Raumati South air quality investigation

Winter 2010 particulate matter concentrations and sources

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Executive summary

This report summarises the findings of a short-term air quality investigation carried out in Raumati South during winter 2010. Air quality was investigated to assess the levels of and sources of particulate matter measured as $PM_{2.5}$ (fine fraction) and $PM_{2.5–10}$ (coarse fraction).

The results show that $PM_{2.5}$ concentrations can become elevated during periods of stable weather, characterised by calm and cold conditions. While the results are not directly comparable to national standards and guidelines, they do indicate that there is a risk of the daily limit set by the national environmental standard for PM_{10} being exceeded on occasion during the winter months.

Elemental analysis of the particulate matter collected during sampling and subsequent receptor modelling showed that the concentrations of $PM_{2.5}$ are dominated by biomass burning from domestic woodburners. The coarse fraction is mainly composed of marine aerosol which has been transported from the Tasman Sea and southern oceans.

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1. Introduction and background

Greater Wellington monitors air quality at a number of permanent stations through out the region as part of its State of the Environment (SoE) monitoring programme that characterises regional air quality. Targeted investigations are also carried out as resources permit to gather information about areas which may have degraded air quality due to local emission sources. Standard monitoring equipment is used for SoE monitoring so results can also be used to assess compliance with the national environmental standards for air quality[1]. Targeted investigations generally use non-standard monitoring equipment which has the advantage of allowing the sources of air pollution to be identified as well as their concentrations.

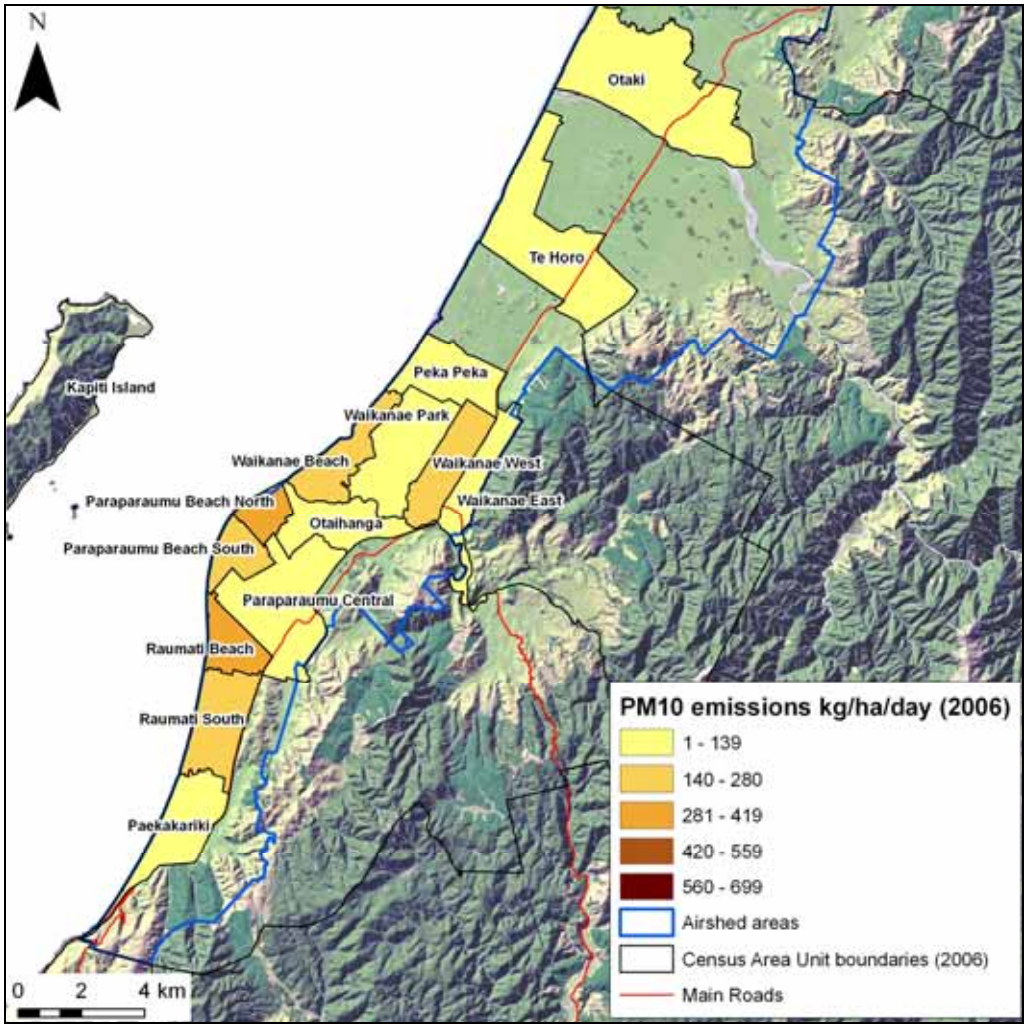
Monitoring carried out in rural Otaki (October 1998 to February 1999) showed that during the summer months there were occasional episodes of high particulate matter concentrations. The source of particulate matter was found to be suspended soil particles, most likely arising from wind-borne alluvial fines from the nearby Otaki River bed (Davy 2005)

Some residents of Raumati South have raised concerns about the effects of wood burner emissions on air quality for a number of years. This report documents the results of a targeted investigation carried out in Raumati South to assess winter air quality. The investigation was designed to provide information on the relative contribution of emissions from woodburners to levels of particulate matter measured in outdoor air.

1.1 Raumati South study area

Raumati South is a small coastal settlement within the Kapiti Coast airshed of the Wellington region. The Raumati South census area unit contains 798 households, of which 738 reported burning wood and 60 reported using coal for home heating (2006 census, Statistics NZ). Figure 1.1 shows the estimated average winter's day emissions density (PM_{10}/ha/day) due to domestic heating using both wood and coal by census area unit in the Kapiti Coast airshed (Wilton et al. 2010).

[1] Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins, and Other Toxics) Regulations 2004.



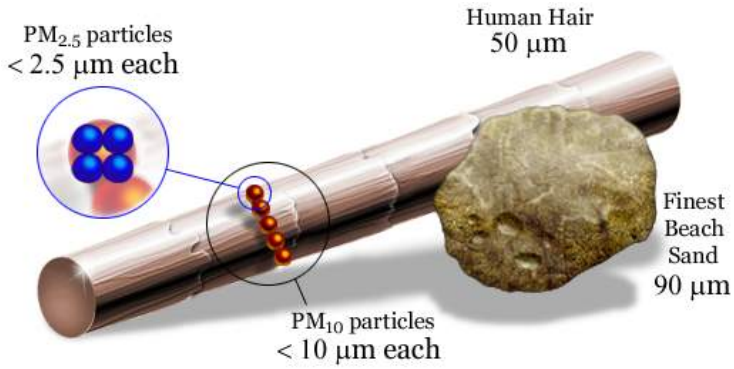
Source: Emission and Socio-Economic Spatial Model (Wilton et al. 2010)

Figure 1.1: PM_{10} emissions density (PM_{10}/ha/day) for Kapiti Coast census area units (2006 data)

1.2 Properties and sources of particulate matter

Particulate matter is a complex mixture of solid particles and aerosols which have a range of physical properties and toxicities depending on its source. Particulate matter is usually classified by size (Figure 1.2); PM_{10} refers to particles less than 10 μm in diameter. The PM_{10} size range is further divided into "fine" particles less than 2.5 μm ($PM_{2.5}$) and "coarse" particles measuring between 2.5 and 10 μm ($PM_{2.5–10}$).

Particulate matter produced by domestic open fires (e.g., woodburners), motor vehicles and other combustion sources is predominantly in the fine size fraction ($PM_{2.5}$). Natural sources, such as marine aerosol (long-range transported sea-salt) and soils produce coarser particles mainly, in $PM_{2.5}$ to PM_{10} size range and above.



(Source: www.mfe.govt.nz)

Figure 1.2: Particulate matter sizes relative to the width of a human hair and a grain of sand. PM_{10} is "inhalable", (i.e., can enter the lung area) and $PM_{2.5}$ is "respirable", (i.e., can be absorbed into the bloodstream via the lung gas-exchange surface).

1.3 National standards and guidelines for particulate matter

National environmental standards for air quality came into force in 2005. These standards include a daily limit for PM_{10} of 50 $\mu g/m^3$; this limit may only be exceeded on one day in a given year. The national environmental standard provides a set level of public health protection for all New Zealanders.

There is currently no national standard or guideline for $PM_{2.5}$. The Ministry for the Environment (2002) recommend undertaking investigations into the sources of $PM_{2.5}$ where daily values exceed 25 $\mu g/m^3$. The World Health Organisation (2006) guideline for $PM_{2.5}$ is 25 $\mu g/m^3$ with the provision that this may be exceeded on three days per year.

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2. Monitoring site and method

2.1 Site location

The monitoring site was situated on Glen Road, next to the Raumati South Bowling Club (Figure 2.1). Raumati South (in particular the Glen Road area) is located within a low-lying area with topography that may be conducive to restricting the dispersion of pollutants under still and cold conditions.

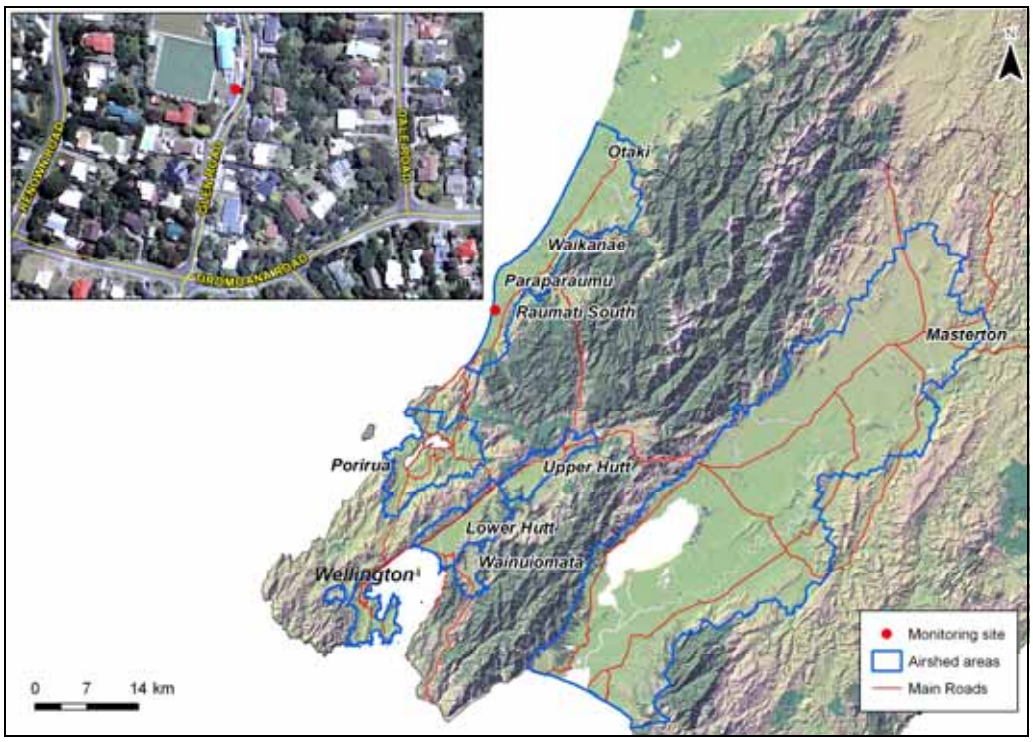


Figure 2.1: Location of Raumati South (red dot) monitoring site within the wider Kapiti Coast airshed. The inset shows the location of the air quality monitor on Glen Road.

2.2 Monitoring variables, frequency and equipment

Particulate matter was sampled as two size fractions – fine ($PM_{2.5}$) and coarse ($PM_{2.5–10}$). Consecutive 12-hour samples were obtained for each am period (midnight to midday) and pm period (midday to midnight) each day from 25 May to 2 August 2010 using a Dichotomous Partisol Sequential sampler (Model 2025-D, Thermo Scientific) as shown in Figure 2.2. This instrument is designated as an "equivalent method" in accordance with USEPA Title 40, Part 53 of the Code of Federal Regulations (40 CFR Part 53) for the measurement of $PM_{2.5}$ (Manual Equivalent Method EQPS-0509-180) and $PM_{2.5-10}$ (Manual Equivalent Method EQPS-0509-180) for continuous 24-hour sample periods.

Figure 2.2: Air quality monitoring equipment (Partisol) on Glen Road, Raumati South

The Partisol does not have USEPA equivalency for PM_{10} monitoring and therefore the requirements of the national regulations with respect to public reporting of monitoring results do not apply. Furthermore, the sampling was not undertaken as a continuous 24-hour period as required by the regulations but as consecutive 12-hour periods in order to provide sufficient samples to undertake source apportionment analysis.

Particulate matter concentrations were determined gravimetrically, (i.e., the mass of particles collected is determined by the difference between the weight of the filter before and after exposure). Samples were collected using Whatman 46.2 mm diameter, 2 μm pore size PTFE filters. Filters were conditioned and weighed by GNS Science in an humidity and temperature controlled environment using a microbalance with a resolution of 0.01 mg. Each filter was weighed three times and the average used to determine its weight.

The Partisol has a volumetric dual flow control system that maintains an overall flow rate of 16.67 L/min that is split into 15.0 L/min and 1.67 L/min flows to sample the fine and coarse particle streams respectively. Instrument flows were monitored via telemetry to ensure that flow rates were correctly maintained during the entire sampling period. Sampled volumes were corrected to standard conditions (i.e., 0^oC and 101.3 kPa).

The Partisol was co-located with a FH62 beta attenuation monitor (Automated Equivalent Method: EQPM-1102-150) for 16 days at the Wairarapa College air quality monitoring site in Masterton during August 2009. A linear relationship (R^2 = 0.82) between the two measurements was established as: Partisol (24-hour PM_{10}) = 2.18 + 0.82*FH62(24-hour PM_{10}). This indicates that the Partisol reads slightly higher than the FH62 although this relationship may not apply to measurements above 35.1 $\mu g/m^3$, the highest measurement obtained by the FH62 during the co-location exercise.

A Vaisala WS425 ultrasonic wind speed and direction sensor was installed on the TV aerial post on the roof of the Bowling Club. The wind sensor was mounted approximately 1.5 m above the roof line – estimated to be 5 m above the air quality monitoring instrument. Ambient air temperature was measured using a shielded Cambell Scientific CS107 at a height of approximately 1.4 m above the air quality monitoring instrument.

2.3 Quality assurance

In total 142 consecutive 12-hour samples were taken. One sample period was invalidated due to instrument failure and seven sample periods were used as field blanks (i.e., filters exposed for 12 hours with no air flow).

2.4 Source apportionment

Source apportionment was carried out by GNS Science using the particulate matter collected on the exposed filters. Elemental concentrations in the particulate samples were determined using ion beam analysis techniques at the New Zealand Ion Beam Analysis Facility at Gracefield, Lower Hutt. The relative emission source contributions were identified using receptor modelling techniques including positive matrix factorisation. A full description of the methodology is available in Davy et al. (2011).

3. Results and discussion

3.1 Particulate matter (PM)

The full set of monitoring results is included in Appendix 1. The 24-hour averages (midnight to midnight) for each day have also been calculated. A summary of the gravimetric monitoring results are presented in Table 1.

Table 3.1: Summary of PM monitoring results for Glen Road, Raumati South, for the period 25 May to 2 August 2010

	24-hour averages (µg/m³)			12-hour averages (µg/m³)		
	PM_{10}	$PM_{2.5}$	$PM_{2.5-10}$	PM_{10}	$PM_{2.5}$	$PM_{2.5-10}$
Mean	24.4	15.7	8.7	24.1	15.5	8.7
Maximum	61.7	54.6	36.6	97.5	75.2	62.0
Minimum	4.8	2.4	0.9	0.2	0.2	0.0
25th percentile	14.2	7.3	4.9	11.9	5.2	4.3
Median	22.5	10.3	7.0	20.0	8.7	7.1
75th percentile	29.9	22.4	9.3	34.0	20.1	9.9
95th percentile	49.8	38.7	20.3	56.0	45.3	24.7
99th percentile	64.3	54.1	35.9	78.3	60.5	37.1
Std deviation	14.1	12.4	7.0	17.3	15.2	8.6

There was a strong positive correlation between daily concentrations of $PM_{2.5}$ and PM_{10} ($r = 0.87$) indicating that daily PM_{10} concentrations are being driven by the $PM_{2.5}$ concentration. There was no obvious relationship between the fine and coarse fractions; this indicates that they originate from different emission sources.

3.2 Meteorology

3.2.1 Wind and temperature summary

A wind rose shows that during the monitoring period winds were predominantly aligned on a north-east to south-west transect (Figure 3.1). Wind speeds were less than 2 m/s well over half the time and less than 1 m/s almost 40% of the time.

During the monitoring period, the minimum hourly temperature recorded was -3.2°C, the maximum was 15.7°C, and the mean was 7.9°C.

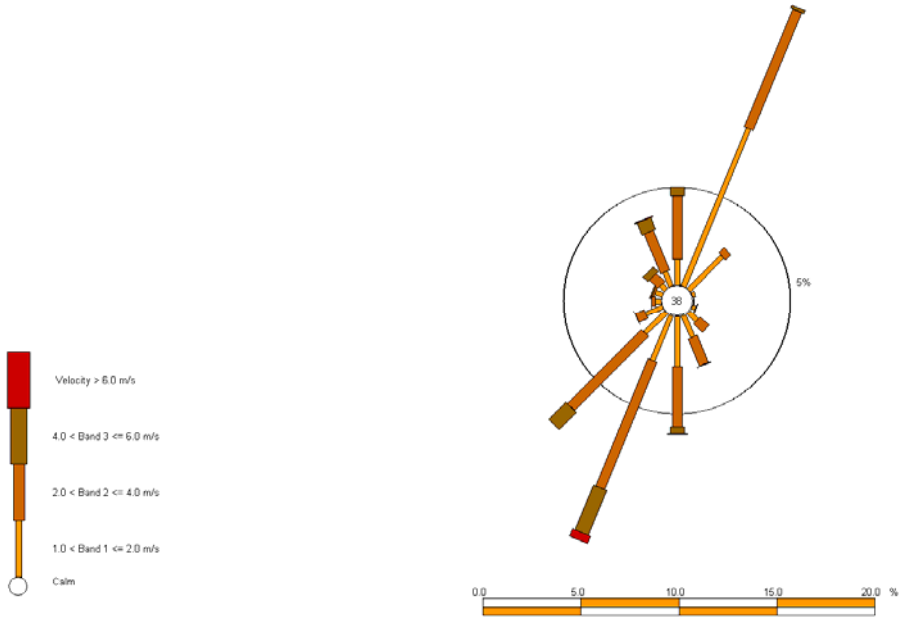
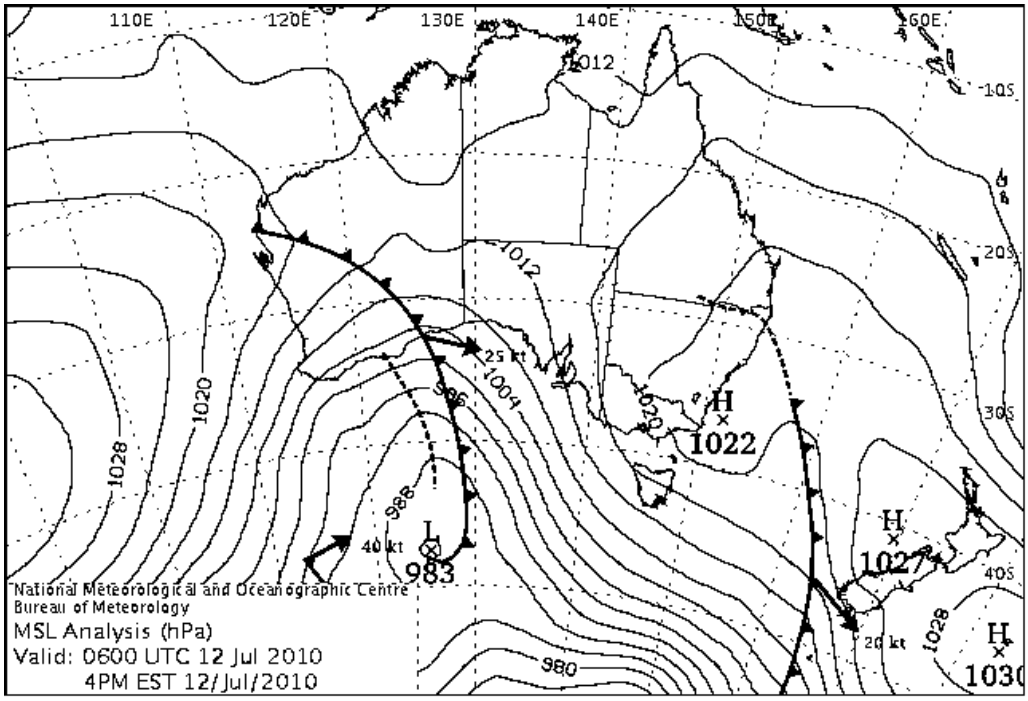


Figure 3.1: Wind rose for Glen Road, Raumati South for the period 1 June to 4 August 2010

3.2.2 Influence of meteorology on air pollution

High pollution days with elevated $PM_{2.5}$ were recorded between 11th and 16th of July. These days are notable because they represent a period of sustained calm weather coupled with very cold overnight temperatures. Anticyclonic conditions were present during this period (Figure 3.2).



(Source: Australian Bureau of Meteorology 2010)

Figure 3.2: Synoptic scale surface pressure map of Australia and New Zealand on 12 July 2010 when the highest $PM_{2.5}$ concentrations were recorded

A simple correlation analysis (Figure 3.3) shows that daily concentrations of $PM_{2.5}$ were inversely related to both mean daily temperatures (r = -0.76) and minimum hourly temperature (r = -0.78). Therefore, colder days lead to higher observed $PM_{2.5}$ levels. Average daily wind speed was also inversely related to daily $PM_{2.5}$ levels, although this relationship was weaker (r = -0.60). The percentage of hours per day with calm winds (i.e., wind speeds less than 1 m/s) were associated with high $PM_{2.5}$ levels (r = 0.76).

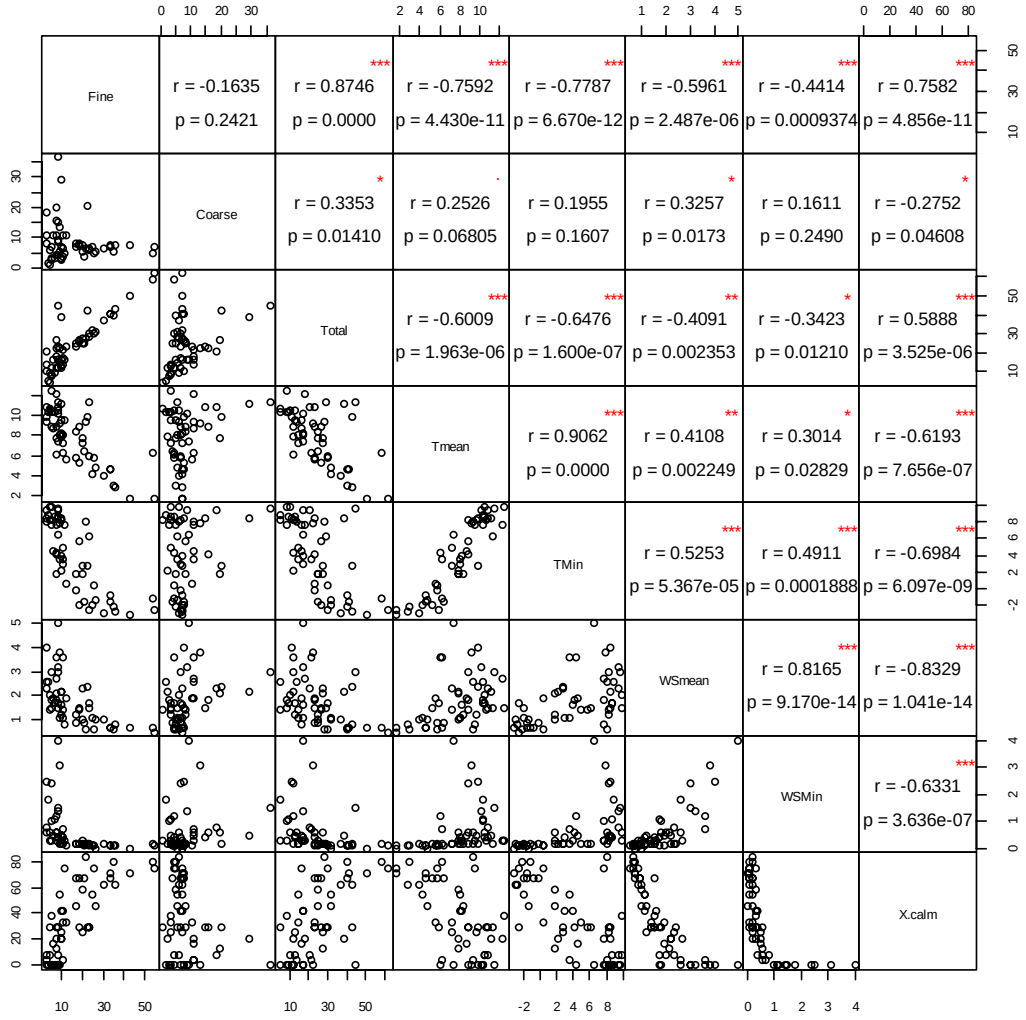


Figure 3.3: Scatter plot of 24-hour average $PM_{2.5}$ (Fine), $PM_{2.5\text{-}10}$ (Coarse) and PM_{10} (Total) concentrations together with selected meteorological variables. The plot shows Pearson correlation coefficients (r values) and associated p values (i.e., whether the correlation coefficient is significantly different from zero).

A multiple linear regression model fitted to the data shows that mean daily temperature and percentage of calm periods during the day explained 75% of the variation in $PM_{2.5}$ daily concentrations. There was a statistically significant interaction effect between mean daily temperature and percentage of calm periods (p = 0.0016). This means that the effect of mean temperature on the concentration of $PM_{2.5}$ varies depending on the percentage of calm periods during the day. On windy days, low mean temperatures do not lead to high $PM_{2.5}$ concentrations, whereas on calm days (percentage calms above about 60%) low mean temperatures are associated with high $PM_{2.5}$ levels.

It should be noted that meteorology not only influences the dispersion of $PM_{2.5}$ but also influences human behaviour. People are more likely to use their woodburners on cold days and cold days are often associated with calm conditions (r = -0.70 for minimum daily temperature and percentage daily calm periods). Because there are no real-time emissions data to compare with air quality data it is not possible to completely disentangle the effects of meteorology on air pollution.

3.3 Comparison to guidelines and standards

Although the results are not directly comparable to air quality standards and guidelines, the results show the *potential* for exceedences in Raumati South. Figure 3.4 shows the national standard for PM_{10} and the World Health Organisation guideline for $PM_{2.5}$ applied to the Raumati South monitoring results.

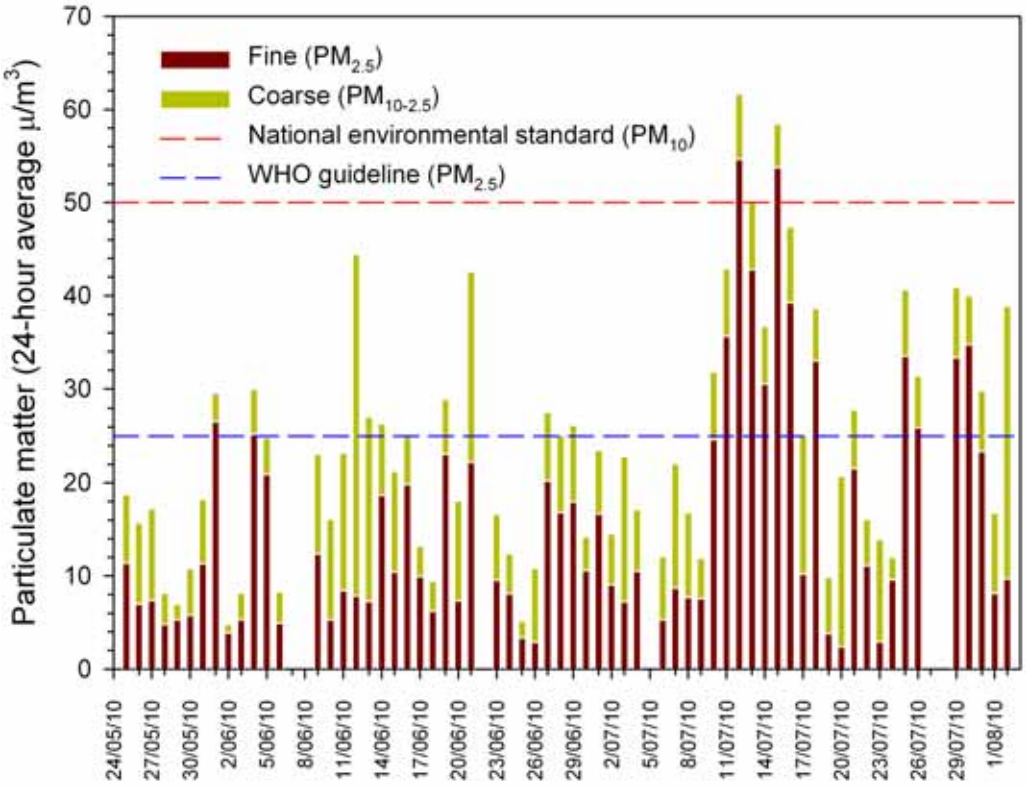


Figure 3.4: Time series of average daily PM_{10} concentrations recorded at Glen Road, Raumati South, for the period 25 May to 2 August 2010

3.4 Source apportionment

3.4.1 Sources of particulate matter

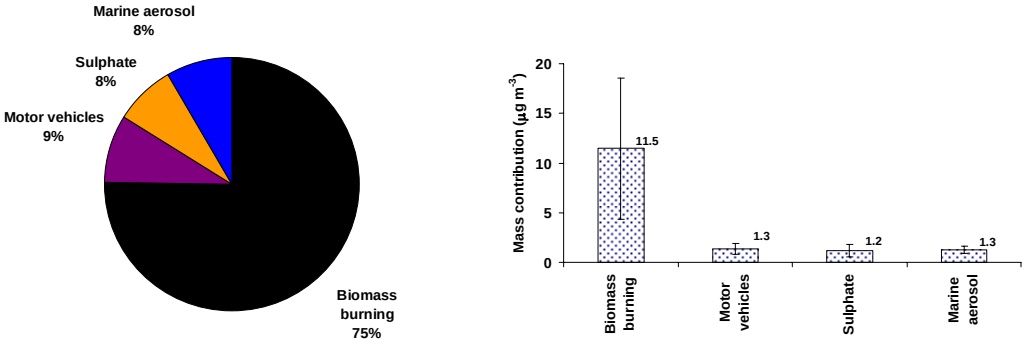
The following sources of particulate matter were resolved using receptor modelling:

- *Biomass burning* arising from emissions from woodburners, open fires and plant burning;

- *Marine aerosol* produced by the long-range transport of fine sea-salt across the Tasman Sea and southern oceans;
- *Soil* derived from wind-blown soil particles;
- *Motor vehicle* emissions from Glen Road; and
- *Secondary sulphate* formed in the atmosphere from precursor sulphur dioxide.

3.4.2 Relative source contributions to fine particulate $PM_{2.5}$

On average, the biomass burning source dominated the fine fraction (75%) with marine aerosol, secondary sulphate and motor vehicles all contributing equally to the remaining 25% (Figure 3.5). Biomass burning was the principal source of $PM_{2.5}$ on days where levels were above 25 µg/m^3.

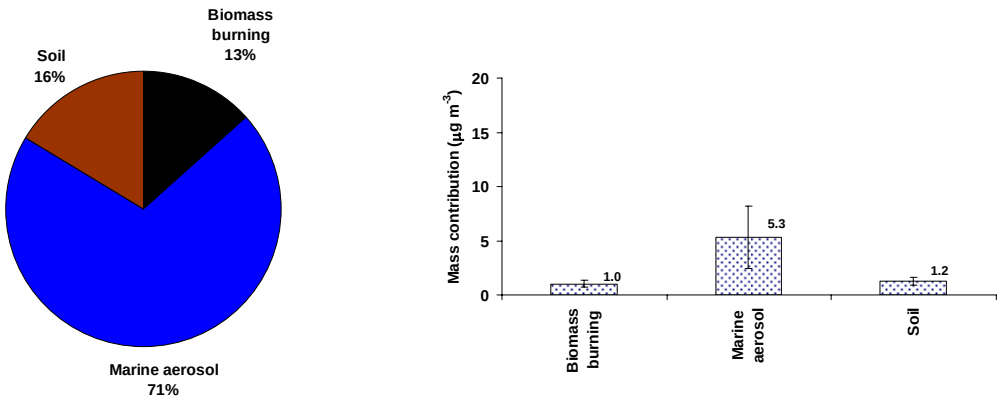


(Source: Davy et al. 2011)

Figure 3.5: Relative source contributions to average $PM_{2.5}$ concentrations (left) and average mass contributions +/- one standard deviation (right)

3.4.3 Relative source contributions to coarse particulate $PM_{2.5–10}$

Marine aerosol dominated the coarse fraction, indicating high naturally occurring background levels of sea-salt (Figure 3.6) which are common across much of the Wellington region. The soil contribution is probably wind-blown soil particles. The biomass burning component is due to carry-over from the fine fraction or agglomeration of smaller sized particles.

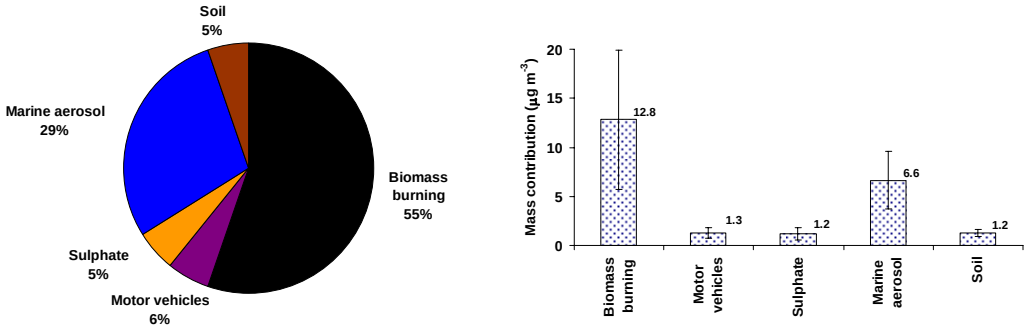


(Source: Davy et al. 2011)

Figure 3.6: Relative source contributions to average $PM_{2.5–10}$ concentrations (left) and average mass contributions +/- one standard deviation (right)

3.4.4 Relative source contributions to PM_{10}

On average biomass burning made up just over half of all PM_{10} measured and marine aerosol accounted for just under a third (Figure 3.7).



(Source: Davy et al. 2011)

Figure 3.7: Relative source contributions to average PM_{10} concentrations (left) and average mass contributions +/- one standard deviation (right)

4. Conclusions and recommendations

The results of the winter 2010 investigation show that the potential exists for elevated concentrations of PM_{10} in Raumati South during periods of cold and calm weather. This result is somewhat surprising given the relatively low emissions density of the Raumati South census area unit coupled with its coastal location.

Glen Road is located within an area of low-lying topography and this may be sufficient to restrict the dispersion of wood smoke during certain meteorological conditions. This finding is consistent with a study by Trompetter et al. (2009) which found that average winter PM_{10} concentrations in many areas throughout New Zealand depend on environmental confinement due to meteorology and are not well correlated with the number of woodburners or population size.

The elevated levels of $PM_{2.5}$ found on high PM_{10} days in Raumati South are also a feature of other locations in the Wellington region, such as Wainuiomata and Masterton, where emissions from wood burners are the principal source of particulate matter. The average winter PM_{10} concentration in Raumati South of 25 $\mu g/m^3$ was similar to that recorded for Masterton over the same period.

It is recommended that further monitoring be carried out in other parts of the Kapiti Coast airshed, as resources permit, to increase our understanding of the spatial variability in PM_{10} concentrations. The results of this study and any future investigations in the Kapiti Coast will be used to decide whether establishing a permanent monitoring site in the Kapiti Coast airshed is warranted.

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Acknowledgments

We are grateful to the Raumati South Bowling club for allowing access to their site for this investigation.

Appendix 1: Monitoring results

Date	24-hour averages			12-hour averages (am)			12-hour averages (pm)		
	$PM_{2.5}$	$PM_{2.5-10}$	PM_{10}	$PM_{2.5}$	$PM_{2.5-10}$	PM_{10}	$PM_{2.5}$	$PM_{2.5-10}$	PM_{10}
25/05/2010	11.4	7.4	18.8	19.8	3.0	6.1	8.6	25.9	11.6
26/05/2010	7.0	8.7	15.7	11.0	3.0	9.7	7.7	20.7	10.7
27/05/2010	7.4	9.9	17.3	5.9	8.7	11.0	8.8	17.0	17.5
28/05/2010	4.8	3.4	8.2	6.7	2.9	5.3	1.4	12.1	4.3
29/05/2010	5.3	1.6	7.0	1.9	8.7	1.5	1.8	3.4	10.5
30/05/2010	5.8	5.0	10.8	9.7	1.9	1.6	8.4	11.3	10.3
31/05/2010	11.3	6.9	18.2	15.2	7.5	8.7	5.1	23.9	12.6
01/06/2010	26.6	3.0	29.6	30.2	22.8	6.3	0.0	36.4	22.8
02/06/2010	3.9	0.9	4.8	2.9	4.9	1.4	0.4	4.3	5.3
03/06/2010	5.3	2.9	8.2	1.0	9.6	4.2	1.6	5.2	11.2
04/06/2010	25.2	4.8	30.0	7.2	43.4	2.1	7.5	9.2	50.8
05/06/2010	20.9	3.9	24.9	22.8	18.9	3.5	4.4	26.4	23.3
06/06/2010	4.9	3.4	8.3	4.5	5.3	6.6	0.1	11.1	5.4
09/06/2010	12.4	10.7	23.1	2.9	21.9	10.8	10.6	13.7	32.5
10/06/2010	5.3	10.8	16.1	3.8	6.8	13.4	8.1	17.2	14.9
11/06/2010	8.4	14.8	23.2	1.0	15.8	7.9	21.7	8.9	37.5
12/06/2010	7.9	36.6	44.4	7.8	7.9	35.5	37.6	43.4	45.5
13/06/2010	7.3	19.8	27.1	6.9	7.7	27.7	12.1	34.5	19.8
14/06/2010	18.7	7.7	26.4	18.9	18.4	5.6	9.6	24.4	28.1
15/06/2010	10.4	10.9	21.3	3.8	17.0	13.3	8.4	17.1	25.4
16/06/2010	19.8	5.2	25.0	17.8	21.9	2.4	8.0	20.2	29.9
17/06/2010	10.0	3.2	13.2	3.8	0.2	3.0	0.1	6.8	0.2
18/06/2010	6.2	3.2	9.4	3.8	8.7	1.3	5.1	5.1	13.8
19/06/2010	23.1	5.8	28.9	4.8	41.3	3.0	8.7	7.8	50.0
20/06/2010	7.3	10.7	18.1	9.7	4.9	4.3	17.2	14.0	22.1
21/06/2010	22.2	20.4	42.6	9.8	34.3	33.6	7.6	43.4	41.9
23/06/2010	9.5	7.1	16.7	11.4	7.6	4.8	9.5	16.2	17.1
24/06/2010	8.1	4.3	12.4	5.7	10.5	7.1	1.5	12.8	12.0
25/06/2010	3.3	1.8	5.2	5.7	1.0	2.0	1.6	7.7	2.6
26/06/2010	2.9	7.9	10.8	1.0	4.9	5.1	10.8	6.0	15.7
27/06/2010	20.2	7.4	27.6	5.8	34.6	6.3	8.5	12.1	43.1
28/06/2010	16.8	8.3	25.1	20.0	13.6	9.1	7.5	29.1	21.1
29/06/2010	18.0	8.2	26.2	5.8	30.1	9.1	7.3	14.9	37.4
30/06/2010	10.6	3.6	14.2	8.7	12.5	4.3	3.0	12.9	15.5
01/07/2010	16.7	6.8	23.5	14.2	19.2	5.3	8.4	19.5	27.6
02/07/2010	9.0	5.5	14.5	3.8	8.5	4.7	14.3	8.5	6.2
03/07/2010	7.2	15.6	22.8	7.6	6.8	6.9	24.5	14.5	31.3
04/07/2010	10.5	6.6	17.2	7.6	13.5	7.8	5.5	15.4	19.0
06/07/2010	5.3	6.8	12.1	4.8	5.8	10.7	2.9	15.5	8.6
07/07/2010	8.7	13.4	22.1	9.6	7.8	12.8	14.0	22.4	21.7
08/07/2010	7.7	9.1	16.8	7.7	7.7	9.5	8.7	17.2	16.4
09/07/2010	7.6	4.3	11.9	6.7	8.5	3.6	5.1	10.3	13.6
10/07/2010	24.7	7.1	31.8	4.7	44.4	10.5	3.9	15.1	48.3
11/07/2010	35.6	7.3	42.9	42.2	29.0	4.9	9.7	47.1	38.7
12/07/2010	54.6	7.0	61.7	52.3	57.0	5.6	8.5	57.9	65.5

Date	24-hour averages			12-hour averages (am)			12-hour averages (pm)		
	$PM_{2.5}$	$PM_{2.5-10}$	PM_{10}	$PM_{2.5}$	$PM_{2.5-10}$	PM_{10}	$PM_{2.5}$	$PM_{2.5-10}$	PM_{10}
13/07/2010	42.8	7.4	50.2	26.6	59.4	10.6	4.1	37.2	63.6
14/07/2010	30.5	6.2	36.7	43.5	17.1	9.0	3.4	52.5	20.5
15/07/2010	53.8	4.7	58.5	32.7	75.2	1.7	7.7	34.5	82.9
16/07/2010	39.2	8.2	47.4	57.5	20.4	6.0	10.3	63.6	30.7
17/07/2010	10.2	14.8	25.0	8.7	11.7	11.4	18.2	20.2	29.8
18/07/2010	33.0	5.6	38.6	4.8	61.0	6.4	4.9	11.2	65.8
19/07/2010	3.8	6.0	9.9	1.0	6.7	0.0	12.2	1.0	19.0
20/07/2010	2.4	18.3	20.7	2.9	1.9	17.8	18.8	20.7	20.7
21/07/2010	21.5	6.4	27.9	4.8	38.5	7.2	5.5	12.0	44.0
22/07/2010	11.1	5.0	16.1	11.5	10.7	0.0	10.4	11.5	21.1
23/07/2010	2.9	11.0	13.9	1.9	3.9	22.4	0.0	24.3	3.9
24/07/2010	9.6	2.4	12.0	4.8	14.3	0.4	4.5	5.2	18.8
25/07/2010	33.5	7.2	40.7	29.2	37.7	4.7	9.7	33.9	47.5
26/07/2010	25.9	5.4	31.4	33.6	18.1	5.9	5.0	39.5	23.1
29/07/2010	33.3	7.6	40.9	35.5	31.1	6.5	8.7	42.0	39.8
30/07/2010	34.7	5.3	40.0	23.9	45.8	5.9	4.6	29.8	50.4
31/07/2010	23.4	6.5	29.8	31.2	15.2	6.0	7.0	37.2	22.2
01/08/2010	8.1	8.6	16.7	5.7	10.6	2.0	15.3	7.7	25.9
02/08/2010	9.7	29.2	38.9	7.8	11.7	33.5	24.9	41.2	36.5

Water, air, earth and energy – elements in Greater Wellington's logo that combine to create and sustain life. Greater Wellington promotes **Quality for Life** by ensuring our environment is protected while meeting the economic, cultural and social needs of the community

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