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PREPARED FOR

West Coast Regional Council

PREPARED BY

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Air Quality Evaluation- Westport and Greymouth 2024

2416-WCRC213

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1 INTRODUCTION

The main air contaminant of concern in most urban areas of New Zealand is particulate typically measured as either the $PM_{2.5}$ or the PM_{10} size fraction. The finer $PM_{2.5}$ size fraction comprises all particles less than 2.5 microns in diameter and is a component of the PM_{10} size fraction. The finer $PM_{2.5}$ size fraction is the most relevant in terms of health impacts as these particles penetrate deep into the lungs resulting in a range of adverse health impacts. In 2021 the WHO released new air quality guidelines including an annual and daily guidelines for $PM_{2.5.}$ (World Health Organization, 2021) Both the annual guideline of 5 $\mu g/m^3$ and the daily guideline of 15 $\mu g/m^3$ are significantly lower than previous WHO guidelines for $PM_{2.5}$ (15 $\mu g/m^3$ and 25 $\mu g/m^3$ respectively (WHO, 2006)). The latter guidelines formed the basis of the proposed (2020) National Environmental Standard (NES) for $PM_{2.5}$ (Ministry for the Environment, 2020).

Air quality monitoring has been carried out in Westport during 2022 and 2023 to determine magnitude and spatial variability in $PM_{2.5}$ concentrations. Spatial variability studies were carried out during the winter months using SDS011 light scattering air quality monitoring instrument (Baynham, 2022). In 2023 $PM_{2.5}$ monitoring was also carried out using a reference method MetOne sampler to determine likely compliance with the proposed NES for $PM_{2.5}$ and the 2021 World Health Organisation (WHO) guidelines.

This report compares $PM_{2.5}$ monitoring data to NES and the WHO (2021) guidelines and evaluates the reliability of the monitoring site in light of the 2023 spatial monitoring. Data are considered in conjunction with meteorology to evaluate future monitoring needs for Westport.

This report also assesses emissions from key sources of particles in Greymouth and evaluates these spatially to identify hot spot areas where concentrations might be highest. These data are considered in conjunction with existing spatial monitoring data carried out in 2023 and meteorology to identify priority areas for the establishment of a long term monitoring site for $PM_{2.5}$ in Greymouth should further monitoring be necessary.

2 $PM_{2.5}$ MONITORING IN WESTPORT

2.1 Monitoring data summary – 2022

The 2023 air quality monitoring strategy for Westport included summary of the Mote 2022 air quality monitoring investigation. That study utilised a total of fifteen air quality samplers measuring concentrations of $PM_{2.5}$ using a light scattering method to assess spatial variability across Westport.

The monitoring period was carried out from 31 May to 8 September. The maximum $PM_{2.5}$ concentrations measured over the period was 55 µg/m^3 (24-hour average) and the majority of the samplers recorded breaches of the Ministry for the Environments 2020 proposed NES for $PM_{2.5}$ of 25 µg/m^3 (Ministry for the Environment, 2020). The report suggests that the proposed NES for $PM_{2.5}$ (daily average of 25 µg/m^3) was exceeded in Westport on three days during 2022. The WHO (2021) value of 15 µg/m^3 was exceeded on 21 days from 31 May to 8 September 2022.

Concentrations were found to be highest near the centre of town and lowest on the town boundaries. Highest concentrations occur at the northern end of the township and on the west side adjacent to the river.

2.2 2023 monitoring for PM_{10} and $PM_{2.5}$

Monitoring of PM_{10} and $PM_{2.5}$ concentrations were carried out in 2023 from 28 May to 27 September using a T640x sampler. This sampler has USEPA Appendix J equivalency status and therefore is a compliant method under the NES for PM_{10}. Monitoring was carried out at the Club Buller between Russell and Queen Streets as illustrated in Figure 2.1.

Figure 2-1: Location of T640x air quality monitoring site in Westport

An evaluation of the T640x PM_{10} and $PM_{2.5}$ concentrations against a MetOne High Volume (reference method - RM) sampler was carried out for the period 27 May to the 27 September. During this period both samplers were operating at the Buller Club monitoring site and a comparison of concentrations was made using Reduced Major Axis regression (Ayers, 2001). Figures 2.2 and 2.3 show the correlation between $PM_{2.5}$ and

PM_{10} concentrations (R^2 = 0.68 for $PM_{2.5}$ and 0.81 for PM_{10}). The relationship between the two samplers based on the 2023 colocation study using RMA regression is:

$PM_{2.5}$ – RM = 0.42 T640x + 1.2

PM_{10} – RM = 0.60 T640x – 1.16

Concentrations of PM_{10} and $PM_{2.5}$ measured using the T640x were adjusted based on the above relationships. The following evaluation of PM_{10} and $PM_{2.5}$ concentrations in Westport are based on T640x data adjusted for reference method equivalency.

Figure 2.2 shows the daily PM_{10} concentrations measured in Westport during 2023. The maximum measured PM_{10} concentrations was 39 µg/m^3 and no exceedances of the NES daily PM_{10} standard were recorded. The daily $PM_{2.5}$ concentrations throughout the monitoring period are shown in Figure 2.3. The maximum measured $PM_{2.5}$ concentration was 17 µg/m^3. The WHO (2021) guideline of 15 µg/m^3 was exceeded on five occasions and there was no breach of the proposed NES for $PM_{2.5}$ of 25 µg/m^3.

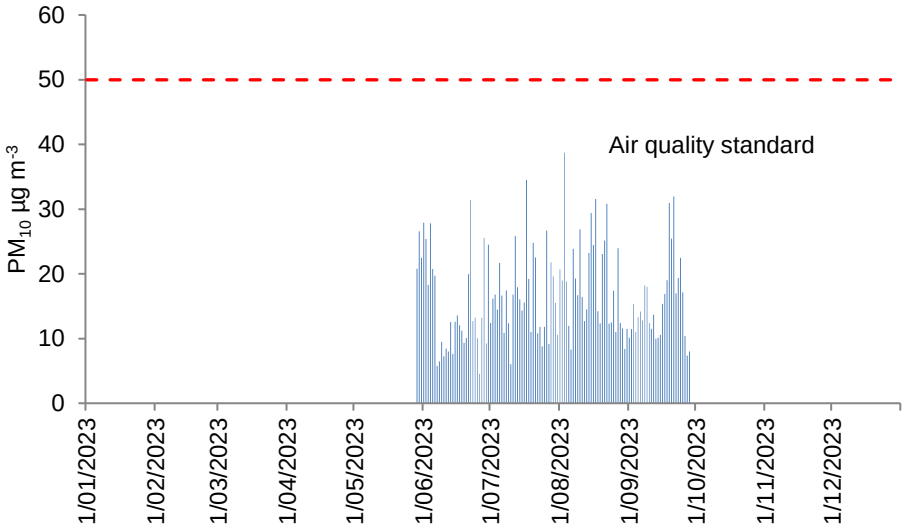


Figure 2-2: Daily average PM_{10} concentrations measured in Westport during 2023 compared with the NES for PM_{10} (50 µg/m^3, 24-hour average)

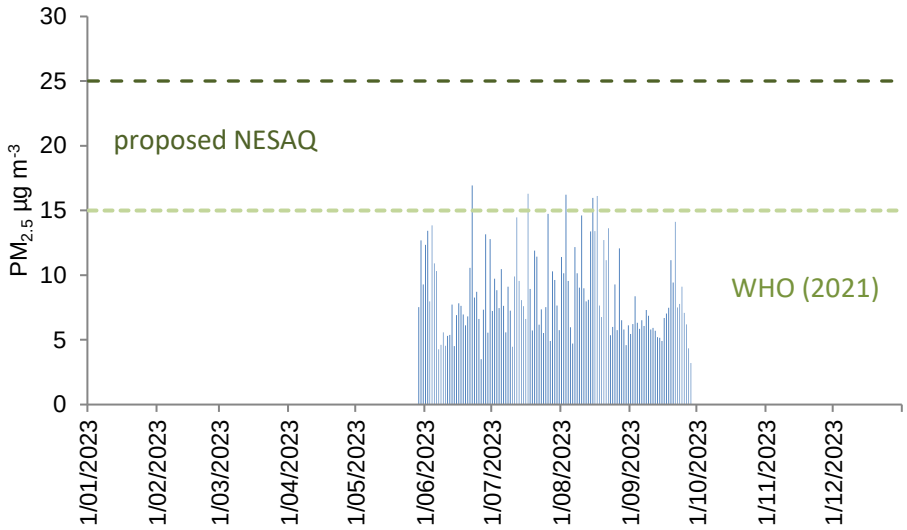


Figure 2-3: Daily average $PM_{2.5}$ concentrations measured in Westport during 2023 compared with the proposed NES and the WHO (2021) guideline.

It was not possible to calculate an annual average $PM_{2.5}$ concentrations from the data owing to only a month of data from non winter months. However, with a winter average $PM_{2.5}$ concentration of 18 µg/m^3 the annual average $PM_{2.5}$ concentrations is unlikely to be lower than 9 µg/m^3.

Figure 2.4 shows a strong correlation between the $PM_{2.5}$ and PM_{10} T640x concentrations measured at Westport with around 60% of the PM_{10} being in the $PM_{2.5}$ size fraction on average (range 31% to 75%). This compares with around 42% for the Met One $PM_{2.5}$ and PM_{10} data. Data suggests coarse mode contributions to PM_{10} concentrations averaging at least 40% during the winter months. Sources of coarse mode PM_{10} (particles between 2.5 and 10 microns) include marine aerosol and wind blown dusts as well as some anthropogenic sources such as aggregate and bulk solid materials handling and vehicle movements on unpaved yards.

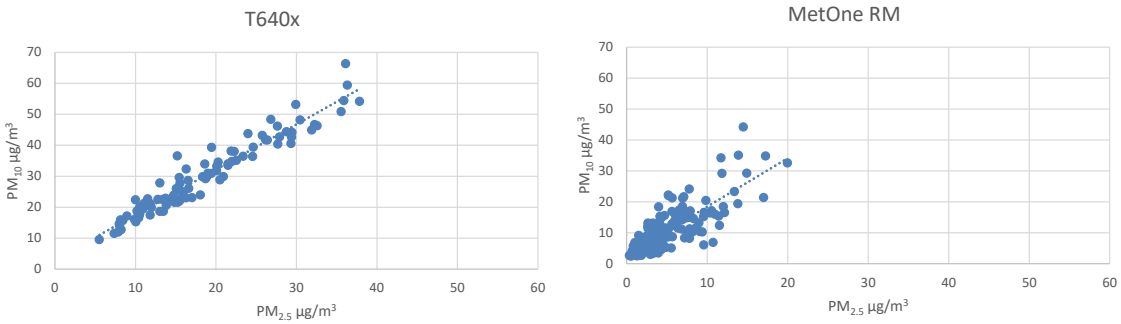


Figure 2-4: Relationship between $PM_{2.5}$ and PM_{10} (daily average) concentrations measured using the T640x and MetOne Reference Method.

2.3 Spatial variability in $PM_{2.5}$ concentrations in Westport

An air quality monitoring programme examining spatial variability in $PM_{2.5}$ concentrations across Westport in 2023 was carried out by Mote Ltd. The programme ran from 25 May until 21 September and measured $PM_{2.5}$ concentrations in 17 locations across Westport using optical $PM_{2.5}$ samplers. Whilst the monitoring method is not able to be used for assessing compliance with the NES, it does provide an indication of the relative differences in concentrations and thus is a useful tool for identifying worst case areas for $PM_{2.5}$ concentrations. Spatial sampling regimes tend to be less rigorous with regards to siting requirements and there may be increased susceptibility to impacts from local sources. Monitoring results should therefore be treated with care. Figure 2.5 shows the locations of 16 sites across Westport with a further site (no 258) located in an area to the north of Westport.

Table 2.1 summarises $PM_{2.5}$ concentrations from each site. The highest average and maximum 24-hour $PM_{2.5}$ concentrations in Westport were measured at site 491 which is located along Derby Street near to the Trotting Club and Rugby Club grounds. This area was the recommended location for monitoring in a 2023 report evaluating spatial distributions in $PM_{2.5}$ emissions in Westport (Wilton & Zawar Reza, 2023). It is noted, however, that the alternative location given in that report (Westport High School) recorded lower concentrations (site 917) and would not be preferable to the current monitoring site location (site 624). Concentrations at site 491 appear to be almost twice as high as those measured at the Club Buller air quality monitoring site (site 624 in Figure 2.5).

The other sites with high average concentrations include sites 153 and 730 (average 12 $\mu g/m^3$) both of which are in the high emission density areas illustrated in Wilton & Zawar Reza, (2023) and sites 258 (area north of Westport not shown) and 793.

Figure 2-5: 2023 spatial air quality monitoring site locations ($PM_{2.5}$)

Table 2.1: Summary $PM_{2.5}$ concentrations from 2023 spatial monitoring programme in Westport

	Site																
	153	**208**	**225**	**258**	**274**	**377**	**433**	**454**	**491**	**603**	**624**	**730**	**793**	**813**	**895**	**917**	**953**
	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$
Average	12	9	9	11	10	4	7	5	17	8	9	12	11	10	8	8	5
May	10	10	9	10	9	10	10	10	10	10	10	10	10	10	9	9	10
June	12	9	8	11	8	4	7	4	16	7	8	11	11	10	7	7	4
July	13	11	11	13	13	5	8	6	19	9	9	14	12	11	9	9	6
August	13	10	9	12	11	4	8	5	20	8	10	12	11	12	8	8	4
September	7	7	5	9	8	4	6	5	13	6	7	8	8	7	6	6	5
Maximum	25	18	18	35	24	13	16	13	45	19	20	27	22	22	16	17	14

2.4 Natural source contributions to PM_{10} and $PM_{2.5}$ concentrations in Westport

The relative contribution of natural sources including marine aerosol and dusts to PM_{10} and $PM_{2.5}$ concentrations in Westport was examined by GNS using analysis of filters collected from May to September 2023 at the Club Buller Site (site 624 in Figure 2.5). Spreadsheet data were provided by GNS to assist with this evaluation. The marine aerosol source contribution to $PM_{2.5}$ for the study period was around 17% and there was a 2% contribution from soils which may be natural or anthropogenic in origin. The relative contribution on high $PM_{2.5}$ concentrations days were lower at around 9% for marine aerosol and 3% for soils (for days when the WHO guideline of 15 µg/m^3 was exceeded) (Davy & Trompetter, 2024).

The main source of $PM_{2.5}$ concentrations at the Buller Club monitoring site is solid fuel burning for domestic heating (biomass combustion) which contributes around 76% of the daily winter $PM_{2.5}$ concentrations on average and 86% on high pollution days. Motor vehicles contributed 5% on average and 2% on high pollution days (Davy & Trompetter, 2024).

2.5 PM_{10}, $PM_{2.5}$ and meteorology

Figure 2.7 shows daytime and night-time wind roses for the Westport monitoring site for the period 25 May to 6 October 2023. During the daytime the most common wind direction at the Buller Street monitoring site is south to southwest. The strongest winds typically are from a south west wind direction. Calm conditions which give rise to elevated concentrations during the evening and nighttime occur predominantly when the wind ranges from south east, south and south west wind directions.

Temporal and seasonal variations in PM_{10} and $PM_{2.5}$ concentrations show highest concentrations occur during the evening period (Figure 2.8). Figures 2.9 and 2.10 show the average PM_{10} and $PM_{2.5}$ concentrations for each wind direction and speed (Figure 2.9) and time of day (Figure 2.10) by season, noting that autumn and spring data are limited. Winter data indicates higher PM_{10} concentrations occur under low wind speeds from east and south directions with highest concentrations occurring during the evening period. Elevated concentrations under high wind speeds occur from the northwest. The latter likely reflects marine aerosol contributions.

Figure 2.11 shows the contribution of each wind direction sector to average PM_{10} and $PM_{2.5}$ concentrations. This evaluation takes into account wind direction prevalence and concentrations. Thus Figure 2.11 shows the areas or directions that are having the most impact on concentrations at the monitoring site. For the Buller Club monitoring site the areas contributing the most to PM_{10} and $PM_{2.5}$ concentrations are south to southeast a pocket sector to the east and to the north west.

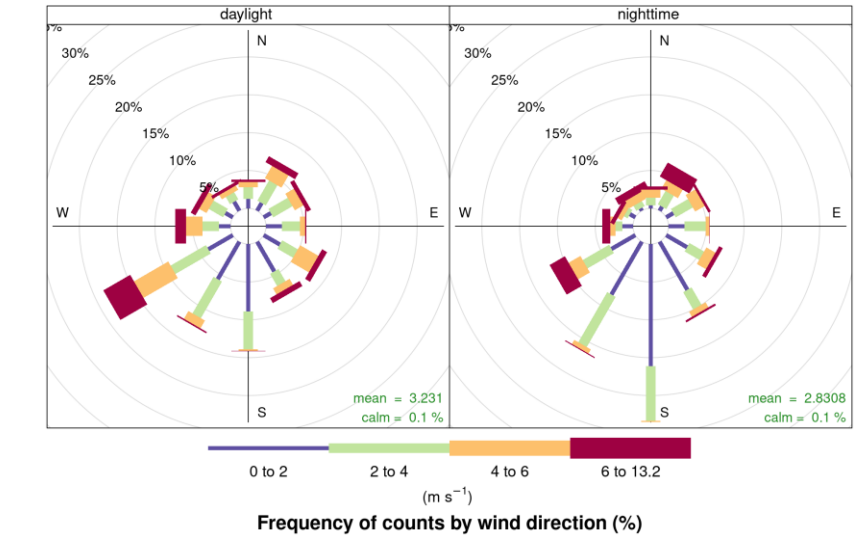


Figure 2-6: Wind roses for the Buller Club monitoring site – May to September 2023

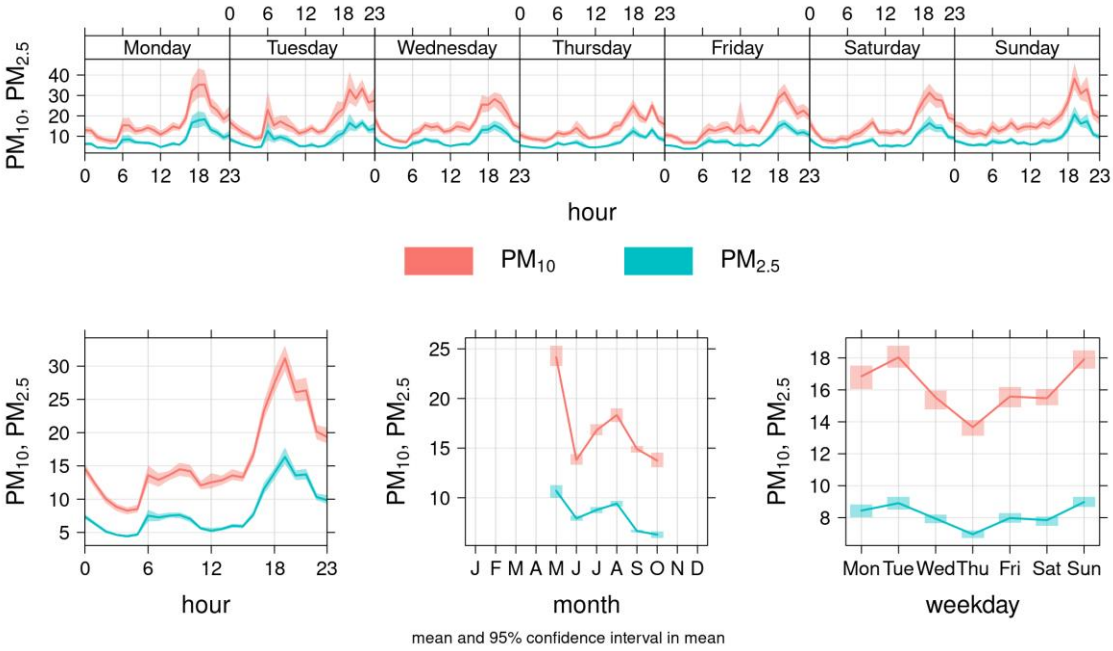


Figure 2-7: Temporal variability in PM_{10} and $PM_{2.5}$ concentrations in Westport

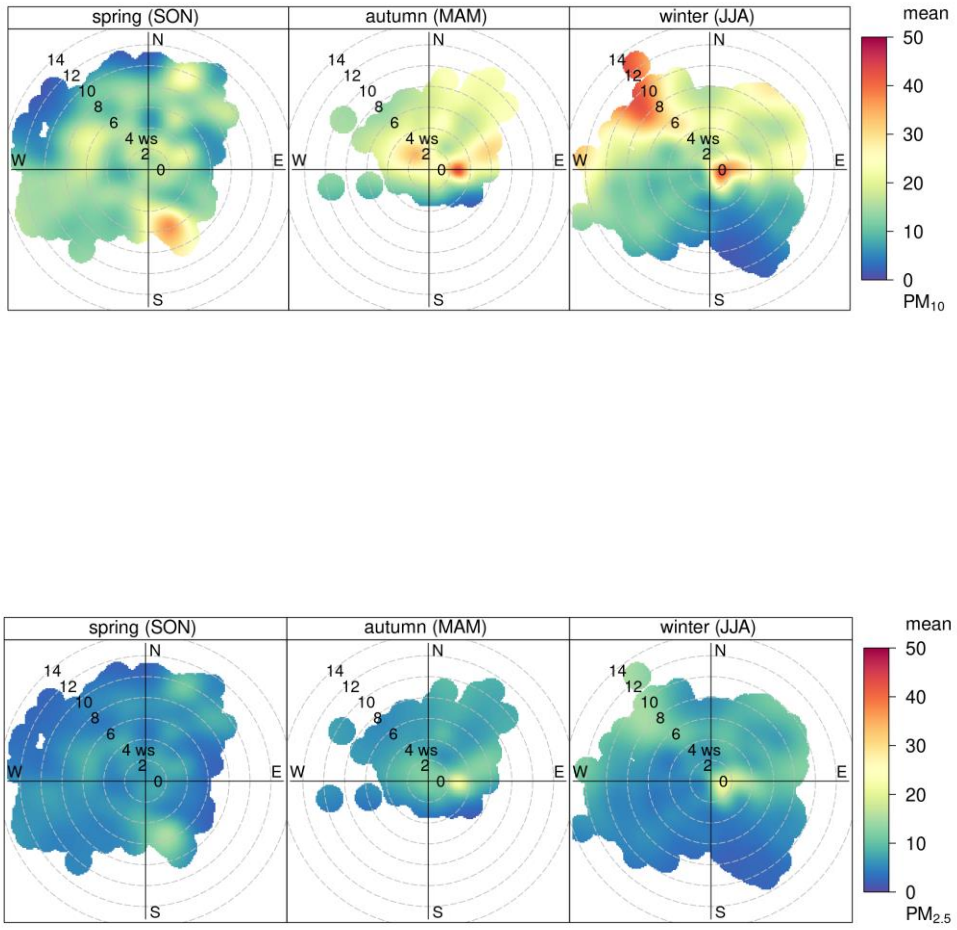
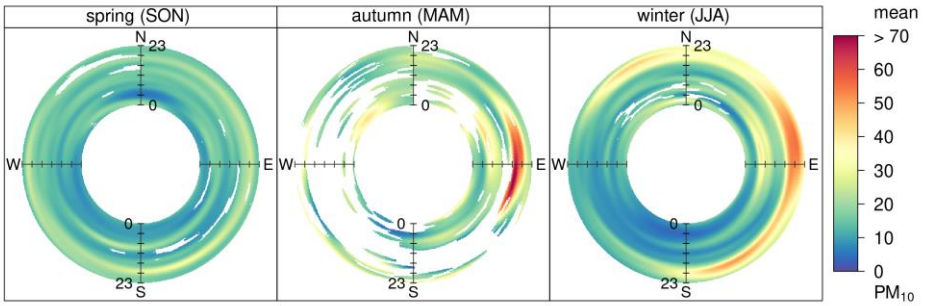


Figure 2-8: PM_{10} and $PM_{2.5}$ concentrations in Westport by wind speed and wind direction



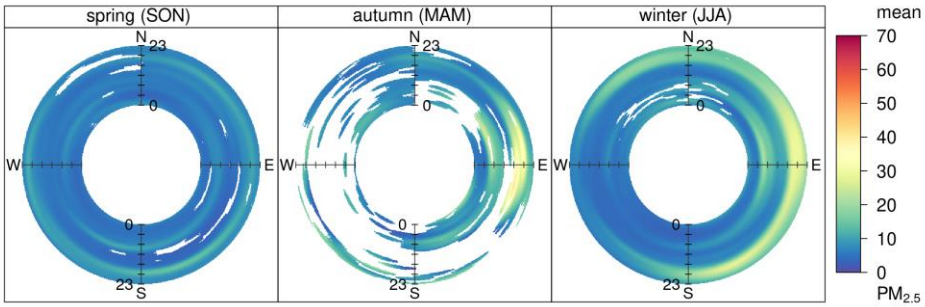


Figure 2-9: PM_{10} and $PM_{2.5}$ concentrations in Westport by wind direction and time of day

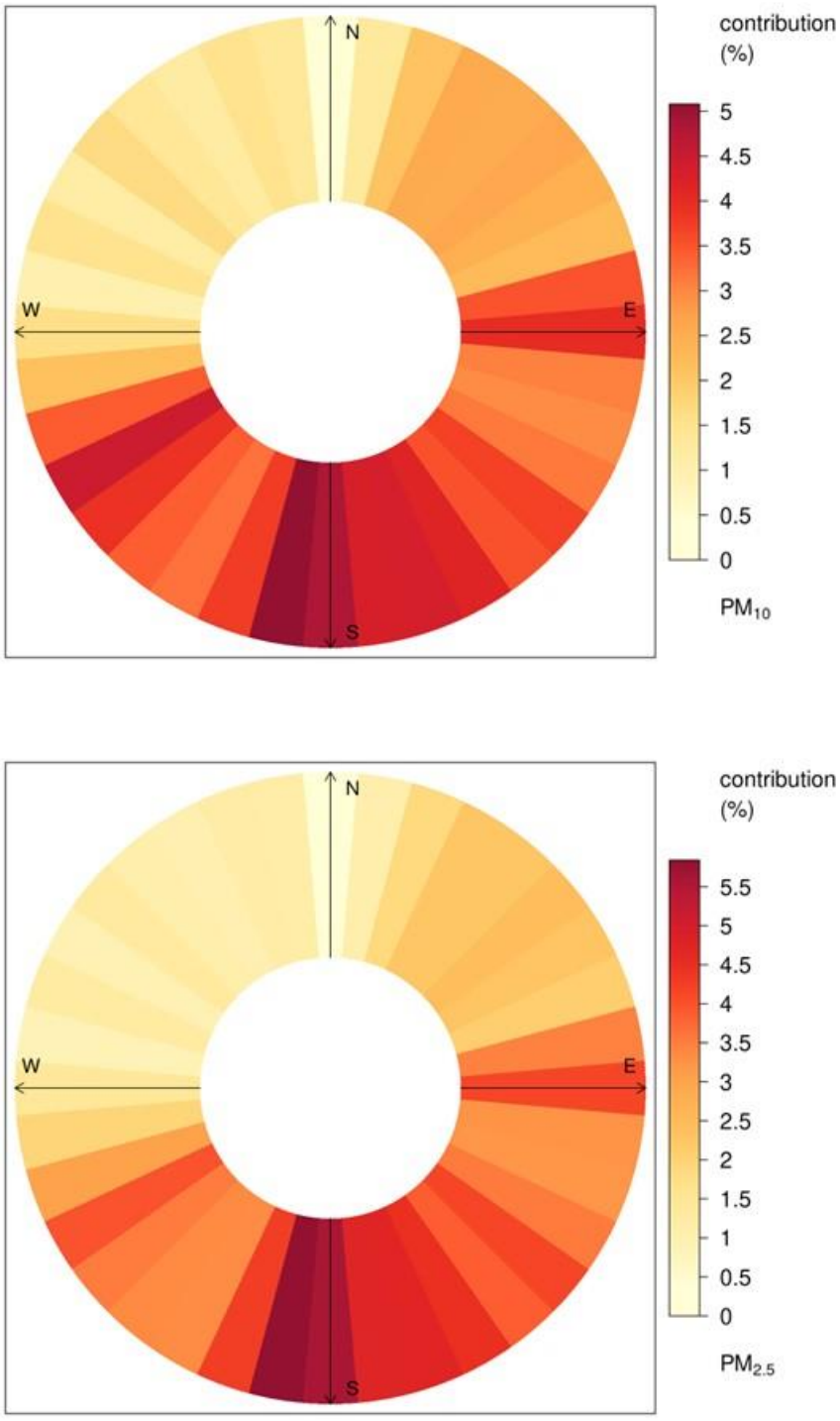


Figure 2-10: Relative contribution to PM_{10} and $PM_{2.5}$ concentrations by wind direction

3 EMISSION DENSITY AND MONITORING ASSESSMENT - GREYMOUTH

An emission density assessment is a useful tool to assist in evaluation air quality monitoring locations. An emission density assessment for Greymouth was carried out to identify hotspots where concentrations may be elevated under stagnant meteorological conditions.

3.1 Methodology

An SA1 level evaluation of emissions from domestic heating, outdoor burning, motor vehicles and industrial and commercial activities was conducted for Greymouth using a combination of census data (home heating emissions), household data, resource consent information and local NZTA vehicle kilometer travelled data.

The Statistical Area Two (SA2) areas of Greymouth Central, Marsden, Blaketown and Kings Park were used to define the emission assessment area. The SA2 areas are further broken down spatially into 36 SA1 level areas. Emissions are estimated at the SA1 level for domestic heating, motor vehicles, outdoor burning and industrial and commercial activities.

3.1.1 Domestic heating

Domestic heating methods were obtained from the 2018 census data SA1 estimates of households using different fuels and appliance types. Home heating methods were classified as; electricity, open fires, wood burners, pellet fires, multi fuel burners, gas burners and oil burners.

Emission factors were applied to these data to provide an estimate of emissions for each study area. The emission factors used to estimate emissions from domestic heating are shown in Table 3.2. The average fuel quantity (18 kilograms of wood per night) and age distribution of older wood burners (48% pre NES burners) was taken from the average of a range of 2022 air emission inventory surveys.

Table 3.1: Emission factors for domestic heating methods.

	PM_{10} g/kg	$PM_{2.5}$ g/kg	CO g/kg	NOx g/kg	SO_2 g/kg
Open fire - wood	7.5	7.5	55	1.2	0.2
Open fire - coal	21	18	70	4	8
Pre 2006 burners	10	10	140	0.5	0.2
Post 2006 burners	4.5	4.5	45	0.5	0.2
Pellet burners	2	2	20	0.5	0.2
Multi-fuel[1] - wood	10	10	140	0.5	0.2
Multi-fuel[1] – coal	19	17	110	1.6	8
Oil	0.3	0.22	0.6	2.2	3.8
Gas	0.03	0.03	0.18	1.3	7.56E-09

[1] - includes potbelly, incinerator, coal range and any enclosed burner that is used to burn coal

Emissions for each contaminant were calculated based on the following equation:

Equation 3.1 CE (g/day) = EF (g/kg) * FB (kg/day)

CE = contaminant emission

EF = emission factor

FB = fuel burnt

3.1.2 Motor vehicles

Motor vehicle emissions to air include tailpipe emissions of a range of contaminants and particulate emissions occurring as a result of the wear of brakes and tyres. Assessing emissions from motor vehicles involves collecting data on vehicle kilometres travelled (VKT) and the application of emission factors to these data.

Emission factors for motor vehicles are determined using the Vehicle Emission Prediction Model (VEPM 6.0) developed by Auckland Council. Emission factors for PM_{10}, $PM_{2.5}$, CO and NOx for this study have been based on VEPM 6.0. Default settings were used for all variables. Resulting emission factors are shown in Table 4.2.

Emission factors for SOx were estimated for diesel vehicles based on the sulphur content of the fuel (10ppm) and the assumption of 100% conversion to SOx. The g/km emission factor was estimated using VEPM 6.0 using the fuel consumption per VKT for the parameters described above.

The number of vehicle kilometres travelled (VKT) was estimated using the New Zealand Transport Authority VKT data (Table 4.3) for Grey District disaggregated to SA1 level based on the proportion of households within each SA1 area.

In addition to estimates of tailpipe emissions and brake and tyre emissions using VEPM an estimate of the non-tailpipe emissions (including brake and tyre wear and re-suspended road dusts) was made using the EMEP/EEA air pollutant emission inventory guidebook (2016). The emission factors from this method are shown in Table 4.4. It is noted that emission factors for fugitive sources such as resuspended dusts can have a high level of uncertainty.

Table 3.2: Emission factors (2023).

2023	CO g/VKT	PM_{10} g/VKT	PM brake & tyre g/VKT	NOx g/VKT	NO_2 g/VKT	$PM_{2.5}$ g/VKT	$PM_{2.5}$ brake & tyre g/VKT
Fleet profile	1.4	0.02	0.02	0.65	0.13	0.02	0.01

Table 3.3: VKT daily and annual (NZTA, 2021).

		Annual VKT
Greymouth	148401	54166341

3.1.3 Industrial and commercial activities

Industrial and commercial activities to be included in the inventory were identified by searching the Council's resource consent database.

Information on activities with resource consents for discharges to air in Greymouth were provided by the West Coast Regional Council. These included a range of combustion activities, and aggregate handling and storage facilities.

Emissions were estimated using activity data and emission factor information, as indicated in Equation 5.2. Activity data from industry includes information such as the quantities of fuel used, or in the case of non-combustion activities, materials used or produced.

Equation 5.2 Emissions (kg) = Emission factor (kg/tonne) x Fuel/Material use (tonnes)

3.1.4 Outdoor burning emissions

Outdoor burning emissions were estimated using 2022 emission inventory data averaged to an emissions per household basis, for areas where outdoor burning is not prohibited during the winter months. These were estimated at the SA1 level using 2018 household data from the census.

Table 3.4: Outdoor burning emissions per household basis

Garden waste kg/hh/year PM_{10}	Garden waste kg/hh/year CO	Garden waste kg/hh/year Nox	Garden waste kg/hh/year Sox	Garden waste kg/hh/year $PM_{2.5}$
2.0	6.8	0.5	0.1	1.9

3.2 Results

Figure 3.1 shows and estimate of the relative contribution of sources to daily and annual $PM_{2.5}$ emission in Greymouth. It is noted that the methodology is less robust than a site specific inventory with surveying but provides a strong indication that domestic heating is the main contributor to $PM_{2.5}$ emissions.

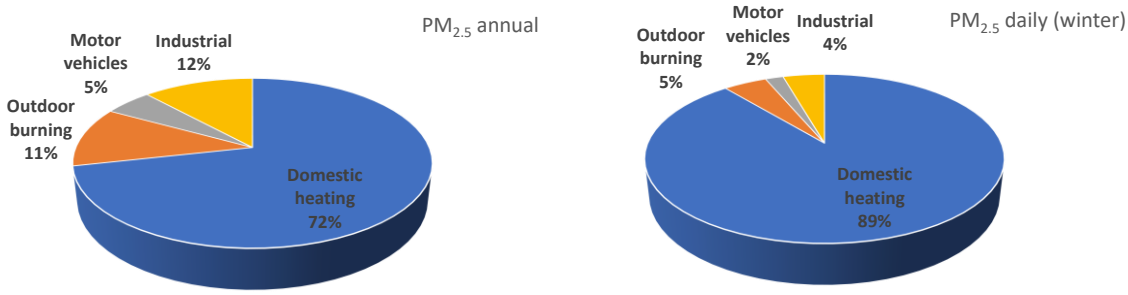


Figure 3-1: Relative contribution of sources to daily and annual $PM_{2.5}$ in Greymouth

The spatial distribution in $PM_{2.5}$ concentrations in Greymouth will depend largely on domestic heating emissions in conjunction with meteorological conditions. Figure 3.2 shows the spatial distribution in daily $PM_{2.5}$ emissions from domestic heating, industry, outdoor burning and motor vehicles in Greymouth.

Annual variations are also illustrated in Figure 3.3. This suggests areas of highest emission density between Milton and High Streets bordered also by Marlborough Street and Joyce Crescent and in the Marsden area between Marlborough Street and Marsden Road and between Marlborough Street and Leith Crescent. The nearby Grey Main School would likely be a suitable monitoring site being located between these highest emission density areas.

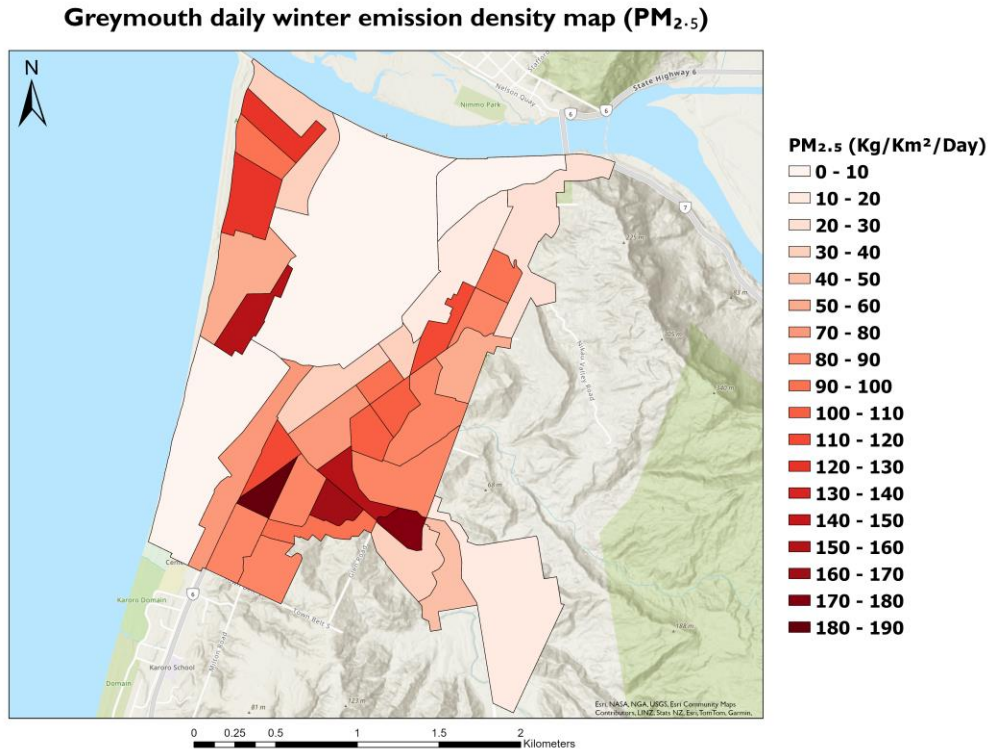


Figure 3-2: Emission density for daily $PM_{2.5}$ in Greymouth (kg/km²/day)

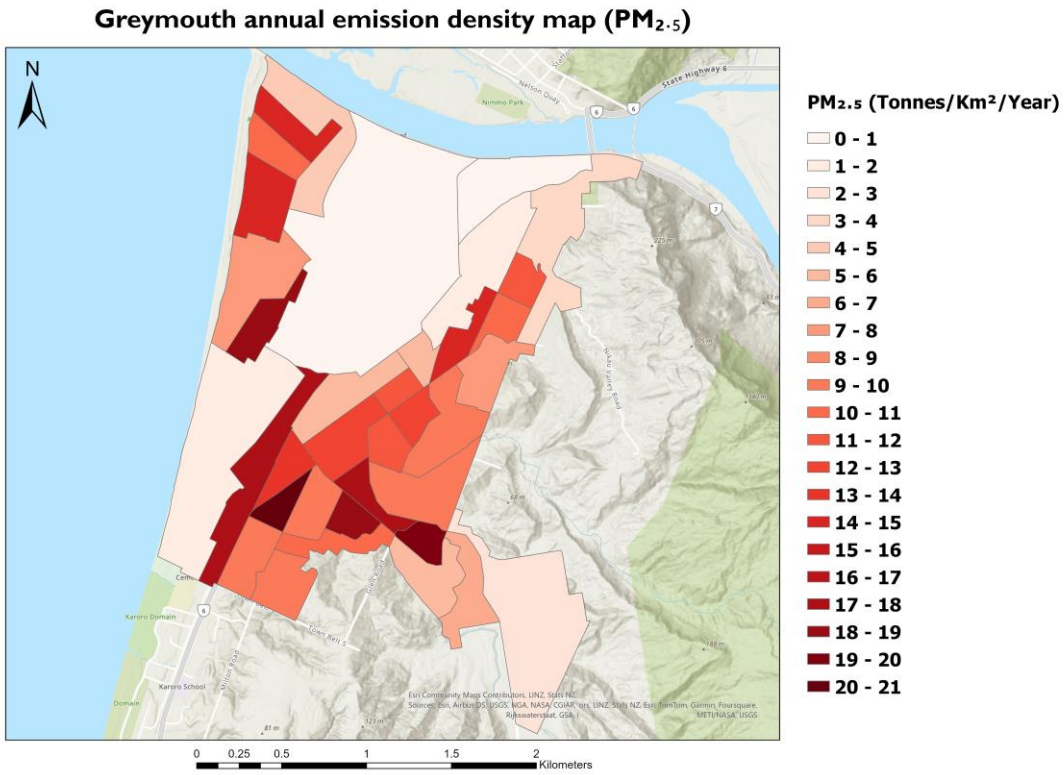


Figure 3-3: Emission density for annual $PM_{2.5}$ in Greymouth (tonnes/km²/year)

3.3 Greymouth investigative monitoring

Investigative monitoring for $PM_{2.5}$ concentrations was carried out during 2023 using purple air samplers. These are an optical method of monitoring which have been used to provide indications of spatial variability in concentrations but cannot be relied upon for absolute concentrations.

Council had difficulties with the purple air data outputs and were unable to obtain adequate information to resolve uncertainties.

It is unlikely that the monitoring data from purple samplers will add significantly to the information presented in the emission density assessment for Greymouth. That work recommends a suitable monitoring site for measuring compliance with the air quality guidelines.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Westport

Air quality monitoring in Westport during winter 2023 was carried out at the Buller Club with several instruments measuring both PM_{10} and $PM_{2.5}$ concentrations. The T640x sampler was found to overestimate $PM_{2.5}$ and PM_{10} concentrations. The following adjustment equations were found using RMA regression of this method against data from a Met One Reference Method sampler.

$PM_{2.5}$ - T640x = 0.42 RM + 1.2

PM_{10} – T640x = 0.60 RM – 1.16

Once data had been adjusted PM_{10} concentrations were found to comply with the NES at the Buller Club monitoring site. Concentrations of $PM_{2.5}$ exceeded the WHO (2021) guideline of 15 µg/m^3 (daily average) on five occasions.

The ratio of $PM_{2.5}$ to PM_{10} averaged at least 60% (T604x result) but could be around 40% (Met One result) indicating a substantive coarse mode contribution to PM_{10} concentrations. An evaluation by GNS found the main sources of coarse mode particulate to be biomass burning (around 70% on average) and natural sources around 26% with 18% of that being marine aerosol and 8% soil.

An evaluation of spatial variability in $PM_{2.5}$ concentrations in Westport found that the Buller Club site is likely to measure $PM_{2.5}$ concentrations almost a factor of two lower than the peak area which was a location at the northern end of Derby Street. The latter is consistent with a 2023 evaluation of emission density in Westport.

It is recommended that T640x monitoring data continue to be adjusted for gravimetric equivalency and that the monitoring site for Westport be relocated to an area in the vicinity of northern Derby Street.

The PM_{10} and $PM_{2.5}$ daily profile was consistent across the week with increasing concentrations in the late afternoon consistent with profiles observed in areas where domestic heating is a key contributor. Source contributions were highest when the wind was from the south to southeast directions and under low wind speeds. Some elevated concentrations when the wind was blowing from the northwest and under high wind speeds were identified and were likely to be associated with marine aerosol contributions.

4.2 Greymouth

An emissions assessment for Greymouth shows domestic heating is the main source of both $PM_{2.5}$ and PM_{10} emissions. The highest emission density areas were identified as locations in the Marsden valley and Central Greymouth around the Grey Main School.

Investigative monitoring carried out during 2023 is not robust enough to inform as to the extent to which concentrations in Greymouth will comply with health guidelines.

It is recommended that a monitoring site be established at the Grey Main School and that $PM_{2.5}$ concentrations be measured using a reference method or equivalent sampler for a minimum period of one year.

4.3 Overall

Results from this work give increased understanding of monitoring requirements and sources of particulate in Westport and Greymouth. Establishing the likely worst case locations for monitoring, as required under the national environmental standards, will help protect the health of Westport and Greymouth residents as it will enable appropriate management measures to be adopted that adequately address the magnitude of the problem. Moreover, analysis of temporal variability and meteorological evaluations conducted supports

previous source identification methods and assists with targeting key contributing sources. This will support any regulatory measures adopted by Council targeting these sources which will ultimately will result in improvements in air quality and benefit the health of the community.

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