deployment details and data capture rate

Instrument	Target minutes[1]	Actual minutes[2]	Data capture rate (%)	Comment
Murchison North	161280	159160	98.7	
Murchison Central	161280	155017	96.1	Intermittent power outages
Murchison South	161280	159160	98.9	
Motueka	161280	158153	98.1	

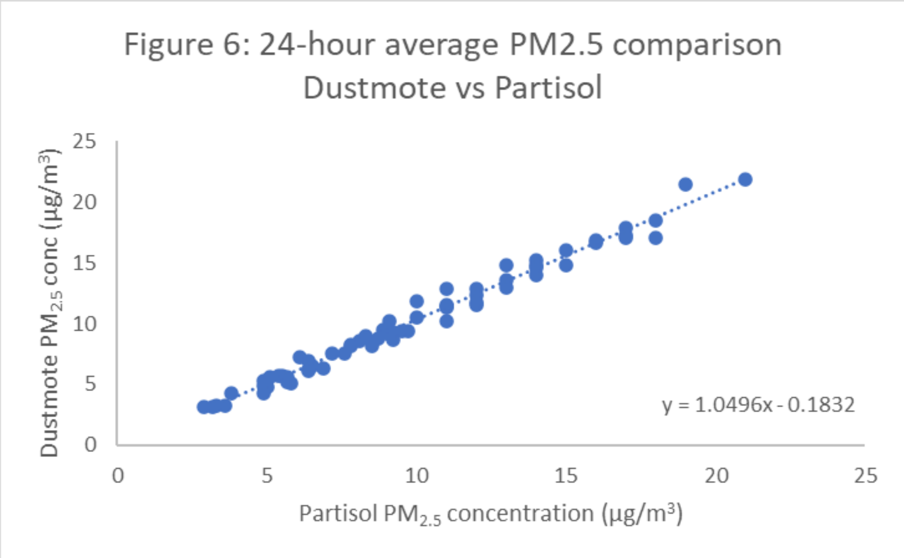
[1] Number of minutes between 24 May and 14 September 2023

[2] Total minutes of data collected

A validated spreadsheet containing the 1 minute and 24-hour average data from Murchison accompanies this report. The spreadsheet is named **Murchison_Data_V1.1.xlsx.**

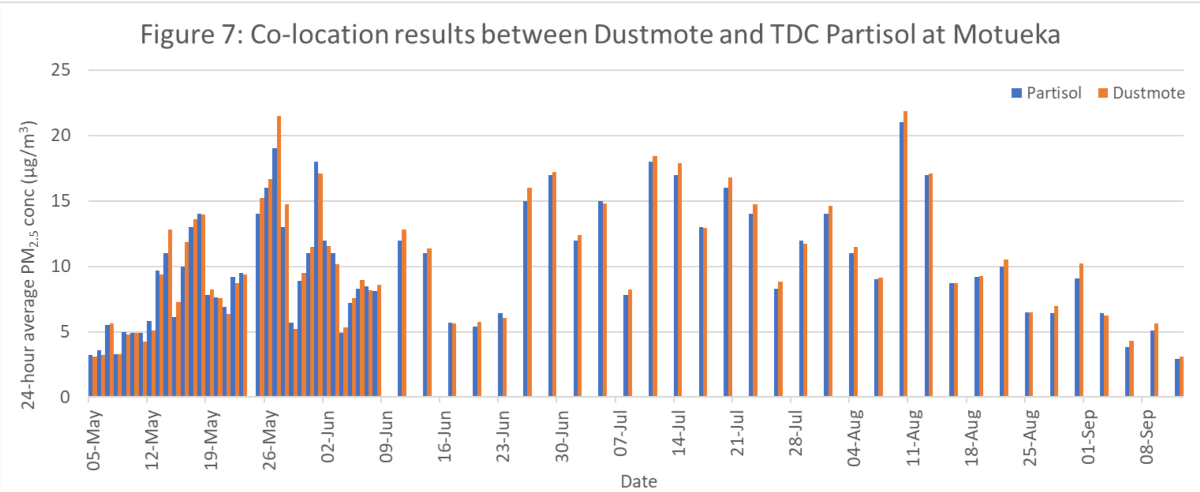
3.1.1 Motueka co-location results

A TDC partisol was co-located with a dustmote at Motueka, both monitoring $PM_{2.5}$, and a comparison of the data reveals good agreement between the two instruments as shown in Figure 6 below. The strength of the relationship between the two instruments indicates that while the dustmote is not a reference instrument, the dustmote results are comparable to the Partisol and suitable for use as a screening and $PM_{2.5}$ assessment tool as used in this study.



Figures 6: Comparison of 24-hour average PM2.5 concentrations as measured by the TDC Partisol with those measured by the dustmote.

Figure 7 below displays a time series plot comparing the results from both instruments over the same period. The frequency of samples collected reduced from daily to '1 day in 3' once the initial co-location had been completed. This plot confirms that the variation between the instruments remained reasonably consistent throughout the duration of the study.



Figures 7: Co-location monitoring results between the Dustmote and Partisol at Motueka

A comparison of the average $PM_{2.5}$ concentration between the Partisol and the Dustmote revealed average concentrations of 9.9 and 10.2 µg/m^3 respectively. The similarity between these two values demonstrates that the relationship between the two types of instruments is acceptable given the different techniques (gravimetric vs nephelometric) methods used to quantify particle concentration.

At the conclusion of a deployment, all instruments were again co-located back at the Motueka TDC monitoring site (**Figure 8**) for a period of 13 days to evaluate whether the initial adjustments made to the instruments remained valid (+/- 2 µg/m^3).

This post-location analysis confirmed that the 24-hour equivalent concentrations remained within +/-2 µg/m^3 at the conclusion of the study.

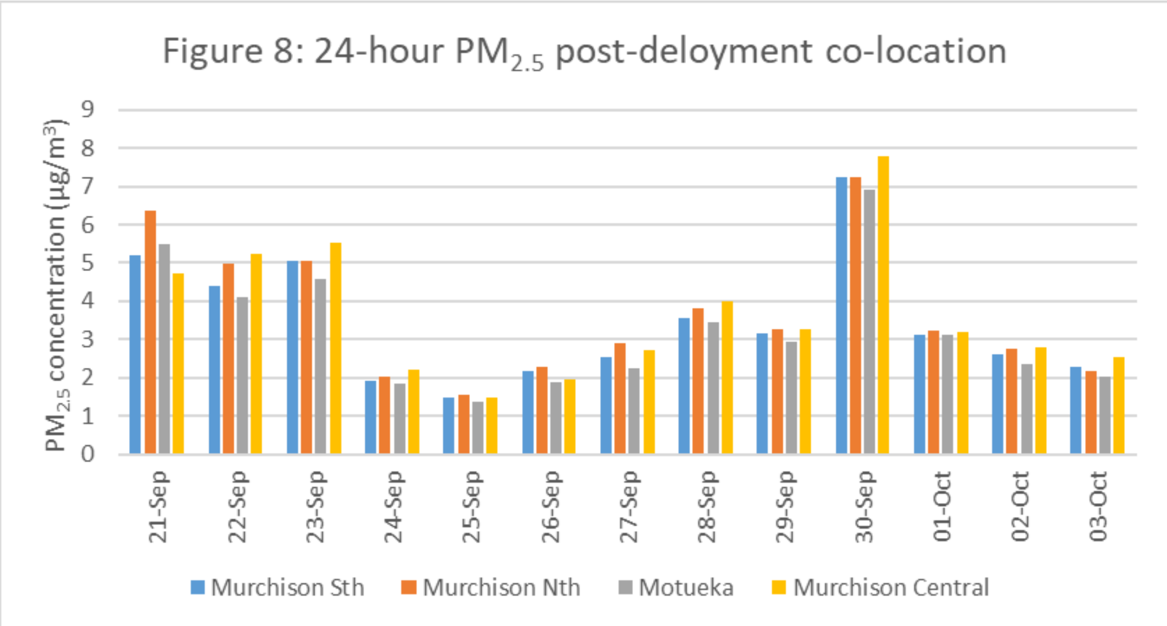
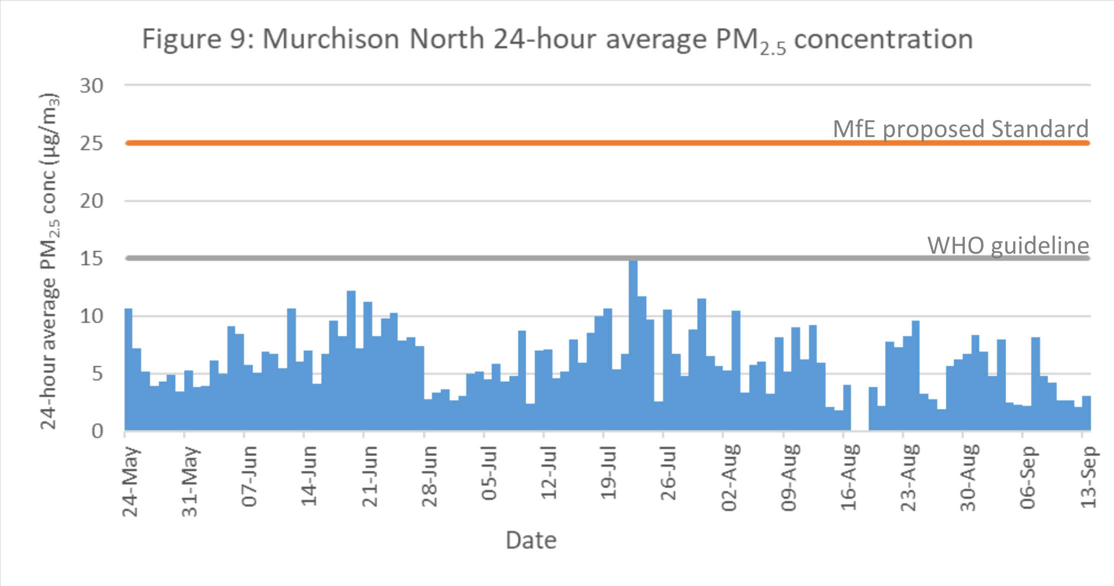


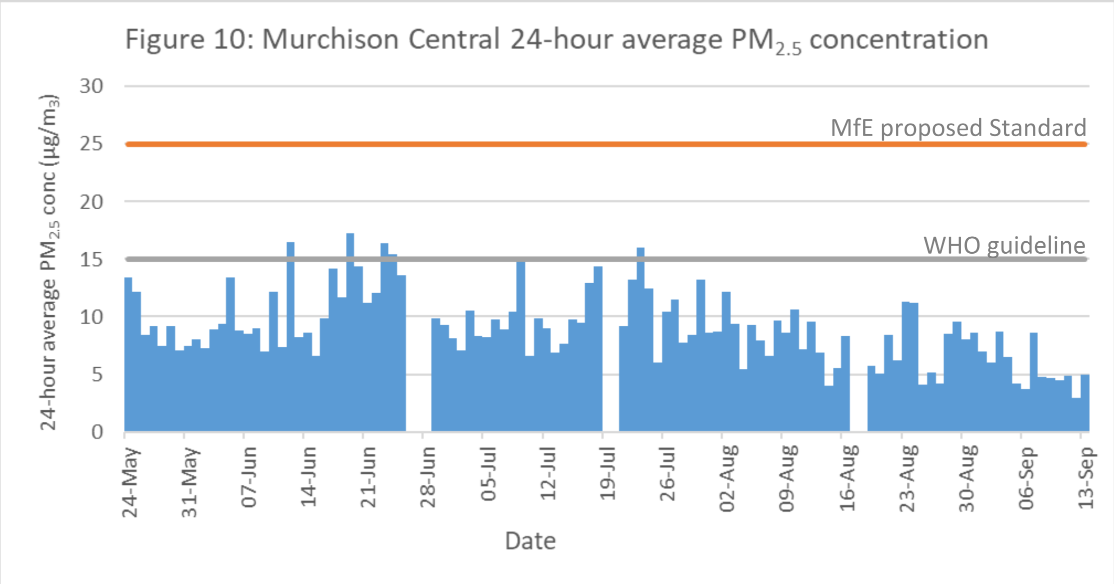
Figure 8: Comparative plot of deployed instruments post-deployment

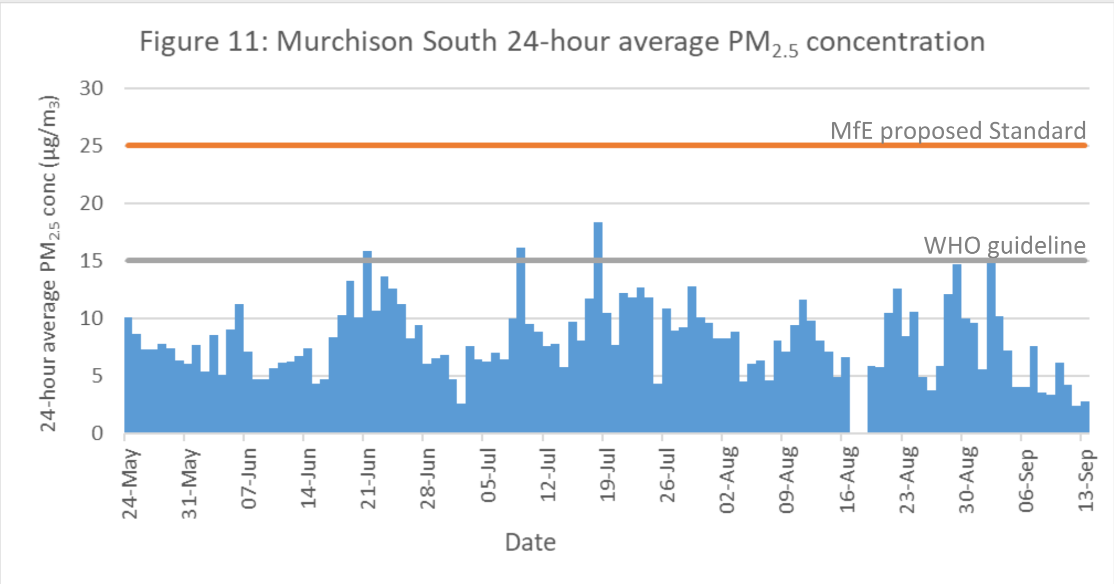
3.2 $PM_{2.5}$ results

The following series of graphs reveal the daily maximum 24-hour $PM_{2.5}$ concentration for each of the monitoring stations. Comparisons are made against the proposed 2020 National Environmental Standard for $PM_{2.5}$ of 25µg/m3 (24-hour)[2], and the more recent 2021 World Health Organisation guideline of 15µg/m3 (24-hour).

[2] Ministry for the Environment. 2020. Proposed amendments to the National Environmental Standards for Air Quality: particulate matter and mercury emissions – consultation document. Wellington: Ministry for the Environment.







Figures 9, 10 & 11. Plots of 24-hour average $PM_{2.5}$ concentration for each instrument. Note periods where less than 75% of the valid data was present have been left blank. The red line indicates the proposed 24-hour National Environmental Standard for $PM_{2.5}$ (25 µg/m^3) while the grey line indicates the World Health Organisation 2021 guideline (15 µg/m^3).

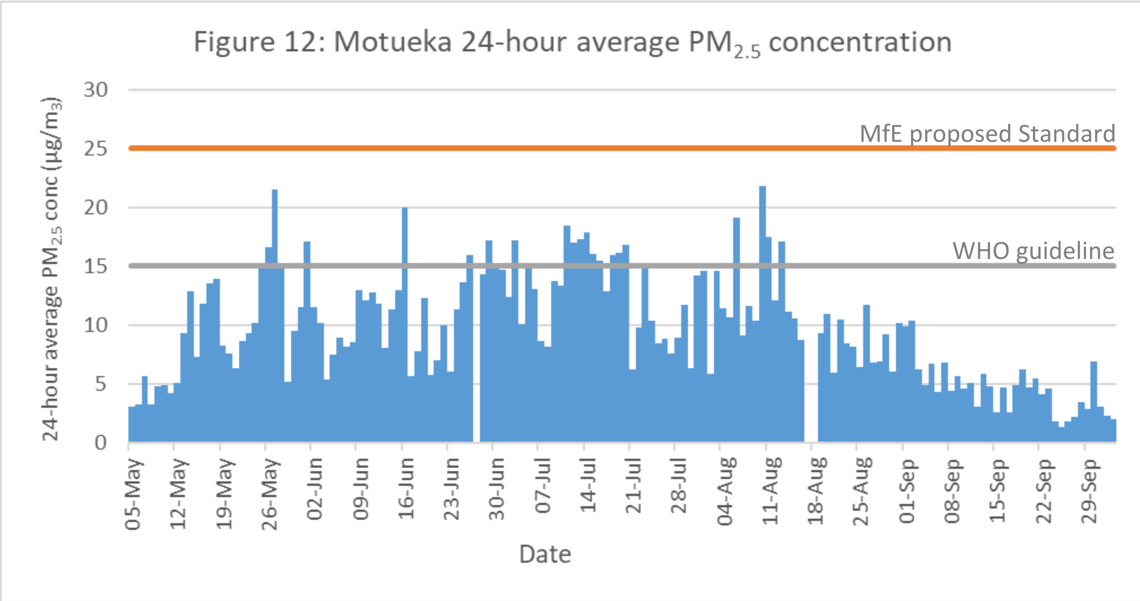


Figure 12: Plot of 24-hour average $PM_{2.5}$ concentration for each instrument. Note periods where less than 75% of the valid data was present have been left blank. The red line indicates the proposed 24-hour National Environmental Standard for $PM_{2.5}$ (25 µg/m3) while the grey line indicates the World Health Organisation 2021 guideline (15 µg/m^3).

An analysis of the maximum 24-hour $PM_{2.5}$ concentrations at all three Murchison sites indicates that Murchison North had the lowest maximum 24-hour average $PM_{2.5}$ concentration of 14.9 µg/m^3 on (22 July) while higher maximum 24-hour average $PM_{2.5}$ concentrations of 17.3 and 18.4 µg/m^3 were measured at Murchison Central and Murchison South respectively.

A similar analysis of the data in Motueka found that the maximum 24-hour $PM_{2.5}$ concentration of 21.8 µg/m^3 occurred on 10 August 2023.

A comparison of the 3-month winter average (June, July and August) $PM_{2.5}$ concentration at each of the four sites found the average concentration was highest in Motueka (11.5 µg/m^3) while the Murchison North site recorded the lowest average PM2.5 concentration of 6.5 µg/m^3. Murchison Central and Murchison South sites recorded average $PM_{2.5}$ concentrations of 9.5 and 8.5 µg/m^3 respectively.

The maximum concentrations at all four sites remained below the 2020 Ministry for the Environment's proposed 24-hour average National Environmental Standard for $PM_{2.5}$ of 25 µg/m^3.

In 2021 the World Health Organisation published the "WHO global air quality guidelines". These health-based guidelines take into consideration the scientific evidence which has accumulated since the previous guidelines were published in 2005.

While traditionally, New Zealand air quality guidelines have maintained consistency with the WHO global air quality guidelines, it is unclear whether the Ministry for the Environment intends to do so on this occasion.

Of relevance to this study is the recommended 2021 WHO 24-hour $PM_{2.5}$ guideline of 15 µg/m^3 which allow for 3-4 exceedances per year. For the purposes of this report, the lower threshold of 3 exceedances has been applied as a comparison. Based on the 2023 monitoring data, only 1 of the 3 Murchison monitoring sites would not comply with the World Health Organisation 24-hour $PM_{2.5}$ guideline.

Table 2: List of World Health Organisation exceedances per site during 2023

Dustmote Location	Number of days where 24-hour average $PM_{2.5}$ is greater than 15 µg/m^3	Allowable number of exceedances per year	Number of days where $PM_{2.5}$ breaches WHO guideline	Total number of days monitored at each site (24 May – 14 Sep)
Murchison North	0	3	0	111
Murchison Central	5	3	2	106
Murchison South	3	3	0	111
Motueka	22	3	19	149

Figure 13 below depicts the proportion of time each site spent in each air quality category during the study period.

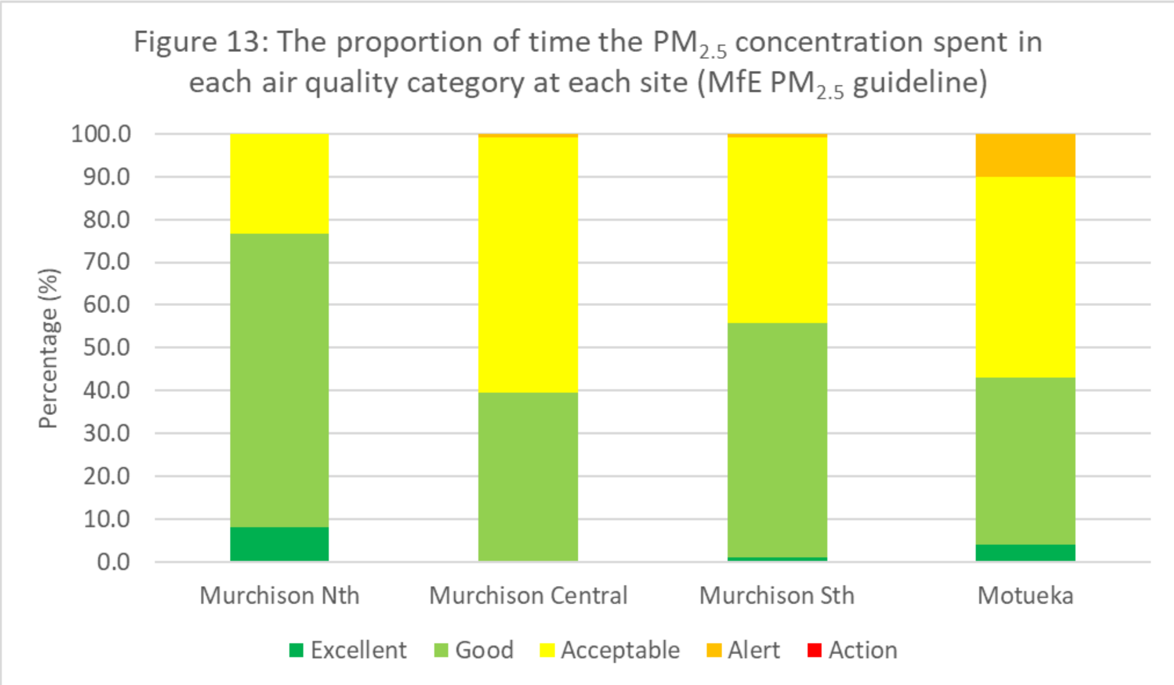


Figure 13: The proportion of time each site spent in each air quality category for the proposed 2020 MfE $PM_{2.5}$ Standard (MfE Environmental Performance Indicator (EPI) programme air quality indicators (2002).

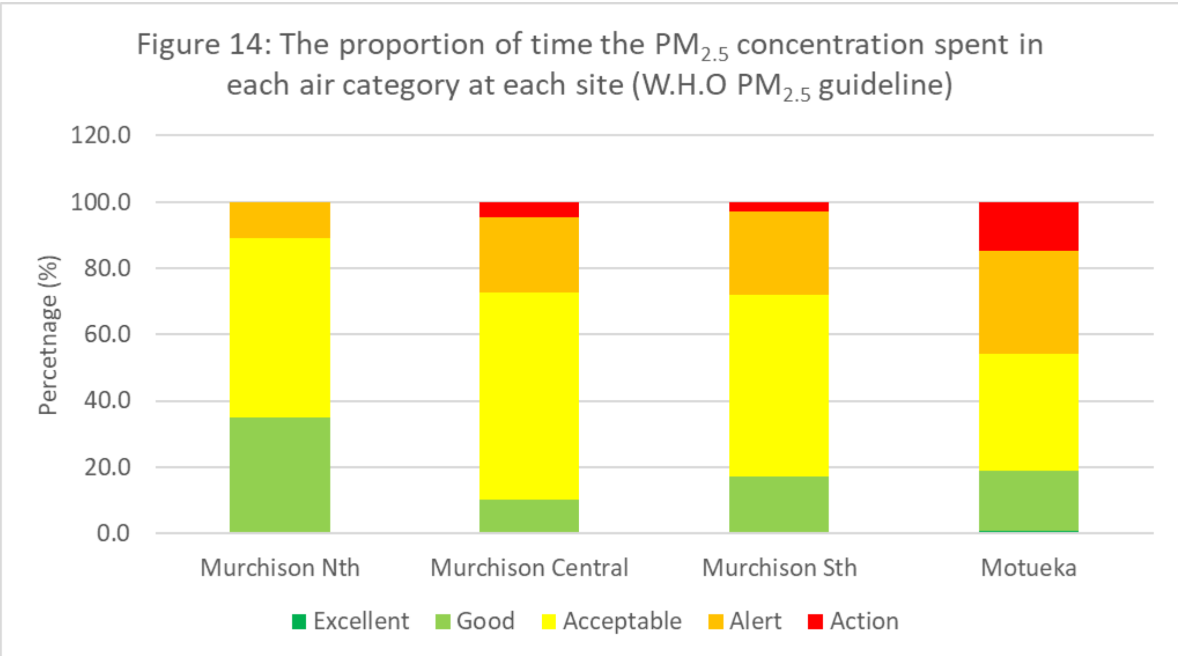


Figure 14: The proportion of time each site spent in each air quality category for the World Health Organisation $PM_{2.5}$ guideline.

Figure 13 confirms that the maximum $PM_{2.5}$ concentrations complied with the draft 2020 Ministry for the Environment $PM_{2.5}$ standard of 25 µg/m^3 at all sites in Murchison and Motueka during the 2023 winter period.

Figure 14 follows similar logic to Figure 13 but instead uses the 2021 World Health Organisation $PM_{2.5}$ guideline of 15 µg/m^3. The WHO guideline allows 3-4 days in any 12-month period to exceed the standard without resulting in a breach. If the WHO guideline is applied to the data collected during the 2023 winter, we find that Murchison North and

Murchison South sites complied with the WHO guideline but that the Murchison Central site did not. Similarly, the Motueka site also fails to comply with the WHO guideline which is consistent with previous monitoring undertaken at the Goodman Ledger Park site.

Traditionally, the Ministry for the Environment have adopted the World Health Organisation guidelines as the basis for ambient air quality guidelines and standards in New Zealand. It is currently unclear whether the Ministry for the Environment intends to amend the current air quality standards to bring them into line with the WHO air quality guidelines.

Table 3 below displays the co-efficient of variation between each of the sites for the period between 24 May through to 14 September 2023. The values provided are based on the 24-hour average data and provide an indication of the degree of similarity between sites during the investigation.

Table 3: Co-efficient of variation between each of the 3 Murchison sites and Motueka

	Murchison North	Murchison Central	Murchison south	Motueka
Murchison North		0.78	0.41	0.09
Murchison Central	0.78		0.48	0.11
Murchison south	0.41	0.48		0.18
Motueka	0.09	0.11	0.18	

The coefficient of variation describes the extent to which one site agrees with another or put another way the proportion of variation at one site (dependant) that can be explained by the variation at another (independent) site.

A value of “1” means that two sites completely agree with each other while a value of “0” means that two sites behave completely independently.

The values have been shaded with darker colouration indicating a stronger relationship than a lighter colouration to assist with visual interpretation of the data. Green shading has been used to highlight variation between instruments.

In an air quality context, these tables can be used to identify whether parts of an airshed or even different airsheds behave in the same way and whether one or more monitoring sites could be representative of the entire airshed or even other airsheds in the region.

By examining the strength of the relationship between instruments and also the change in relationships between sites, it is possible to deduce information about the sources of particulate impacting a given location.

From Table 3 we can see that there is reasonable agreement between the northern and central sites, but that the relationship with the southern Murchison site is somewhat weaker. This suggests that either there are slightly different atmospheric dispersive mechanisms – such as katabatic down valley dispersion and/or that emission sources near the southern monitor operated at different times or that the southern monitor was influenced by proximity to an emission source which was not representative of other sources in Murchison.

There is also a weak relationship between $PM_{2.5}$ concentrations in Murchison with those in Motueka. This likely reflects the regional impact of weather systems such as anticyclones which are associated with temperature inversions and increased ground level concentrations of $PM_{2.5}$.

Table 3 confirms that a moderate relationship exists between many of the Murchison sites and when consideration is given to previous observations suggests:

1. That the emission sources are linked. Given the geographic spread of the monitoring stations, this suggests that most of the variation at the monitoring sites probably relates to home heating rather than that of other sources.

2. There is a reasonable agreement between the two monitoring stations in Northern and Central Murchison but that the southern monitoring site may be influenced by different atmospheric dispersion mechanisms and/or slightly different emission characteristics.

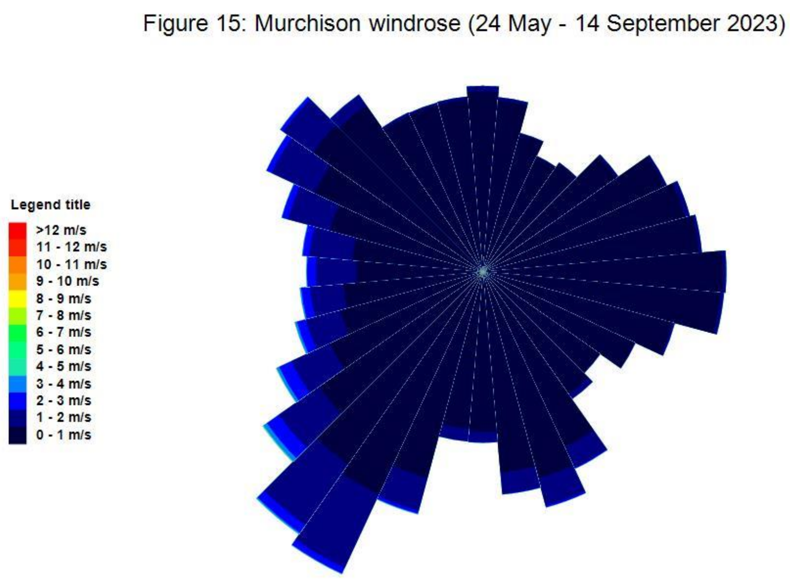
3. A review of the hourly emission data on elevated pollution days confirms that emissions typically begin increasing above background in the evening (6pm) and typically peak between 11:00pm and 2:00am in the morning then decrease in the hours prior to sunrise. This emission profile is consistent with emissions from domestic home heating.

4. If we examine emissions within each community, we can see that there is a general gradient increasing the $PM_{2.5}$ from the south to the north of each community during periods of elevated $PM_{2.5}$ concentration. A review of the meteorological data during these events confirms light variable winds generally from the Northeast/East which is consistent with katabatic cold flow drainage down the Buller River. This drainage, although typically slow moving is likely to be more prevalent closer to the river and may provide a possible explanation as to why the southern site may exhibit slightly different dispersive mechanisms.

3.3 Effect of meteorology

One meteorological monitor was deployed at the northern monitoring site. Ultrasonic meteorological sensors were selected to monitor wind speed and direction. This type of sensor is much more sensitive at lower wind speed than traditional cup and vane anemometers and recorded wind speed and direction at 1 second intervals during the study. This one second data was converted to 1 minute (vector) averaged wind speed and direction to enable comparison with the one-minute data collected by the $PM_{2.5}$ nephelometers.

A windrose plot for the meteorological monitoring station is shown in **Figure 15**.



Figures 15: Windrose plot at Murchison North site for the period from 24 May through until 14 September 2023.

The windrose plot confirms that low winds dominated the wind in Murchison and that most directions were well represented. Slightly higher wind speeds – those above 3 metres per second, were more prevalent from the southwest and this is reflected in the slightly higher percentage of winds from this direction.

The time series plot shown in **Figure 16** depicts the averaged $PM_{2.5}$ concentration along with the windspeed measured at Murchison North site on 24 August 2023. The wind conditions were typical of Murchison at this time with a peak in wind speed usually occurring around midday and lower wind speeds during evening and early morning.

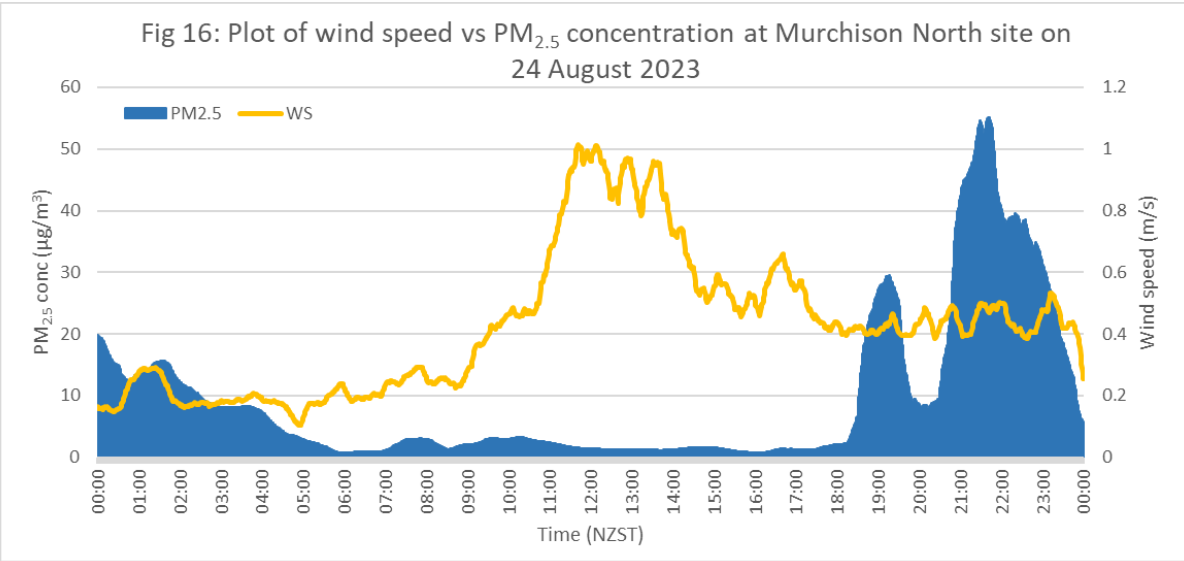


Figure 16: Plot of 60-minute running average of $PM_{2.5}$ alongside the wind speed on 24 August 2023.

Peak $PM_{2.5}$ concentrations from domestic fires are typically observed in the early evening when families return home and light their fires. Emissions usually increase following this period until around midnight when most families retire and the emissions from domestic home fires slowly decrease.

It is helpful to compare average daily air temperatures during the study period with previous years to confirm whether ambient air temperatures were unusually cold or warm during the study period when compared with previous years. This is because cooler or warmer weather can influence the use of domestic home heating which in turn can impact $PM_{2.5}$ concentrations during the study period.

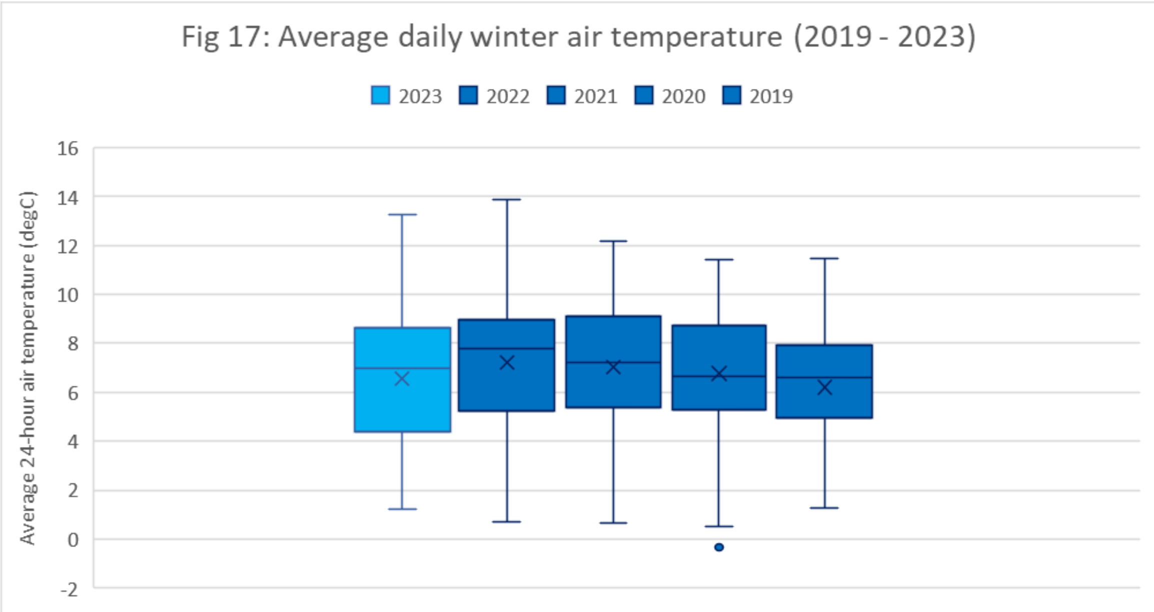


Figure 17: Comparison of the average daily air temperature during the study period (24 May – 14 September) with the same period in previous years (Murchison). Data sourced from Tasman District Council.

Figure 17 reveals that the average air temperature between 24 May and 14 September was slightly cooler than the same period in 2022. However, this reduction in air temperature was relatively small (<1 degree Celsius) and was not statistically significant (p value <0.05) when compared to the previous 4 years. For these reasons, the measured $PM_{2.5}$ concentrations in Murchison are very likely to be typical of winter $PM_{2.5}$ concentrations and broadly similar to those of recent winters.

4.0 CONCLUSION

Mote Limited deployed a network of 3 continuous nephelometers and 1 continuous meteorological sensor in Murchison during the winter of 2023.

The data capture rate for the field deployed instruments between 24 May to 14 September 2022 was 97% which exceeds the recommended data capture rate of 95% for distributed sensor networks. Pre and post deployment collocation data confirmed all instruments were comparable (+/- 2 $\mu g/m^3$). The instruments also displayed reasonable agreement with TDC's National Environmental Standard compliant equipment operated in Motueka.

Maximum 24-hour $PM_{2.5}$ concentrations of between 14.9 and 18.4 $\mu g/m^3$ were measured at each of the 3 instruments located in Murchison during the study period. The proposed 2020 Ministry for the Environment $PM_{2.5}$ standard of 25 $\mu g/m^3$ allows for three exceedances per year. On this basis all three sites complied with the proposed $PM_{2.5}$ standard.

In comparison to the 2021 World Health Organisation (WHO) 24-hour global guideline for $PM_{2.5}$ of 15 $\mu g/m^3$ which also allows for 3-4 exceedances per year, 1 of the 3 monitoring sites breached the guideline. The Murchison central site measured a total of 5 days in which the average PM2.5 concentration exceeded 15 $\mu g/m^3$. The monitoring station at Motueka also exceeded the WHO guideline and recorded a total of 22 days above 15 $\mu g/m^3$.

Wind speeds during the study remained low throughout the study period and all wind directions were well represented reflecting the sheltered location of Murchison township. Under strong inversion conditions, there was evidence of katabatic cold-flow drainage down the river valley and this is probably the dominant dispersive mechanism during inversion conditions.

5.0 REFERENCES

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