Annual air quality monitoring report for the Wellington region, 2011

Quality for Life

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1. Introduction

Greater Wellington Regional Council (Greater Wellington) monitors ambient air quality at selected sites in the Wellington region to identify areas where air quality may be degraded and to compare air quality against national standards and guidelines designed to protect public health. Ambient air is outdoor air where people live, work and play (ie, does not include air indoors or inside tunnels and vehicles). The region is divided into eight airsheds for air quality management and for reporting against the national environmental standard.

The core air quality monitoring programme is focussed on monitoring three contaminants: carbon monoxide, nitrogen dioxide and particulate matter (PM_{10}). These three pollutants are emitted in the greatest quantities in the region and all have adverse health effects if concentrations in air are elevated.

Air quality depends not only on the amount and types of pollutants discharged to air from human activities, but also on whether meteorological conditions are favourable for dispersion of those pollutants. Monitoring alone cannot fully characterise air quality and complementary assessment tools such as source apportionment studies (including emission inventories and receptor modelling) are carried out as needed.

This report summarises the results of ambient air quality monitoring undertaken in the Wellington region during the 2011 calendar year. During this period, air quality was monitored at six stations.

2. Overview of ambient air quality monitoring programme

2.1 Background

Air quality has been monitored in the Wellington region since 1998, when a series of pilot investigations were carried out. The first long-term site was established in Upper Hutt in 2000 (this site was relocated in 2006). Progressively other sites have been added to the monitoring network, which now comprises four long-term sites (Masterton, Lower Hutt, Upper Hutt and Wellington central) and is complemented by other stations which may be re-located as air quality monitoring priorities change.

2.2 Monitoring objectives

The objectives of Greater Wellington's ambient air quality monitoring programme are to:

- Determine compliance with national guidelines and standards designed to protect human health and the environment;
- Identify areas where air quality may be degraded;
- Assess spatial variability and temporal trends in air quality;
- Determine 'background' air quality to assist with assessing the impact of resource consent proposals; and
- Provide scientifically defensible information about air quality for policy and decision makers to use when considering resource management issues.

2.3 Monitoring sites and regional airsheds

The Wellington region is divided into eight airsheds, constrained by valleys between steep hills or mountains (Figure 2.1): Kapiti Coast, Porirua Basin (including Tawa valley and Pauatahanui Inlet), Wellington city, Karori, Lower Hutt Valley, Wainuiomata, Upper Hutt Valley, and Wairarapa Valley. Each airshed has a distinct microclimate, meteorological conditions and air quality pressures. These airsheds were formally Gazetted in 2005 in accordance with the National Environment Standards for Air Quality[1] (Davy 2005).

Currently six of the eight airsheds are monitored (Table 2.1).

[1] Resource Management (National Environmental Standards for Air Quality) Regulations 2004

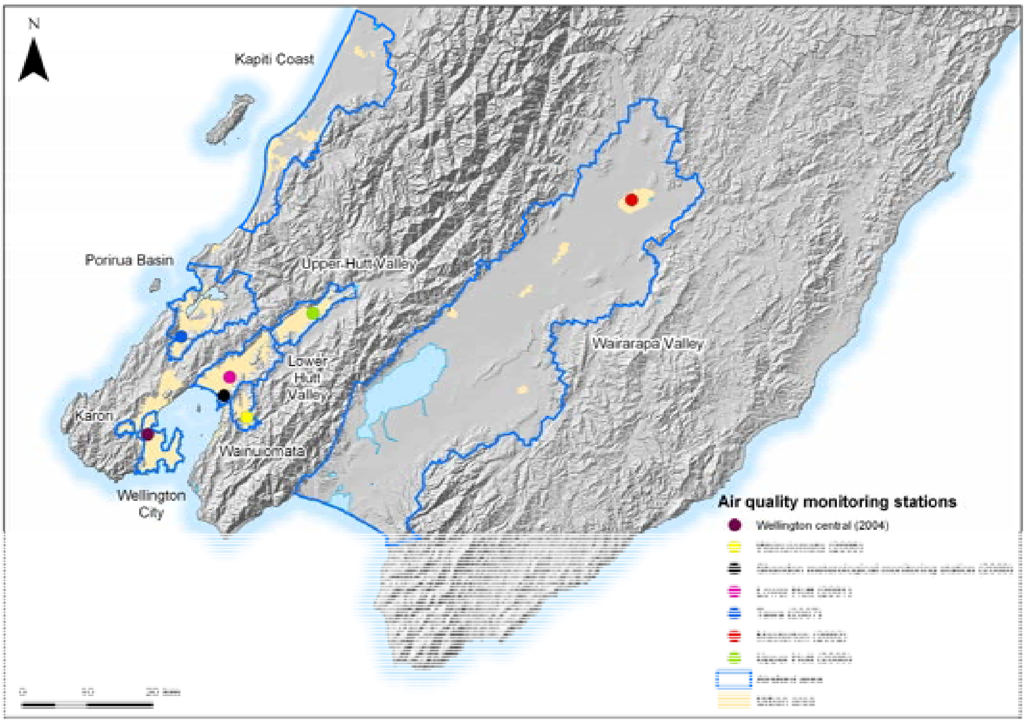


Figure 2.1: Location of Greater Wellington air quality and meteorological monitoring sites (as at 2011) and airshed boundaries established in 2006

Table 2.1: Air quality monitoring sites operated in the 2011 calendar year

Site	Station	Airshed	Location	Pollutants monitored	Valid data from
Wellington central	Corner V	Wellington City	Corner Victoria & Vivian Streets	PM_{10}, CO, NOx	2004
Lower Hutt	Birch Lane	Lower Hutt Valley	Phil Evans Reserve	PM_{10}, CO, NOx	2001
Wainuiomata	Wainuiomata Bowling Club	Wainuiomata	Moohan Street	PM_{10}	2006
Upper Hutt	Savage Park	Upper Hutt Valley	Savage Crescent	PM_{10}, CO, NOx	2006
Masterton	Wairarapa College	Wairarapa Valley	Cornwell Street	PM_{10}, $PM_{2.5}$, CO, NOx	2002
Tawa	Duncan Park	Porirua	Linden Street	PM_{10}, CO, NOx	2007
Shandon	Shandon golf course	Lower Hutt Valley	Gear Island, Petone	Meteorological parameters	2000

2.4 Air pollutants and meteorological variables monitored

The pollutants currently monitored in the Wellington region are particulate matter (PM_{10}), carbon monoxide (CO) and nitrogen oxides (NOx) which include nitrogen dioxide (NO_2) and nitric oxide (NO). These are the contaminants emitted in the greatest amounts throughout the region and all have known adverse human health effects when concentrations in air are elevated. In 2011, continuous $PM_{2.5}$ monitoring was installed at the Masterton air quality monitoring site. The two other pollutants regulated by the national standards, sulphur dioxide (SO_2) and ozone (O_3), are not presently monitored in the region. Meteorological conditions in the region are not usually conducive to the formation of ozone and there are no major point source emissions of sulphur dioxide.

Meteorological instruments for recording variables such as wind speed, wind direction and temperature are co-located at each monitoring site to assist with the interpretation of air quality data. Wind roses showing wind speeds and wind direction in 2011 at each monitoring site are presented in Appendix 1.

2.5 Air quality assessment criteria and reporting

Greater Wellington's air quality monitoring results for PM_{10} are provided to the Ministry for the Environment (MfE) as part of the national reporting framework (http://www.mfe.govt.nz/environmental-reporting/air/air-quality/pm10/index.html). Detailed information on how air quality monitoring results are reported is presented in Appendix 2.

2.5.1 National environmental standards and guidelines for air quality

National ambient air quality guidelines (NAAQG) were established by MfE in 1994 and revised in 2002. Some of these guideline values were adopted as part of the National Environmental Standards for Air Quality (NES-AQ) in 2004. The NES-AQ specifies minimum requirements for outdoor air quality that provide a consistent level of protection for human health and the environment. The relevant national environmental standards and guidelines for pollutants measured in the Wellington region are provided in sections 3 to 5 of this report.

2.5.2 Air quality reporting categories

A useful way to illustrate the significance of ambient air quality monitoring results is to show the percentage of time that monitoring results fall into different categories (Table 2.2). This method is described by MfE (1997).

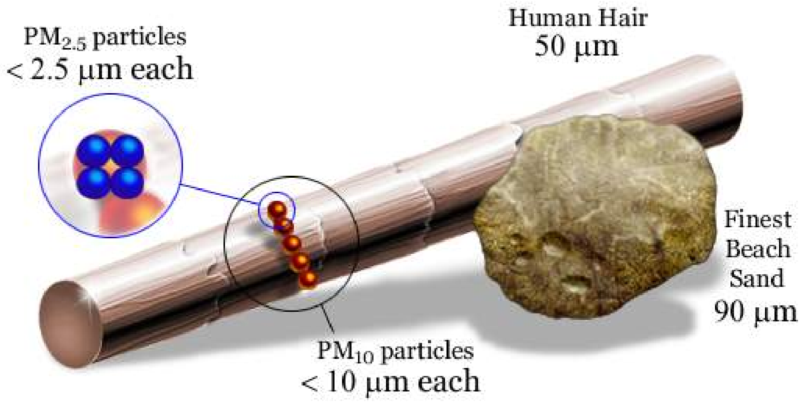
Table 2.2: Air quality categories for reporting monitoring results

Category	Measured values	Comment
Action	Exceed guideline/standard	Completely unacceptable by national and international standards.
Alert	Between 66% and 100% of the guideline/standard	A warning level which can lead to guidelines being exceeded if trends are not curbed.
Acceptable	Between 33% and 66% of the guideline/standard	A broad category, where maximum values might be of concern in some sensitive locations, but are generally at a level that does not warrant dramatic action.
Good	Between 10% and 33% of the guideline/standard	Peak measurements in this range are unlikely to affect air quality.
Excellent	Less than 10% of the guideline/standard	Of little concern.

3. Particulate matter (PM_{10} and $PM_{2.5}$)

3.1 Sources and health effects

Particulate matter (PM) is a mixture of solid particles and liquid droplets that are dispersed in air. PM_{10} is that portion of particulate matter with an equivalent aerodynamic cross section less than 10 microns (Figure 3.1). This size fraction is small enough to be inhaled into the respiratory system.



(Source: www.mfe.govt.nz)

Figure 3.1: Particle sizes relative to the width of a human hair and a grain of sand

Particulate matter arises from human activities and from natural sources. Sources of PM_{10} in the Wellington region include:

- Domestic solid fuel heating (eg, wood burners)
- Motor vehicles, particularly from diesel-fuelled vehicles
- Industrial combustion processes
- Quarrying activities
- Natural sources such as sea salt and wind-blown soil particles

Domestic fires and vehicles produce very fine particles less than 2.5 microns in diameter ($PM_{2.5}$). Road dust and natural sources, such as sea salt and soils, produce particles that are typically larger than 2.5 microns and are commonly described as the ‘coarse’ fraction of PM_{10}.

Epidemiological studies show adverse health effects from both short-term and long-term exposure to PM_{10}. However, a threshold below which there are no observed adverse effects has not been reliably established to date (WHO 2006). The adverse health effects associated with exposure to PM_{10} range from increases in the number of restricted activity days to increases in hospital admissions and premature deaths for people with existing lung and heart disease. The fine component of PM_{10} (ie, $PM_{2.5}$) causes the most harm to people’s health because smaller particles can penetrate deeper into the lungs.

3.2 Monitoring method

PM_{10} is now monitored by Thermo Andersen series FH62 C14 beta attenuation monitors at all monitoring sites. This instrument is designated as an automated method equivalent to the United States Code of Federal Regulations (CFR)[2] [EQPM-1102-150] and therefore complies with the monitoring method specified by the national standard. $PM_{2.5}$ is monitored at one site using a Thermo Scientific model 5030 SHARP monitor. This instrument is designated by CFR as an automated equivalent method [EQMP-0609-184] to the reference method for measuring $PM_{2.5}$[3].

3.3 National standards and guidelines

The short-term daily average limit set by the NES-AQ and the long-term annual average national guideline value are both designed to minimise (not eliminate) adverse health effects associated with PM_{10} exposure. Table 3.1 presents the national standard and guideline values for PM_{10}.

Table 3.1: National standard and guideline values for PM_{10}

PM_{10}	Threshold concentration	Averaging period	Permissible exceedances per year
Standard	50 µg/m^3	24-hour	One 24-hour period
Guideline	20 µg/m^3	Annual	–

There are no national standards or guidelines currently available for $PM_{2.5}$, apart from a 'monitoring' value of 25 µg/m^3 (24-hour average) that can be used for assessing monitoring results (MfE 2002). In the absence of New Zealand health-based guidelines, World Health Organisation (WHO) guidelines presented in Table 3.2 are a useful starting point for assessing the environmental significance of $PM_{2.5}$ monitoring results.

Table 3.2: World Health Organisation (2006) guideline values for $PM_{2.5}$

$PM_{2.5}$	Threshold concentration	Averaging period
Guideline	25 µg/m^3	24-hour[4]
	10 µg/m^3	Annual

3.4 Monitoring results

3.4.1 National standard (24-hour average)

Ambient 24-hour PM_{10} concentrations recorded at the various air quality monitoring sites within the Wellington region during 2011 are shown in Table 3.3. There was only one day in 2011 in where PM_{10} concentrations failed to meet the limit set by the national standard and that was at the Masterton monitoring site in the Wairarapa airshed.

[2] Title 40 – Protection of the Environment, Volume 2, Part 50, Appendix J: Reference Method for the Determination of Particulate Matter as PM_{10} in the Atmosphere.
[3] Title 40 – Protection of the Environment, Volume 2, Part 50, Appendix L: Reference Method for the Determination of Fine Particulate Matter as $PM_{2.5}$ in the Atmosphere.
[4] 99th percentile (3 days/year).

Table 3.3: PM_{10} summary statistics (24-hour average) for air quality monitoring stations in the Wellington region during the 2011 calendar year

PM_{10} (µg/m³)	Wellington Central	Lower Hutt	Upper Hutt	Masterton	Tawa	Wainuiomata
Mean	13	11	11	13	12	11
Maximum	34	29	30	61	31	48
Median	12	9	10	10	11	10
Standard deviation	4.32	4.23	4.95	8.90	4.88	5.85
25th percentile	10	7	7	7	8	7
75th percentile	15	13	14	16	14	14
95th percentile	20	18	21	33	21	23
99th percentile	24	23	23	40	27	28
Valid averages	98.9%	99.7%	99.2%	98.9%	98.9%	96.2%

3.4.2 National guideline (annual average)

Figure 3.2 displays the distribution of monitoring results across all sites in the region. All annual averages were below the national guideline of 20 µg/m³.

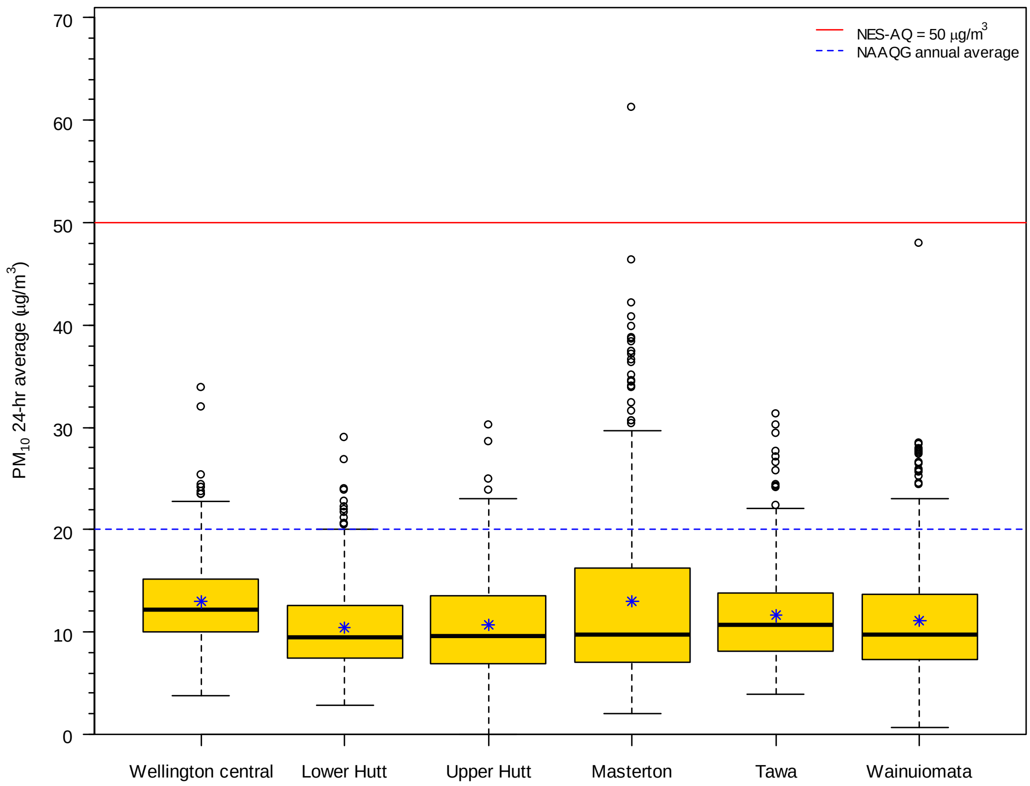


Figure 3.2: Box plot[5] showing the distribution of PM_{10} (24-hour average) concentrations at air quality monitoring stations in the Wellington region during the 2011 calendar year. The blue stars on the box plot show the annual average for each site and the dashed blue line is national annual average guideline value. The red line is the national environmental standard limit.

[5] Appendix 4 provides a key for the interpretation of the box plots used in this report.

3.4.3 Air quality reporting categories (24-hour average)

Ambient PM_{10} daily averages are reported as the number of days per year in each air quality category (Table 3.4) described in Section 2.5. Air quality assessed this way was ‘good’ or better on just over 80% of monitored days in 2011. In Masterton there were 18 days, and in Wainuiomata and in Wellington central one day, when air quality was at or above ‘alert’ levels.

Table 3.4: PM_{10} by air quality category (24-hour average) in the 2011 calendar year

Monitoring site	Total days sampled	Excellent <5 µg/m³	Good 5 to 16.5 µg/m³	Acceptable 16.5 to 33 µg/m³	Alert 33 to 50 µg/m³	Action >50 µg/m³
Wellington central	361	3	291	66	1	
Lower Hutt	364	12	315	37		
Upper Hutt	362	24	286	52		
Masterton	360	29	243	70	17	1
Tawa	361	13	299	49		
Wainuiomata	351	33	265	52	1	

3.4.4 PM_{10} national standard exceedance days

The NES-AQ for PM_{10} allows an airshed to exceed the threshold concentration of 50 µg/m^3 (24-hour average) on one day per year – known as a ‘permissible’ exceedance. At least two exceedances per year are required for the NES-AQ to be breached. During winter 2011 there was one permitted exceedance of 61 µg/m^3 recorded in Masterton on 4 August. Therefore, the Wairarapa airshed did not breach the NES-AQ in 2011.

3.4.5 $PM_{2.5}$ summary statistics

Average daily $PM_{2.5}$ concentrations recorded at the Wairarapa College monitoring site in Masterton during 2011 are shown in Table 3.5. There were 41 days in 2011 where daily $PM_{2.5}$ concentrations failed to meet the guideline of 25 µg/m^3 recommended by WHO (2006). The $PM_{2.5}$ annual average in 2011 also failed to meet the WHO guideline of 10 µg/m^3. The relationship between PM_{10} and $PM_{2.5}$ measured in Masterton is outlined in Appendix 3.

Table 3.5: $PM_{2.5}$ summary statistics (24-hour average) recorded at Masterton during the 2011 calendar year

$PM_{2.5}$ (µg/m³)	Masterton
Mean	11.3
Maximum	67.1
Median	6.8
Standard deviation	11.22
25th percentile	36.4
75th percentile	14.8
95th percentile	36.4
99th percentile	48.3
Valid averages	89.7%

4. Carbon monoxide

4.1 Sources and health effects

Carbon monoxide (CO) is a colourless and odourless gas produced by the incomplete combustion of carbon-containing fuels such as petrol and diesel used by motor vehicles, or wood and coal used by domestic appliances or industrial boilers. Motor vehicles are the main source of carbon monoxide in urban areas.

When inhaled, carbon monoxide reduces the oxygen carrying capacity of the blood and, depending on its concentration, causes a range of adverse health effects.

4.2 Monitoring method

Carbon monoxide is monitored using the Gas Filter Correlation Infrared method in accordance with AS3580.7.1:1992. API 300 series analysers are employed at all of Greater Wellington's air quality monitoring stations.

4.3 National standards and guidelines

The national standards and guidelines for carbon monoxide (Table 4.1) are set at a level to protect susceptible people, such as those with existing heart disease, children and pregnant women.

Table 4.1: National standard and guideline values for carbon monoxide

Carbon monoxide	Threshold concentration	Averaging period	Permissible exceedances per year
Standard	10 mg/m^3	8-hour moving	One 8-hour period
Guideline	30 mg/m^3	1-hour	–

4.4 Monitoring results

4.4.1 National standard (8-hour moving average)

Ambient concentrations of carbon monoxide measured at the various air quality monitoring sites in the Wellington region during 2011 are shown in Table 4.2. All concentrations were well within the national standard for carbon monoxide during the reporting period. Figure 4.1 displays the distribution of carbon monoxide measurements across all air quality monitoring sites in the region.

Table 4.2: Carbon monoxide summary statistics (8-hour moving average) for air quality monitoring stations in the Wellington region during the 2011 calendar year

Carbon monoxide (mg/m^3)	Wellington central	Lower Hutt	Upper Hutt	Masterton	Tawa
Mean	0.6	0.2	0.2	0.3	0.2
Maximum	2.5	1.4	2.3	2.7	1.6
Median	0.5	0.1	0.1	0.1	0.1
Standard deviation	0.36	0.14	0.24	0.33	0.21
25th percentile	0.3	0.1	0.1	0.1	0.1
75th percentile	0.8	0.2	0.3	0.3	0.2
95th percentile	1.3	0.5	0.8	1.0	0.7
99th percentile	1.7	0.8	1.1	1.6	1.1
Valid averages	99.0%	98.2%	91.7%	99.5%	99.8%

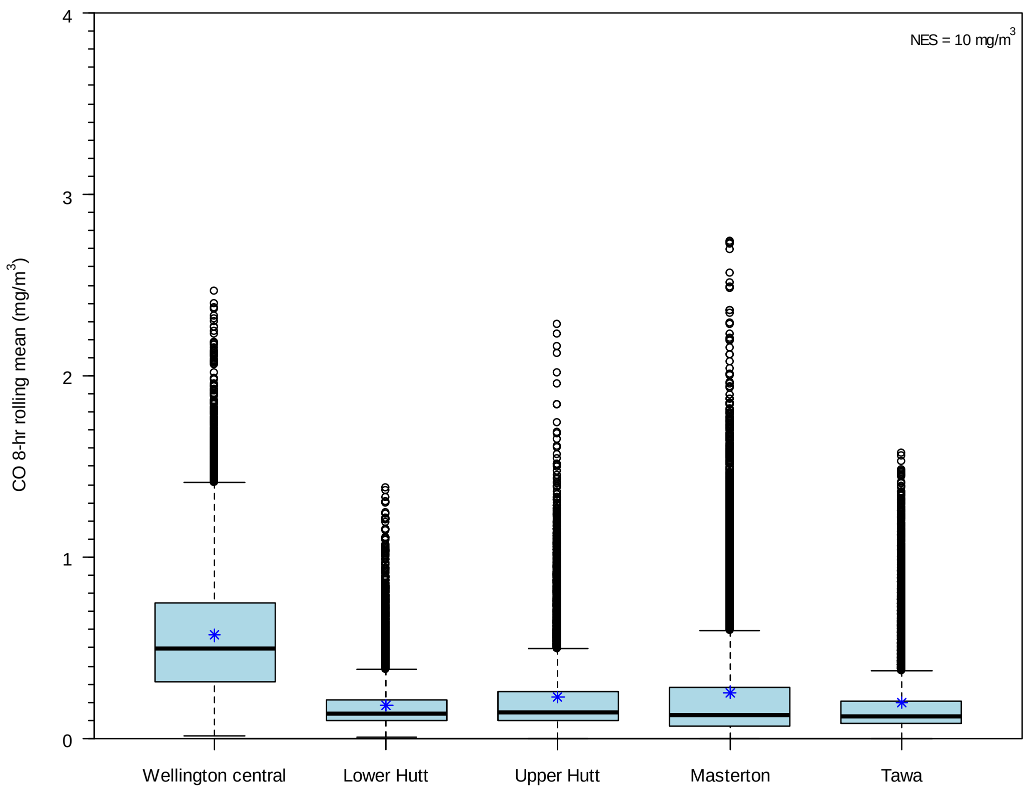


Figure 4.1: Box plot showing the distribution of carbon monoxide (8-hour moving average) concentrations at air quality monitoring stations in the Wellington region during the 2011 calendar year. The blue stars on the box plot show the annual average for each site.

4.4.2 National guideline (1-hour average)

All hourly average carbon monoxide concentrations were well within the national guideline of 30 mg/m^3 (1-hour average), as shown in Table 4.3.

Table 4.3: Carbon monoxide statistics (1-hour average) for air quality monitoring stations in the Wellington region during the 2011 calendar year

Carbon monoxide (mg/m^3)	Wellington central	Lower Hutt	Upper Hutt	Masterton	Tawa
Mean	0.6	0.2	0.2	0.3	0.2
Maximum	3.8	2.6	3.6	3.7	2.6
Median	0.5	0.1	0.1	0.1	0.1
Standard deviation	0.47	0.19	0.29	0.40	0.26
25th percentile	0.3	0.1	0.1	0.1	0.1
75th percentile	0.8	0.2	0.2	0.2	0.2
95th percentile	1.5	0.5	0.8	1.1	0.8
99th percentile	2.4	1.0	1.6	2.1	1.5
Valid averages	99.0%	97.9%	99.1%	99.5%	99.8%

4.4.3 Air quality reporting categories

At all monitoring sites concentrations of carbon monoxide were mostly 'excellent' (Table 4.4), apart from Wellington central where concentrations were 'good' on 11% of the 8-hour averaging periods measured during 2011.

Table 4.4: Carbon monoxide by air quality category (8-hour moving average) for air quality monitoring stations in the Wellington region during the 2011 calendar year

Monitoring site	Total no. 8-hour samples	Excellent <1 mg/m^3	Good 1 to 3.3 mg/m^3	Acceptable 3.3 to 6.6 mg/m^3	Alert 6.6 to 10 mg/m^3	Action >10 mg/m^3
Wellington central	8,665	7,686	979			
Lower Hutt	8,597	5,864	33			
Upper Hutt	8,663	5,486	177			
Masterton	8,572	8,164	408			
Tawa	8,725	8,591	134			

5. Nitrogen dioxide

5.1 Sources and health effects

Nitrogen dioxide (NO_2) arises from combustion processes, with vehicle emissions being the main source in urban areas. Vehicle exhausts contain a mixture of nitrogen dioxide and nitric oxide (NO), collectively known as oxides of nitrogen (NOx). Most of the NOx discharged from vehicle exhausts is in the form of nitric oxide which is subsequently converted to nitrogen dioxide by oxidation.

Nitrogen dioxide appears as a brown and acidic gas in the atmosphere and can be seen as a haze over some cities during periods of calm weather and heavy traffic congestion. As well as contributing to poor visibility, nitrogen dioxide has adverse health effects such as lung inflammation and eye, nose and throat irritation.

5.2 Monitoring method

Nitrogen dioxide is monitored using chemiluminscence in accordance with AS3580.5.1:1993. API 200 series analysers are used at all air quality monitoring stations.

5.3 National standards and guidelines

The national standard and national guideline concentration thresholds (Table 5.1) are designed to protect children, asthmatics and adults with chronic respiratory and cardiac conditions.

Table 5.1: National standard and guideline values for nitrogen dioxide

Nitrogen dioxide	Threshold concentration	Averaging period	Permissible exceedances per year
Standard	200 µg/m³	1-hour	9 hours
Guideline	100 µg/m³	24-hour	–

5.4 Monitoring results

5.4.1 National standard (1-hour average)

A summary of 1-hour average concentrations of nitrogen dioxide measured throughout the Wellington region during 2011 is presented in Table 5.2. The national standard was not exceeded at any site or time during the reporting period.

Figure 5.1 displays the distribution of nitrogen dioxide concentrations across all air quality monitoring sites in the region. There are no national guidelines or standards for annual average nitrogen dioxide concentrations, although Figure 5.1 shows that all annual concentrations were below the WHO (2006) guideline of 40 $\mu g/m^3$. The Wellington central site, which is the most heavily trafficked, recorded the highest annual average nitrogen dioxide concentration. Nitrogen dioxide monitoring carried out by NZ Transport Authority (NZTA) is summarised in Appendix 4.

Table 5.2: Nitrogen dioxide summary statistics (1-hour average) for air quality monitoring stations in the Wellington region during the 2011 calendar year

Nitrogen dioxide (µg/m³)	Wellington central	Lower Hutt	Upper Hutt	Masterton	Tawa
Mean	24.4	10.6	7.1	6.1	8.2
Maximum	93.7	59.8	57.9	50.2	50.3
Median	22.4	7.6	4.0	3.4	5.2
Standard deviation	15.18	8.89	8.18	7.25	8.23
25th percentile	12.5	4.4	1.6	1.7	2.4
75th percentile	34.7	14.2	9.5	7.4	11.3
95th percentile	51.6	29.5	24.7	22.2	25.9
99th percentile	64.7	41.3	37.2	36.0	35.9
Valid averages	98.3%	97.4%	97.4%	97.9%	98.1%

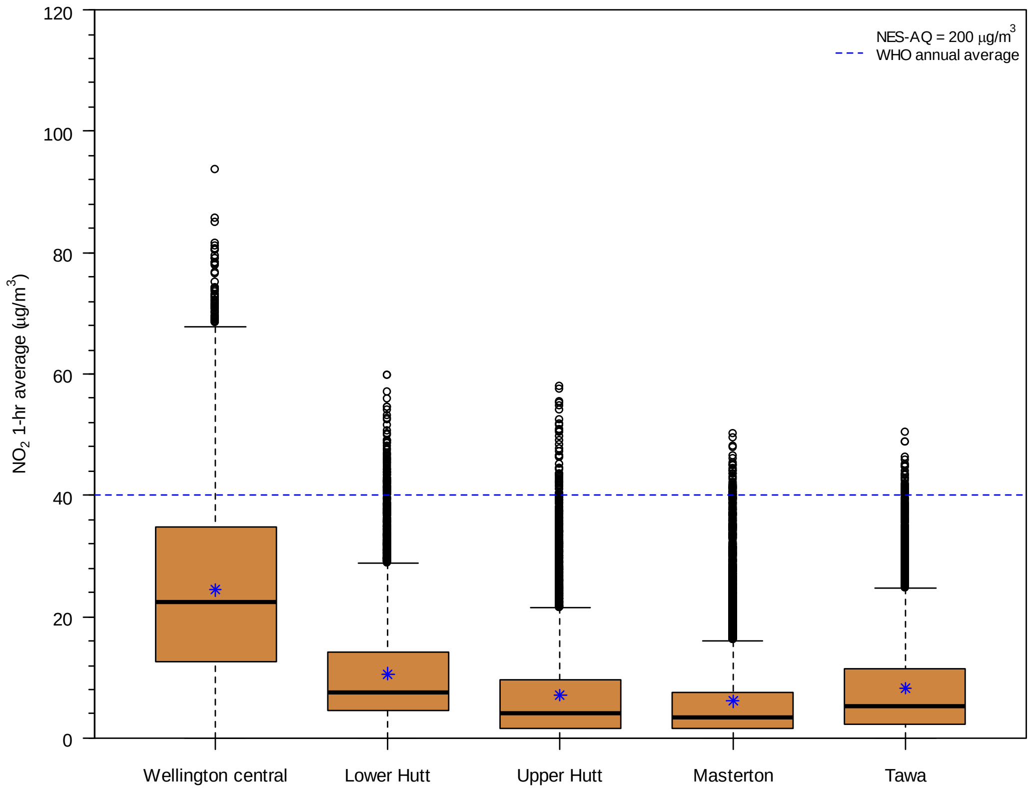


Figure 5.1: Box plot showing the distribution of nitrogen dioxide (1-hour average) concentrations at air quality monitoring stations in the Wellington region during the 2011 calendar year. The blue stars on the box plot show the annual average for each site and the dashed blue line is the WHO (2006) annual average guideline value.

5.4.2 National guideline (24-hour average)

A summary of daily average concentrations of nitrogen dioxide measured during 2011 is presented in Table 5.3. Concentrations were well within the national guideline at all times during the reporting period.

Table 5.3: Nitrogen dioxide summary statistics (24-hour average) for air quality monitoring stations in the Wellington region during the 2011 calendar year

Nitrogen dioxide ($\mu g/m^3$)	Wellington central	Lower Hutt	Upper Hutt	Masterton	Tawa
Mean	24.4	10.6	7.1	6.1	8.2
Maximum	49.9	32.7	23.3	21.3	26.0
Median	24.6	9.7	6.0	4.6	7.2
Standard deviation	8.92	5.53	4.93	4.25	5.31
25th percentile	17.7	6.2	3.1	2.8	4.1
75th percentile	30.7	14.2	10.0	8.4	11.5
95th percentile	40.1	20.5	16.1	15.4	18.7
99th percentile	45.6	24.8	19.9	17.4	21.7
Valid averages	99.7%	99.7%	98.4%	99.2%	100.0%

5.4.3 Air quality reporting categories

At all but one of the air quality monitoring sites concentrations of nitrogen dioxide were mostly ‘excellent’ during 2011 (Table 5.4). The exception was Wellington central which had a greater proportion of hours in the ‘good’ category (and a small number of hours in the ‘acceptable’ category).

Table 5.4: Nitrogen dioxide by air quality category (1-hour average) for air quality monitoring stations in the Wellington region during the 2011 calendar year

Monitoring site	Total no. hours sampled	Excellent <20 $\mu g/m^3$	Good 20 to 66 $\mu g/m^3$	Acceptable 66 to 133 $\mu g/m^3$	Alert 133 to 200 $\mu g/m^3$	Action >200 $\mu g/m^3$
Wellington central	8,602	3,768	4,755	79		
Lower Hutt	8,533	7,340	1,193			
Upper Hutt	8,165	7,447	718			
Masterton	8,559	8,029	529			
Tawa	8,359	7,474	885			

Summary

- Apart from one day in Masterton, PM_{10} concentrations measured in the Wellington region were below the national environmental standard during 2011.
- During 2011 there were 17 days in Masterton and one day each in Wainuiomata and Wellington central where the ‘alert’ level for PM_{10} was reached (ie, daily concentrations were above 66% of the limit allowed by the NES-AQ).
- Over the winter months in 2011, $PM_{2.5}$ concentrations were elevated in Masterton. There were 41 days where the WHO (2006) daily guideline was not met.
- Concentrations of two pollutants associated with motor vehicle emissions, carbon monoxide and nitrogen dioxide, were highest at Wellington central but well within national environmental standards and guidelines at all air quality monitoring stations.

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Acknowledgements

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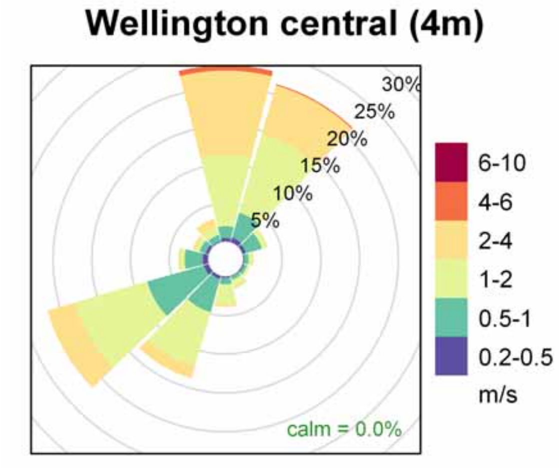
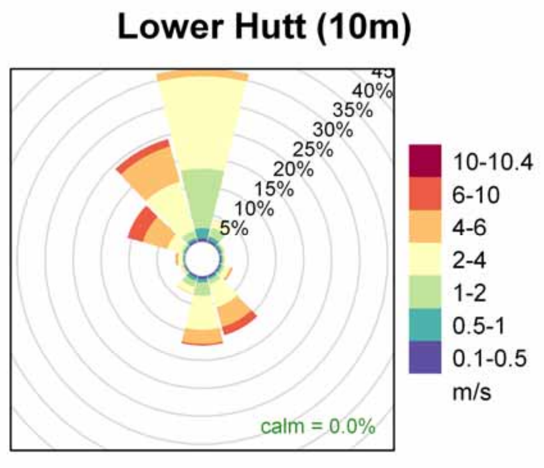
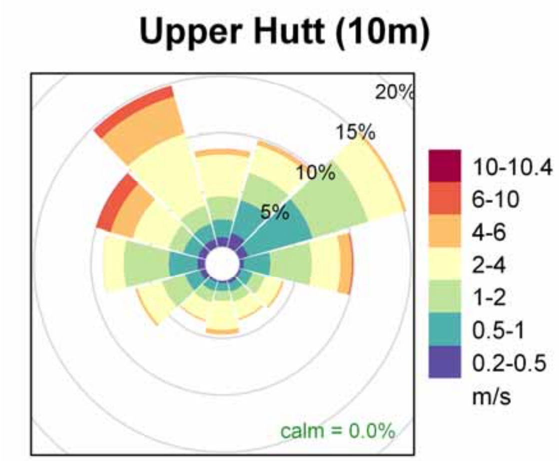
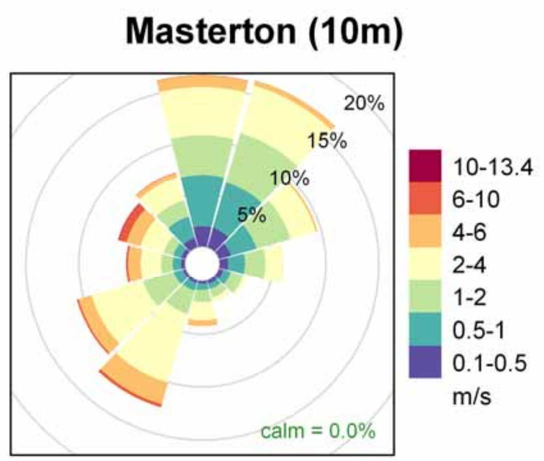
Appendix 1: Wind roses by monitoring site for 2011

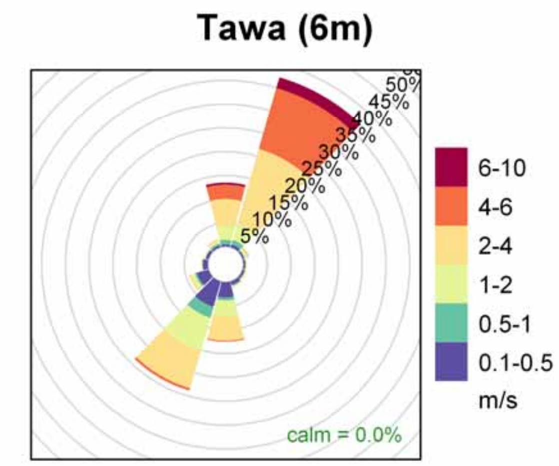
See Appendix 2 for interpretation.

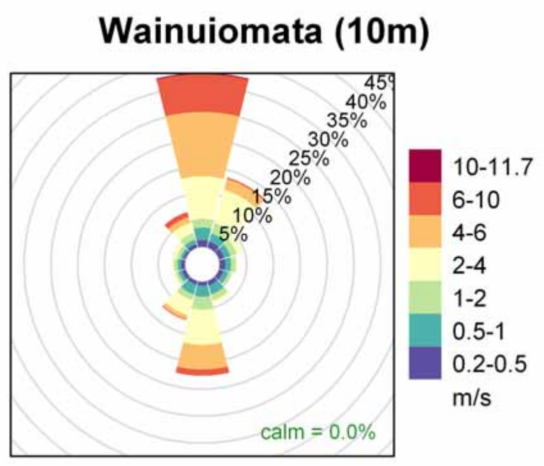


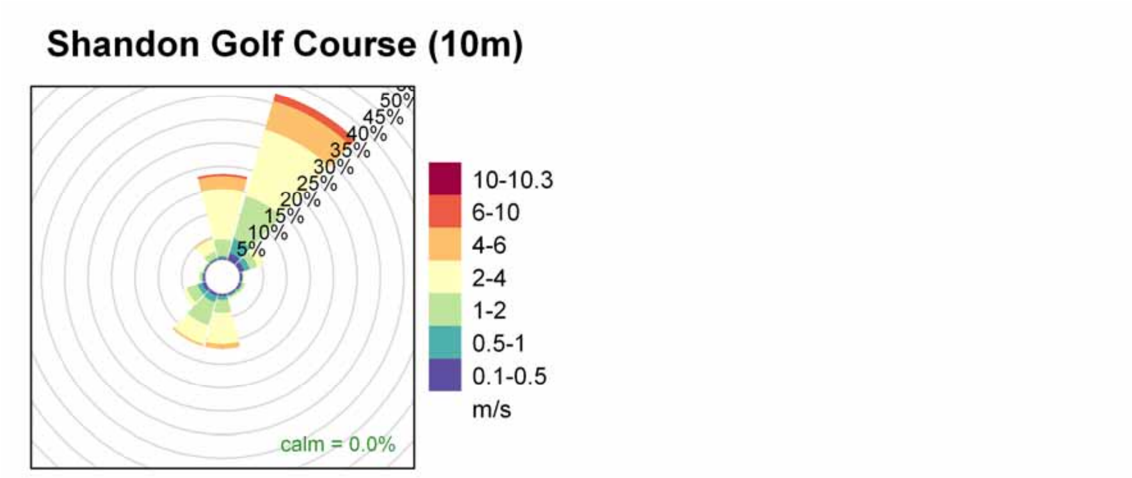











Shandon Golf Course (10m)
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
10-10.3
6-10
4-6
2-4
1-2
0.5-1
0.1-0.5
m/s
calm = 0.0%

Appendix 2: Data analysis presentation methods

Reporting units

All pollutants at Greater Wellington's long-term air quality monitoring sites are measured continuously with instruments that are connected by digital interface to data loggers. Ambient air is sampled at 10 to 20 second intervals (depending on the number of instruments at a site) and these measurements are averaged and reported as 10-minute averages at New Zealand Standard Time (NZST). These 10-minute values are then aggregated to hourly averages where there is at least 75% data capture (ie, at least five 10-minute means must be present for a 1-hour average to be considered valid and included in the data set). The hourly averages apply to the preceding hour (eg, a 1-hour average at 17:00 refers to data collected between 16:00 and 16:59).

Carbon monoxide is measured in parts per million (ppm) and is converted to mg/m^3 by multiplying by 1.25 (0^{o}C). For comparison with the NES-AQ, 8-hour moving means are calculated on the hour for the preceding 8-hour period using 1-hour averages. At least 6 hours (ie, 75% or greater data capture) must be present for an 8-hour mean to be considered valid and included in the data set. Carbon monoxide values are rounded to one significant figure for reporting purposes in accordance with MfE (2009) recommendations.

Nitrogen dioxide is measured in parts per billion (ppb) and is converted to µg/m^3 by multiplying by 2.05 (0^{o}C) NES-AQ. Nitrogen dioxide 1-hour averages are rounded to one significant figure for reporting purposes in accordance with MfE (2009) recommendations.

PM_{10} is measured as µg/m^3 which is the same unit as the NES-AQ limit. 24-hour averages are calculated from 1-hour averages between midnight to midnight (00:00 to 23:59) and require at least 18 hours of data for each 24-hour period to be included in the data set. PM_{10} values are rounded up to the nearest whole number for reporting purposes in accordance with MfE (2009) recommendations. An exceedance of the NES-AQ is therefore 51 µg/m^3 or higher.

Box plots

The box plots presented in this report were produced using R Statistical Software version 2.13.0 (R Development Core Team 2011). Details of the construction of the box plots are presented in Figure A2.1.

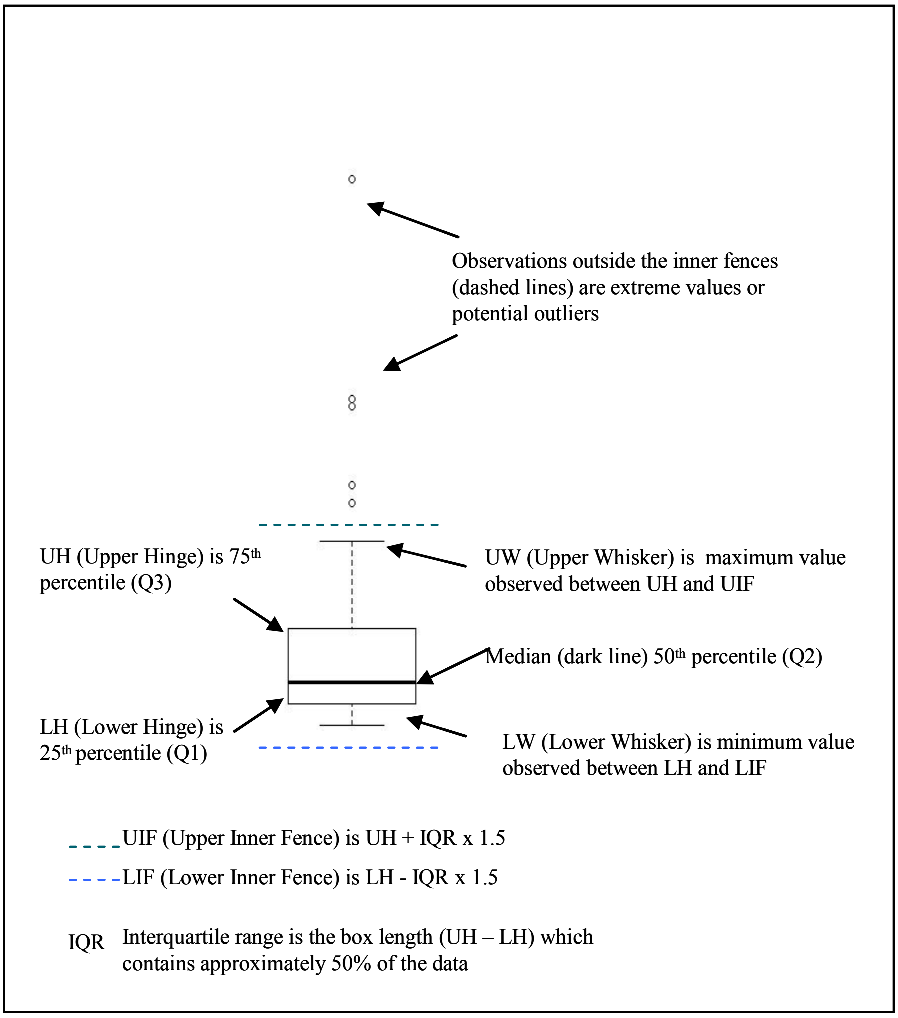


Figure A2.1: Interpretation of Tukey box plot as implemented in R

Temporal variation

The time variation plot presented in Appendix 3 (Figure A3.2) was produced in R statistical software (R Development Core Team. 2011) using the 'openair' package version 05-16 (Carslaw & Ropkins 2012). The diurnal plot was produced using hourly averages with a least 75% data capture. Also shown on the plot is the 95% confidence interval in the mean calculated through bootstrap re-sampling.

Wind roses

The wind roses presented in Appendix 1 were created using R statistical software (R Development Core Team. 2011) using the 'openair' package version 05-16 (Carslaw & Ropkins 2012). The wind roses show the proportion of time (represented as a percentage on the grey circles) that the wind is from a particular angle (30^{o} increments) and wind speed range (shown on the right-hand scale in metres per second). The wedge points towards the direction the wind is blowing from.

Appendix 3: Analysis of $PM_{2.5}$ concentrations in Masterton

$PM_{2.5}$ has been monitored at the Wairarapa College air quality monitoring site since the beginning of 2011 in recognition of the finding that compliance with the NES-AQ for PM_{10} may not be sufficiently protective to ensure compliance with the WHO (2006) guideline for $PM_{2.5}$ (Mitchell 2012). Average daily $PM_{2.5}$ concentrations peaked during the winter months (Figure A3.1) and were frequently above the WHO (2006) guideline of 25 $\mu g/m^3$ (24-hour average).

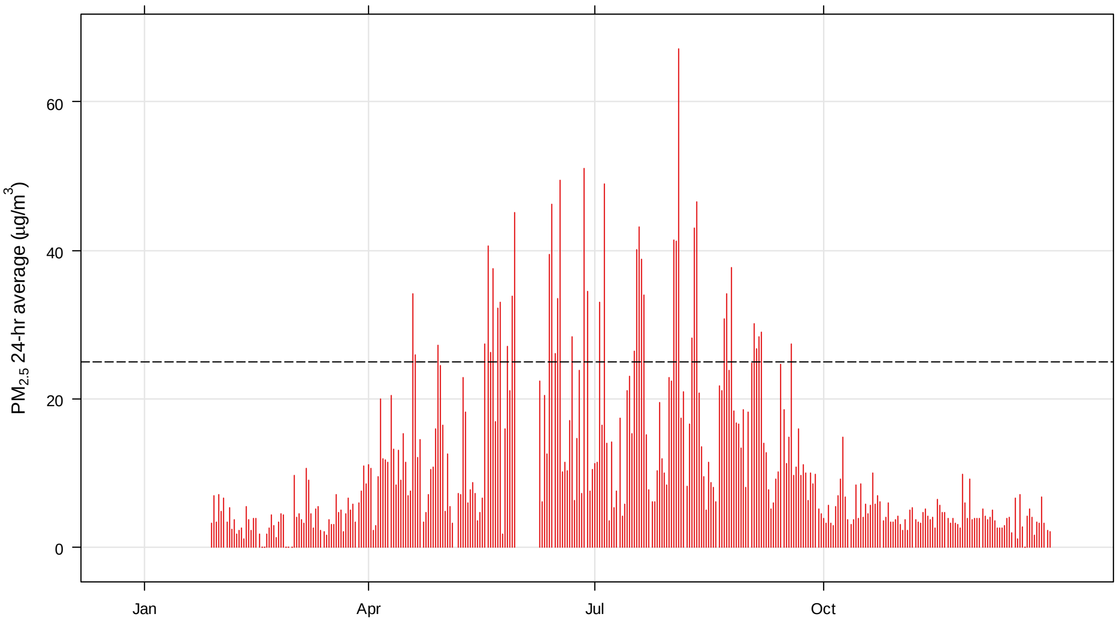


Figure A3.1: Time series of $PM_{2.5}$ (24-hour average) concentrations measured at Masterton during the 2011 calendar year. The dashed grey line shows the WHO (2006) guideline.

It is not possible to calculate the ratio of PM_{10} to $PM_{2.5}$ because different measurement methods were used. PM_{10} was measured by FH62 with the sample inlet heated to a constant 40°C to minimise moisture interference. In contrast, $PM_{2.5}$ was measured by 5030 SHARP in which the temperature of the sampled air is controlled by the relative humidity of the ambient air. Therefore, the 5030 SHARP is less prone to loss of the semi-volatile component of particulate matter through sample heating. As a result, it is expected that on days when emissions containing a significant proportion of semi-volatile compounds (such as those found in smoke from home fires) are high, $PM_{2.5}$ levels measured in air may be higher than PM_{10} levels measured over the same period due to the difference in instrument measurement technology.

$PM_{2.5}$ concentrations showed a distinct diurnal and seasonal profile, with the morning and evening peaks most pronounced during the winter months (Figure A3.2). Concentrations of $PM_{2.5}$ were noticeably lower than PM_{10} during the summer months and during the middle part of the day in spring, autumn and winter. This pattern reflects the differences in emissions source contributions by time of day and season.

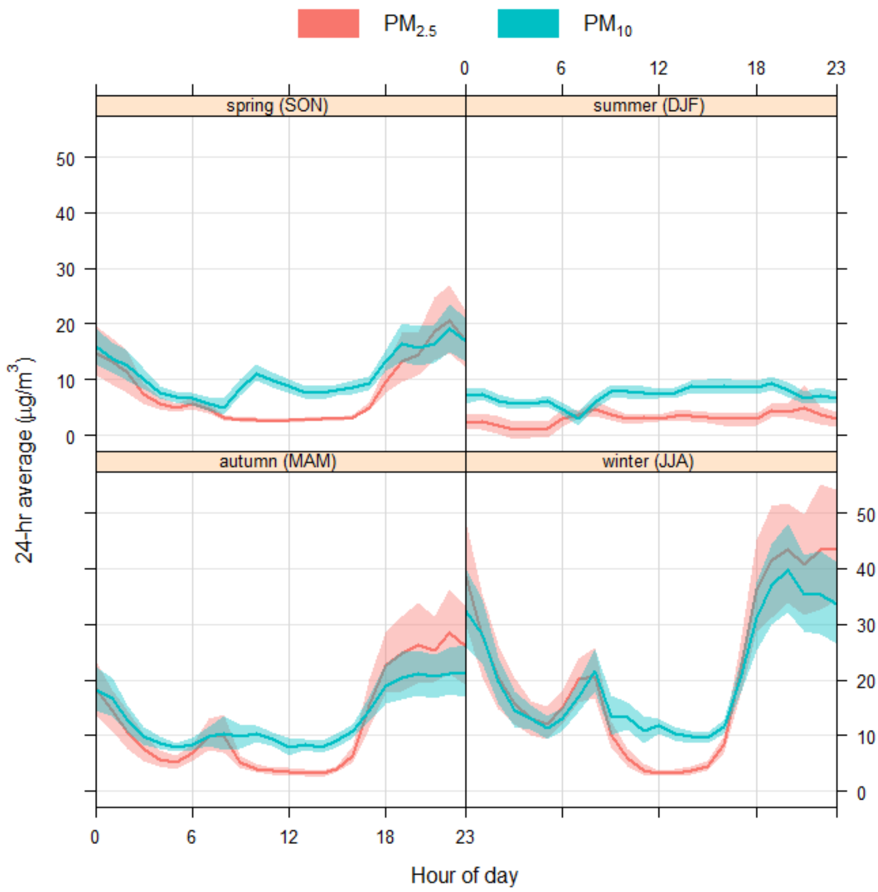


Figure A3.2: Diurnal plots of $PM_{2.5}$ and PM_{10} (1-hour average) concentrations measured at Masterton during the 2011 calendar year. The width of the shading around the line shows the 95% confidence interval in the mean.

Appendix 4: NZTA passive nitrogen dioxide monitoring

In 2011, the New Zealand Transport Agency (NZTA) monitored nitrogen dioxide concentrations at 20 sites throughout the Wellington region (Figure A4.1), these sites forming part of their national passive monitoring network[6]. These sites were located next to state highways and local roads, and in urban background locations. Four of these sites were co-located with Greater Wellington air quality monitoring sites to enable comparisons to be made between continuous monitoring using a reference method and the passive screening method. The Upper Hutt, Tawa and Lower Hutt monitoring sites are classified by NZTA as 'background' sites due to their residential location.

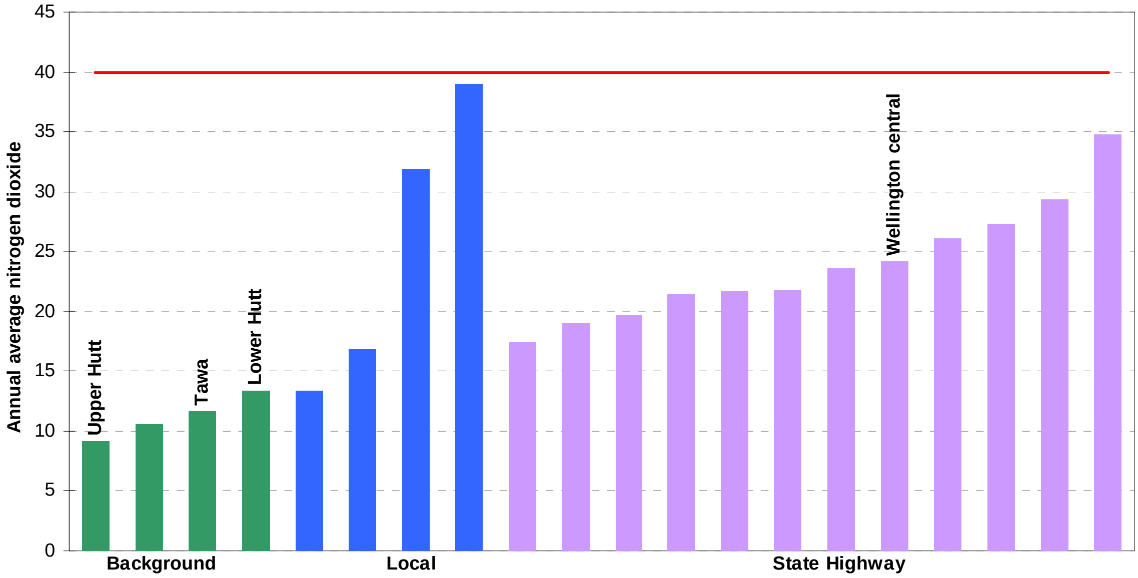


Figure A4.1: Annual average nitrogen dioxide concentrations (µg/m3) measured by the passive diffusion method at NZTA and Greater Wellington monitoring sites (labelled) during the 2011 calendar year. The red line shows the WHO (2006) annual average guideline.

Details for the five sites that recorded the highest annual concentrations are listed in Table A4.1. The annual nitrogen dioxide concentration measured at a NZTA site located in Newtown approached the annual WHO (2006) guideline of 40 µg/m^3. Some of the highest concentrations were recorded on local roads, which carry less traffic than state highways but may have elevated nitrogen dioxide concentrations due to confinement of vehicle emissions as a result of street 'canyon effects' caused by tall buildings on either side of the road. Another possible reason for the higher nitrogen dioxide concentrations found on the local roads is that the passive monitoring device is located very close to the roadside. Nitrogen dioxide concentrations have been shown to decrease with distance from the road side (MfE 2008). Monitoring of nitrogen dioxide using the reference method[7] (as utilised at Greater Wellington monitoring stations) requires a greater distance between the monitoring instrument and the roadside than that required by the passive monitoring method.

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[6] Nitrogen dioxide (NO_2) is a widely used indicator of pollution from motor vehicles. NZTA established a national NO_2 passive monitoring network in 2007 in order to determine the impact of vehicle emissions on air quality across the state highway network (NZTA 2011). Diffusion tubes are an indicative monitoring technique that is ideal for examining spatial variability in long-term (ie, annual) NO_2 concentrations across a wide area.
[7] AS/NZS 3580.1.1:20077 Methods for sampling and analysis of ambient air. Part 1.1:Guide to siting air monitoring equipment.

Table A4.1: Five highest annual average concentrations of nitrogen dioxide measured by passive monitoring in the Wellington region during 2011

(Source: NZTA)

Monitoring site	Site classification	Distance to road	Annual concentration
Riddiford St/Hall St, Newtown, Wellington	Local road	1 m	39.0 µg/m^3
Rugby Street, Basin Reserve, Wellington	SH	1.5 m	34.8 µg/m^3
Knights Road, Bloomfield Tce, Lower Hutt	Local road	1 m	31.9 µg/m^3
Wellington central *(Greater Wellington site)*	SH	5 m	29.4 µg/m^3
Western Hutt Rd / Manor Park Rd	SH	1 m	27.3 µg/m^3

The co-location results to date indicate that the passive monitoring method used by NZTA over-estimates the nitrogen dioxide concentration relative to the standard method by up 30%. The relationship between NZTA and Greater Wellington's monitoring methods appears to be site-specific and a longer period of monitoring is needed to better understand this relationship.

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