Waikato Regional Council Technical Report 2012/06

Air quality monitoring report for Hamilton, Tokoroa, Taupo,Te Kuiti, Matamata, Putaruru, Ngaruawahia, Waihi and Turangi – 2011

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

Prepared by:
by Emily Wilton (Environet Ltd.) and Jonathan Caldwell (Waikato Regional Council)

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

May 2012

Approved for release by:
Dr Ed Brown Date May 2012

Disclaimer

This technical report has been prepared for the use of Waikato Regional Council as a reference document and as such does not constitute Council's policy.

Council requests that if excerpts or inferences are drawn from this document for further use by individuals or organisations, due care should be taken to ensure that the appropriate context has been preserved, and is accurately reflected and referenced in any subsequent spoken or written communication.

While Waikato Regional Council has exercised all reasonable skill and care in controlling the contents of this report, Council accepts no liability in contract, tort or otherwise, for any loss, damage, injury or expense (whether direct, indirect or consequential) arising out of the provision of this information or its use by you or any other party.

Air Quality Monitoring Report for Hamilton, Tokoroa, Taupo,Te Kuiti, Matamata, Putaruru, Ngaruawahia, Waihi and Turangi – 2011

Waikato Regional Council

Prepared for Waikato Regional Council

by Emily Wilton[1] and Jonathan Caldwell[2]

[1] Environet Limited
[2] Waikato Regional Council

www.environet.co.nz

March 2012

Acknowledgements

Monitoring data used in this report were provided by Ralph Ostertag of Waikato Regional Council.

Executive Summary

Air quality monitoring in the Waikato Region focuses primarily on concentrations of PM_{10}, the main air contaminant of concern. A National Environmental Standard (NES) for PM_{10} has been set at 50 µg m^{-3} (24-hour average, one allowable exceedence per year) and must be achieved by September 2016 in all urban areas of the Waikato with the exception of Tokoroa. Tokoroa is required to achieve three exceedences by September 2016 and meet the NES by September 2020. The NES requires air quality monitoring to take place in areas that are likely to exceed the standard for PM_{10}.

During 2011 concentrations of PM_{10} were measured at air quality monitoring sites in Hamilton, Tokoroa, Taupo, Te Kuiti, Matamata, Putaruru, Ngaruawahia, Waihi and Turangi. Monitoring of arsenic, benzene, toluene and xylenes were measured in Hamilton and concentrations of radon were measured in Hamilton, Tokoroa, Taupo, Te Kuiti, Matamata, Putaruru, Ngaruawahia, Waihi and Turangi. Monitoring of NO_2 was also carried out in Hamilton during 2011. This report compares PM_{10} concentrations measured in these areas to the NES for PM_{10} and to the Ministry for the Environment's air quality guidelines and indicator categories.

The NES was breached in Tokoroa during 2011 but concentrations in all other areas were compliant. One exceedence of 50 µg m^{-3} was measured in Hamilton, Te Kuiti, Putaruru and Taupo. In comparison, in 2009, concentrations breached the NES in Hamilton, Tokoroa, Te Kuiti, Taupo and Putaruru. In 2011 Tokoroa recorded a similar number of breaches to 2010 but the maximum measured concentration of 73 µg m^{-3} was lower than the 2010 maximum of 99 µg m^{-3}. Concentrations of PM_{10} in Taupo and Te Kuiti show slightly lower concentrations during 2010 and 2011 than for previous years. Further data or investigations would be required to confirm whether the decrease is indicative of a reduction in PM_{10} emissions or occurring as a result of meteorological conditions being less conducive to elevated pollution.

Table E1 shows summary PM_{10} data for all sites for 2011 including the maximum measured concentration, the number of exceedences of 50 µg m^{-3} breaches of the NES and the annual average PM_{10} concentration. The latter can be compared with an annual average guideline of 20 µg m^{-3} (MfE, 2002).

Concentrations of NO_2 were measured in Hamilton at the corner of Avalon Drive and Te Rapa Road from March 2011 to March 2012, including a three month period when road works increased congestion and truck movements in the area. A total of 52 exceedences of 200 µg m^{-3} (hourly average) were measured. The NES for NO_2 allows for nine exceedances of 200 µg m^{-3} per year indicating that the NES for NO_2 was breached on 43 occasions during 2011. No exceedences were measured following the completion of the road works in July 2011.

In Hamilton, concentrations of benzene were within the guideline of 3.6 µg m^{-3} although concentrations at several sites had increased relative to recent years. The highest annual concentration was measured at the Greenwood Street monitoring site and was 3.5 µg m^{-3} which is close to the 2010 benzene guideline. Concentrations of toluene and xylene were well within

acceptable levels. Arsenic concentrations were also within the ambient air quality guideline of 5.5 ng m^{-3}.

Concentrations of radon at all monitoring sites were within acceptable levels.

Table E.1: Summary of PM_{10} monitoring results for 2011.

	Maximum measured concentration µg m^{-3-}	Measured exceedences	Number of NES breaches	Annual Average
Hamilton	64	1	0	14 µg m^{-3}
Tokoroa	73	16	15	18 µg m^{-3}
Taupo	51	1	0	14 µg m^{-3}
Te Kuiti	51	1	0	15 µg m^{-3}
Matamata	31	0	0	12 µg m^{-3}
Putaruru	54	1	0	13 µg m^{-3}
Ngaruawahia	44	0	0	13 µg m^{-3}
Waihi	43	0	0	13 µg m^{-3}
Turangi	33	0	0	10 µg m^{-3}

Table of Contents

List of Figures

List of Tables

1 Introduction

In the Waikato Region the main air contaminant of concern is PM_{10} (particles in the air less than 10 microns in diameter). Concentrations of PM_{10} have historically exceeded the National Environmental Standards for Ambient Air Quality (NES) in Hamilton, Tokoroa, Taupo, Te Kuiti and Putaruru during winter months. The main source of PM_{10} concentrations in these areas during the winter months is solid fuel burning for domestic home heating.

In 2011 PM_{10} concentrations were measured in Hamilton, Tokoroa, Taupo, Te Kuiti, Matamata, Putaruru, Ngaruawahia, Waihi and Turangi. Concentrations of radon were also measured in each of these locations. In Hamilton additional monitoring was carried out for arsenic as well as benzene, toluene and xylenes. Monitoring of arsenic and radon had not been carried out previously as part of the air quality monitoring programme.

Concentrations of PM_{10} are compared to the Ministry for the Environment (MfE) National Environmental Standards (NES) for air quality (Table 1.1). The required target date for compliance with the NES for PM_{10} was reviewed in 2011 and revised from 2013 to 2016 for most airsheds in New Zealand. Areas that experienced more than 10 exceedences of 50 $\mu g\ m^{-3}$ were allowed until September 2020 to achieve the target of one exceedence and an interim target of no more than three exceedences by September 2016 was also set. Tokoroa was identified as qualifying for the more lenient timeframe. All other non-complying areas within the Waikato are required to meet the NES by September 2016.

Most other contaminants are unlikely to be in breach of their respective NES or guideline concentrations in urban areas of the Waikato. A few exceptions have been identified. These include benzo(a)pyrene concentrations which appear to occur well in excess of guideline concentrations in Christchurch, and may occur at guideline values in Hamilton (Wilton and Baynes, 2009). Concentrations of NO_2 may also be of concern in situations such as road works, which increase load and congestion. In addition, concentrations of arsenic have been monitored to determine compliance with guideline values. In 2011 concentrations of radon were measured at sites using BAM instrumentation for measuring PM_{10}. These measurements are carried out by the BAM instrument but have not historically been reported. Generally the majority of resources for air quality monitoring in the Waikato Region have focused on PM_{10}.

The Ministry for the Environment provides guidelines for ambient air quality (Table 1.2) and air quality indicator categories to assist in the presentation and management of air quality in New Zealand (Table 1.3). Air quality monitoring data in this report are presented relative to air quality guidelines and these indicator categories. These categories provide a useful perspective on the overall quality of the air and provide an indicative tool for evaluating trends in concentrations over time.

In the Waikato Region previous PM_{10} monitoring has taken place at Hamilton, Tokoroa, Taupo, Te Kuiti, Matamata, Putaruru, Ngaruawahia, Waihi and Turangi. Passive sampling for benzene has been carried out since 2003 in Hamilton. Monitoring of PAHs was carried out in Hamilton in 2007 and 2008.

Table 1.1: National Environmental Standards for ambient air quality (MfE, 2004).

Contaminant	**NES values**		
	Concentration [a]	**Averaging Period**	**Allowable exceedences per year**
Carbon monoxide	10 mg m^{-3}	8-hour	1
Particles (PM_{10})	50 µg m^{-3}	24-hour	1
Nitrogen dioxide	200 µg m^{-3}	1-hour	9
Sulphur dioxide [b]	350 µg m^{-3}	1-hour	9
Sulphur dioxide [b]	570 µg m^{-3}	1-hour	0
Ozone	150 µg m^{-3}	1-hour	0

Table 1.2: Ambient air quality guidelines for New Zealand (MfE 2002).

Contaminant	2002 guideline values	
	Concentration[a]	Averaging Period
Carbon monoxide	30 mg m^{-3} 10 mg m^{-3}	1-hour 8-hour
Particles (PM_{10})	50 µg m^{-3} 20 µg m^{-3}	24-hour Annual
Nitrogen dioxide	200 µg m^{-3} 100 µg m^{-3}	1-hour 24-hour
Sulphur dioxide [b]	350 µg m^{-3} 120 µg m^{-3}	1-hour 24-hour
Ozone	150 µg m^{-3} 100 µg m^{-3}	1-hour 8-hour
Hydrogen sulphide [c]	7 µg m^{-3}	1-hour
Lead [d]	0.2 µg m^{-3} (lead content of PM_{10})	3-month moving, calculated monthly
Benzene (year 2002) Benzene (year 2010)	10 µg m^{-3} 3.6 µg m^{-3}	Annual Annual
1,3-Butadiene	2.4 µg m^{-3}	Annual
Formaldehyde	100 µg m^{-3}	30-minutes
Acetaldehyde	30 µg m^{-3}	Annual
Benzo(a)pyrene	0.0003 µg m^{-3}	Annual
Mercury (inorganic) [d] Mercury (organic)	0.33 µg m^{-3} 0.13 µg m^{-3}	Annual Annual
Chromium VI [d] Chromium metal and chromium III	0.0011 µg m^{-3} 0.11 µg m^{-3}	Annual Annual
Arsenic (inorganic) [d] Arsine	0.0055 µg m^{-3} 0.055 µg m^{-3}	Annual Annual

Notes for Tables 1.1 and 1.2:

[a] All values apply to the gas measured at standard conditions of temperature (0° C) and pressure (1 atmosphere).

[b] The sulphur dioxide guideline values do not apply to sulphur acid mist.

[c] The hydrogen sulphide value is based on odour nuisance and may be unsuitable for use in geothermal areas.

[d] The guideline values for metals are for inhalation exposure only; they do not include exposure from other routes such as ingestion. These other routes should be considered in assessments where appropriate.

Table 1.3: Environmental Performance Indicator categories for air quality (MfE, 2002).

Category	Value relative to guideline	Comment
Excellent	Less than 10% of the guideline	Of little concern: if maximum values are less than a tenth of the guideline, average values are likely to be much less
Good	Between 10% and 33% of the guideline	Peak measurements in this range are unlikely to affect air quality
Acceptable	Between 33% and 66% of the guideline	A broad category, where maximum values might be of concern in some sensitive locations but generally they are at a level which does not warrant urgent action
Alert	Between 66% and 100% of the guideline	This is a warning level, which can lead to exceedences if trends are not curbed
Action	More than 100% of the guideline	Exceedences of the guideline are a cause for concern and warrant action, particularly if they occur on a regular basis

Although the MfE categories are primarily used as air quality indicators, the Waikato Regional Plan takes a further regulatory step by specifying designated policy responses that should correspond to each zone. Policy 3 of the Air Module of the Waikato Regional Plan contains regional ambient air quality categories and the designated response that the Council will take when developing air quality management framework. Policy 3 states that air quality in the "Excellent" category is to be protected, while "Good" air quality is to be maintained or protected. "Acceptable" air quality is to be maintained. Air quality in the "Alert" category is to be maintained or enhanced. For air quality in the "Action" category, the only designated policy response is to aim to enhance (improve) the situation.

1.1 Reporting period

The reporting period for PM_{10} is from 1 January to 31 December 2011. The reporting period for arsenic is 7 November 2010 to 27 November 2011. The reporting period for benzene, toluene and xylenes is 20 December 2010 to 20 December 2011. The reporting period for NO_2 is 1 March 2011 to 8 March 2012.

In 2006 Environment Waikato introduced a September to August reporting period. This reporting period was introduced for a number of reasons including ensuring that results were reported as soon as possible after the peak winter PM_{10} concentrations and to ensure compliance with the NES reporting requirements. The 2011 annual air quality report has been prepared based on a reporting period of January to December. This is the same format as historical reports.

2 Methodology

Measured concentrations of PM_{10} can be influenced by the method used to monitor $PM_{10.}$ From 2006 a number of air quality monitoring sites in the Waikato region have had gravimetric samplers run in conjunction with existing BAM methods. Waikato Regional Council staff have used the results to determine site specific differences between methods and data were adjusted for gravimetric equivalence. Prior to 2007 data were not adjusted. Some adjustment equations were updated in 2010 as a result of additional monitoring and these equations have been used in the 2011 report.

At the Peachgrove Road air quality monitoring site in Hamilton, PM_{10} concentrations were monitored using a Tapered Elemental Oscillation Microbalance (TEOM) with a sample temperature setting of 40 degrees centigrade. Concentrations of PM_{10} measured using the TEOM in 2011 were based on the same adjustment for 2009 reporting (equation 2.1).

Corrected PM_{10} = 1.19975 x RawTEOM - 3.9182 Equation 2.1

In Tokoroa, a ThermoAndersen FH62 C14 BAM has been used to monitor air quality since 2005. A Sequential Partisol gravimetric sampler was co-located at this site. Equation 2.2 shows the adjustments made to the FH62 data for consistency with the gravimetric method.

Corrected PM_{10} = $10^{(1.09945\log BAM - 0.08595)}$ Equation 2.2

Gravimetric sampling was conducted at the Gillies Street site in Taupo from March 2007. Concentrations of PM_{10} measured using the FH62 C14 BAM during 2011 were adjusted based on equation 2.3.

Corrected PM_{10} = 1.255BAM – 1.538 Equation 2.3

Air quality data at the Putaruru site has been adjusted based on Equation 2.4. This equation was updated in 2010.

Corrected PM_{10} = 1.106BAM - 2.38 Equation 2.4

Concentrations of PM_{10} at Te Kuiti, Matamata, Ngaruawahia and Turangi site were measured using an FH62 C14 BAM. No adjustments have been made to concentrations measured at these sites. In the case of Te Kuiti and Matamata, reference method sampling has confirmed that no adjustment of BAM data is necessary. For the other towns, the possible need for any site-specific correction remains to be assessed. In Waihi PM_{10} concentrations are measured using a gravimetric partisol sampler.

At the Hamilton, Tokoroa, Taupo,Te Kuiti and Matamata air quality monitoring sites, meteorological data, including temperature, wind speed and wind direction were collected. Relative humidity was also collected at Hamilton, Taupo and Matamata. Meteorological data was not available for the Putaruru, Ngaruawahia, Waihi and Turangi sites. At sites where it was available, meteorological data were compared with PM_{10} on days when pollution was elevated.

Waikato Regional Council staff have managed most sites in the Waikato air quality monitoring network since August 2005. Prior to that the monitoring network was operated and maintained by NIWA. The Partisol Model 2000 PM_{10} sampler at the Taupo site has been operated by the Institute of Geological and Nuclear Sciences Ltd (GNS) on behalf of Waikato Regional Council.

Hourly data from the BAM monitors are recorded and logged by an iQuest iRIS 320 datalogger. Results are telemetered hourly to Waikato Regional Council and stored in the hydrotel database.

3 Hamilton

3.1 Air Quality Monitoring in Hamilton

In Hamilton air quality has been measured at a monitoring site in Peachgrove Road located on the south-east side of Hamilton City since November 1997. The site meets the requirements of the "Residential Peak" site classification as described in the '*Good Practice Guideline for Air Quality Monitoring and Data Management 2009'* report (MfE, 2009). During 2011, PM_{10}, arsenic, benzene, ethyl-benzene, toluene and xylenes were measured at Peachgrove Road.

Benzene, ethyl-benzene, toluene and xylenes (BTEX) have also been monitored during recent years at other sites in Hamilton. These include Bridge Street, Claudelands Road, Hamilton Intermediate School, Greenwood Street and Tristram Street. Monitoring of NO_2 was carried out at the corner of Avalon Drive and Te Rapa Road, Hamilton over the period 1 March 2011 to 16 March 2012. Figure 3.1 shows the main (Peachgrove Road) air quality monitoring site in Hamilton.

During 2011, PM_{10} monitoring at Peachgrove Road was carried out using a Tapered Elemental Oscillating Microbalance (TEOM) with a sample temperature setting of 40°C. The PM_{10} data were collected at the Peachgrove Road site as ten minute averages and subsequently hourly averages and 24 hour averages were calculated from these data. Data were adjusted for gravimetric equivalency based on the equation outlined in section two.

Passive sampling for the volatile organic compounds (VOCs) benzene, ethyl-benzene, toluene and xylenes was carried out using 3M Passive Diffusion Monitors. The method used is as described in Stevenson and Narsey (1999) with filters being deployed for periods of three months. The analysis was carried out by Hill Laboratories in Hamilton. While this type of passive sampling is recommended as a screening method only, it is the most common approach to benzene monitoring in New Zealand and is significantly more cost effective than the method recommended by the Ministry for the Environment's ambient air quality guidelines (MfE 2002).

Monitoring of arsenic was carried out in Hamilton using filters from a sequential partisol sampler located at the Peachgrove Road site. The filters were collected from 7 November 2010 to 27 November 2011 and were analysed for arsenic using ICP-MS.

Concentrations of NO_2 were measured using an Ecotech Serinus 40 NO_2/NO_x analyser (gas phase chemiluminescence). Operational aspects of the NO_2 monitoring including maintenance, calibration and quality assurance were carried out by CRL Energy Ltd for Waikato Regional Council.

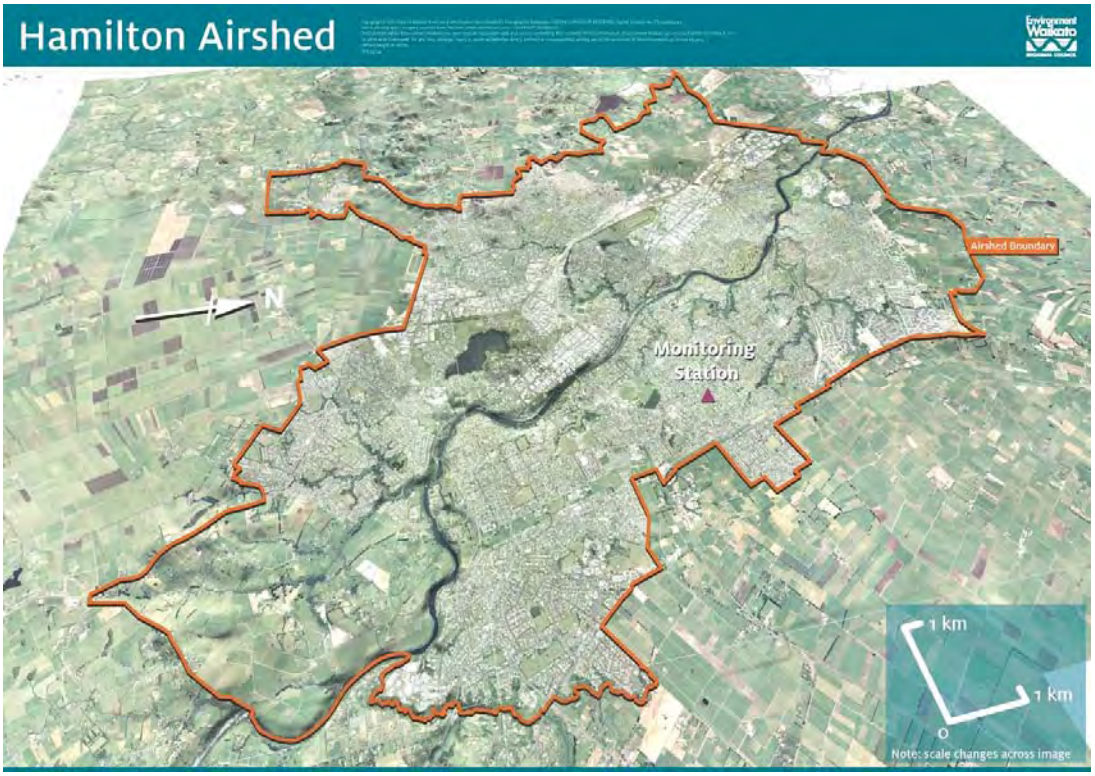


Figure 3.1: Hamilton Airshed and air quality monitoring site (Source: Environment Waikato, 2010).

3.2 PM_{10} concentrations for Hamilton

There was one exceedence of 50 µg m^{-3} (24-hour average) measured in Hamilton during 2011. A concentration of 64 µg m^{-3} was measured on 19 May. This compares with no exceedences (maximum 30 µg m^{-3}) during 2010 and two winter time maximums of 54 µg m^{-3} measured during 2009. A further exceedence in 2009 and the maximum PM_{10} concentration recorded at Hamilton reached 101 µg m^{-3} and coincided with a dust storm event in Australia.

Daily PM_{10} concentrations measured at Hamilton during 2011 are shown in Figure 3.2.

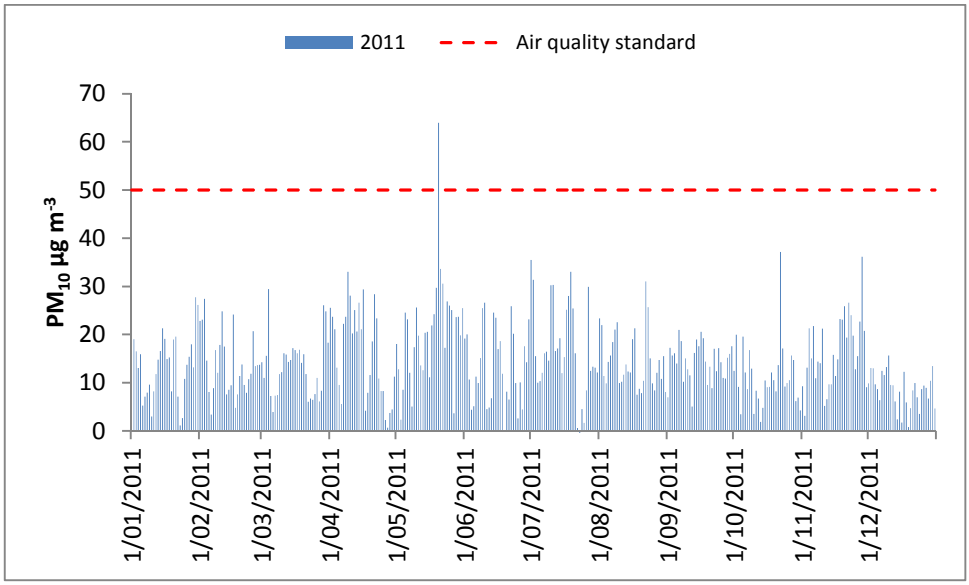


Figure 3.2: 24-hour average PM_{10} concentrations measured at Peachgrove Road during 2011.

Figure 3.3 compares daily PM_{10} concentrations measured from 2000 to 2010 to the MfE air quality indicator categories (shown in Table 1.3). During 2011 the majority of the PM_{10} concentrations measured were less than 66% of the air quality guideline. Figure 3.4 shows the seasonal variations in the distribution of PM_{10} concentrations during 2011. Figure 3.5 shows the number of days when 50 µg m^{-3} was exceeded, the maximum concentration and the second highest concentration from 2006 to 2011.

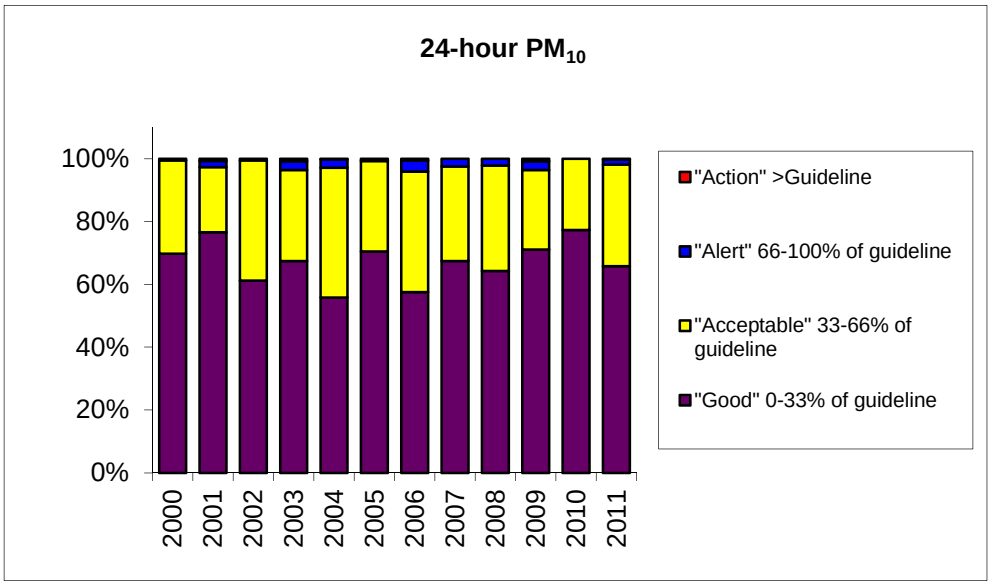


Figure 3.3: Comparison of PM_{10} concentrations measured at Peachgrove Road in Hamilton from 2000 to 2011 to air quality indicator categories.

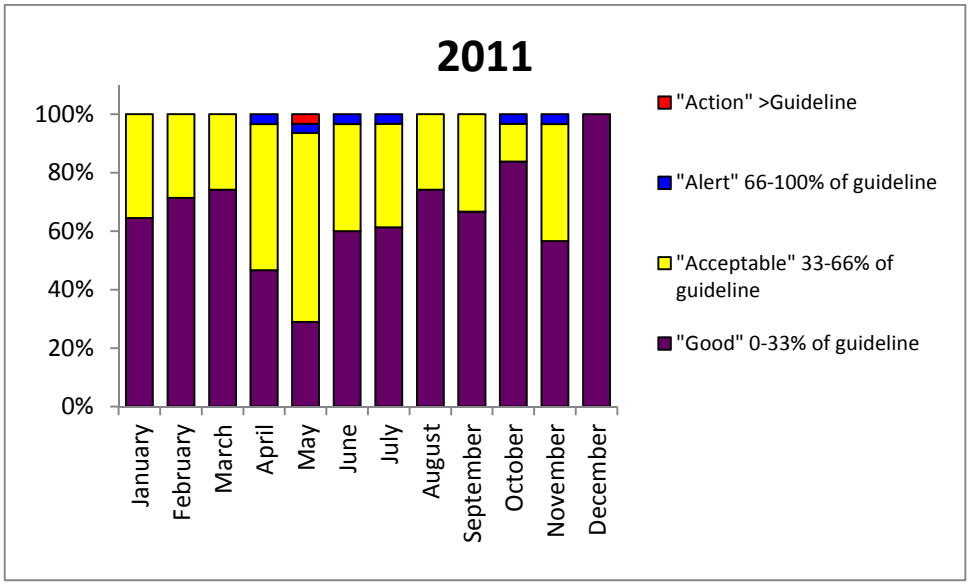


Figure 3.4: Comparison of daily PM_{10} concentrations each month for 2011 to air quality indicator categories.

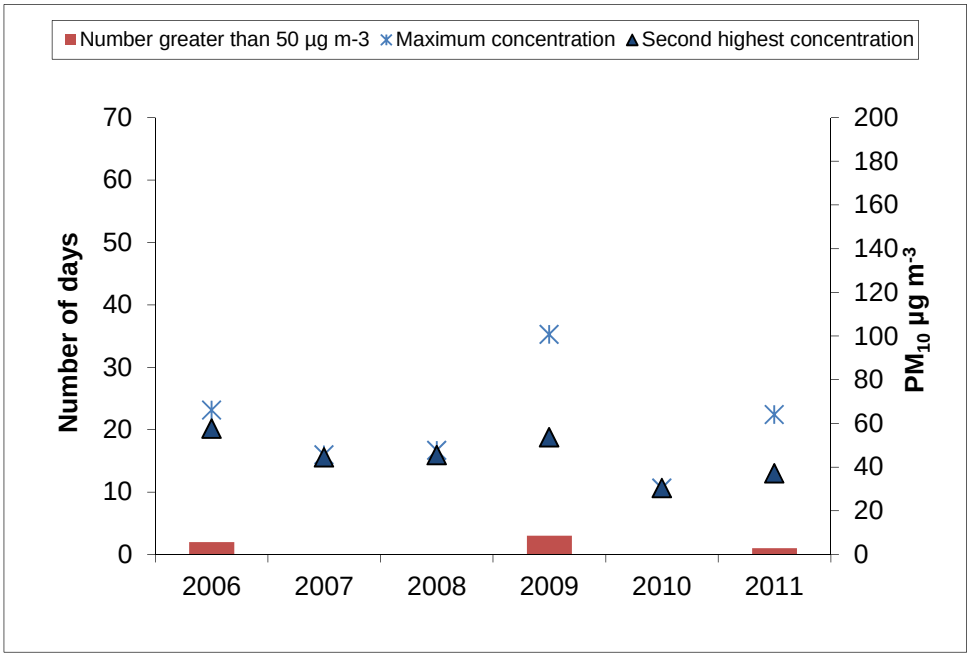


Figure 3.5: Number of days when 50 µg m^{-3} was exceeded, the maximum concentration and the second highest concentration from 2006 to 2011.

The annual average PM_{10} concentration for Hamilton for 2011 was 14 µg m^{-3} and it is similar in magnitude to previous years. The Ministry for the Environment specifies an annual average guideline for PM_{10} of 20 µg m^{-3}. An annual average PM_{10} concentration is not specified in the NES.

Summary statistics for PM_{10} monitoring results from the Hamilton site from 2000 to 2011 are shown in Table 3.1. Since 2007 concentrations have been adjusted for differences between the TEOM and gravimetric sampling methods as detailed in Section 2 of this report.

Table 3.1: Summary of PM_{10} concentrations measured at Peachgrove Road in Hamilton from 2000 to 2010.

	2000	2001	2002	2003	2004	2005	2006	2007*	2008	2009	2010	2011
"Good" 0-33% of guideline	70%	77%	61%	67%	56%	70%	58%	67%	64%	71%	77%	66%
"Acceptable" 33-66% of guideline	30%	21%	38%	29%	41%	29%	38%	30%	34%	25%	23%	32%
"Alert" 66-100% of guideline	1%	2%	1%	3%	3%	1%	4%	2%	2%	3%	0%	2%
“Action” >Guideline	0%	1%	0%	1%	0%	0%	1%	0%	0%	1%	0%	0%
Percentage of valid data	91%	70%	93%	91%	94%	77%	99%	66%	99%	99%	99%	100%
Annual average (µg m^{-3})	15	15	16	16	17	15	17	15	15	14	13	14
Measured exceedences	0	3	0	4	1	0	2	0	0	3	0	1
Second highest PM_{10} concentration (µg m^{-3})							58	44	45	54	30	37
Annual maximum (24-hr average µg m^{-3})	43	67	36	62	55	37	66	46	48	101	30	64
Number of records	334	256	340	331	344	281	363	242	364	363	361	365

*Data post 2007 is adjusted for gravimetric equivalency.

3.3 Concentrations of Benzene, Toluene and Xylenes

In Hamilton, monitoring of benzene at the Peachgrove Road air monitoring site and at a high-density traffic area at Bridge Street has taken place since 2003. In 2004 an additional benzene sampling site was established at the intersection of Claudelands Road and Victoria Street (Claudelands Bridge). This is also a high density traffic area. Additional sites were established in 2006 in Tristram Street, Greenwood Street and at Hamilton Intermediate School.

Benzene concentrations measured at all locations in Hamilton during 2011 were within the Ministry for the Environment's 2010 annual guideline of 3.6 µg m^{-3} (Table 3.2). The guideline prior to 2010 was 10 µg m^{-3} (annual average). The highest average annual concentration during 2009 was 3.0 µg m^{-3} and was measured at the Greenwood Street monitoring site.

Prior to 2011, benzene concentrations had tapered relative to decreases observed from 2004 to 2007 (Figure 3.6). The earlier decreases (from 2004 – 2007) were attributed to changes in fuel specifications and improved vehicle technology (Smith, 2007). Results for 2011 show an increase at all sites, with the exception of Bridge Street which showed a decrease in concentrations. For most sites the 2011 concentrations were similar to the 2008 concentrations. The exception was the Peachgrove Road site which showed benzene concentrations similar to 2005 levels. The maximum measured benzene concentration at Greenwood Street of 3.5 µg m^{-3} is close to the 2010 guideline for benzene of 3.6 µg m^{-3}.

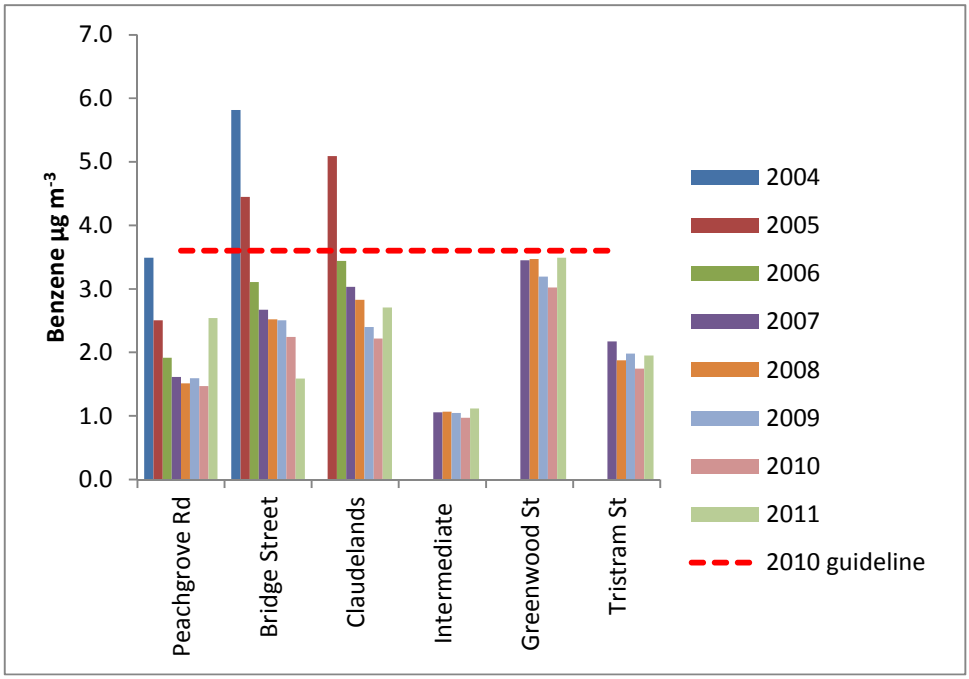


Figure 3.6: Annual average benzene measured at Hamilton sites ((February 2003 – February 2004) (July 2004 – July 2005), (September 2005 – September 2006), (December – December for 2007 - 2010)).

Toluene and xylene were also measured at the benzene monitoring sites for each year. An MfE document discussing amendments to the 1994 ambient air quality guidelines suggests an annual threshold of 190 µg m^{-3} and 950 µg m^{-3} for toluene and total xylenes respectively (MfE, 2000). Concentrations of toluene and xylene measured in Hamilton at all sites were significantly lower than the thresholds suggested by MfE (2000).

Table 3.2: Annual average concentrations of volatile organic compounds (VOCs) at Hamilton sites between December 2010 to December 2011.

	Bridge St	Peachgrove Road	Claudelands	Intermediate	Greenwood Street	Tristram Street	Guideline[a]
	µg m^{-3}						
Benzene	2.7	1.6	3.0	1.1	3.5	2.2	3.6 (10[a])
Toluene	10.72	6.81	11.60	4.74	17.65	9.61	190[b]
Total Xylenes	8.84	5.33	9.20	3.62	11.49	7.06	950[b]

[a] The historical guideline for benzene of 10 µg m^{-3} reduced to 3.6 µg m^{-3} in 2010.

[b] There are currently no guideline values for toluene and xylenes. Threshold values used here are from proposed amendments to the 1994 ambient air quality guidelines.

3.4 Concentrations of arsenic

An annual average arsenic concentration of 3.57 ng/m^3 was measured at Peachgrove Road during the 12 month period from November 2010 to November 2011. This is less than the annual average MfE (2002) ambient air quality guideline of 0.0055 µg/m^3 (5.5 ng/m^3).The maximum four day average concentration of 20.69 ng/m^3 and was recorded during August 2011.

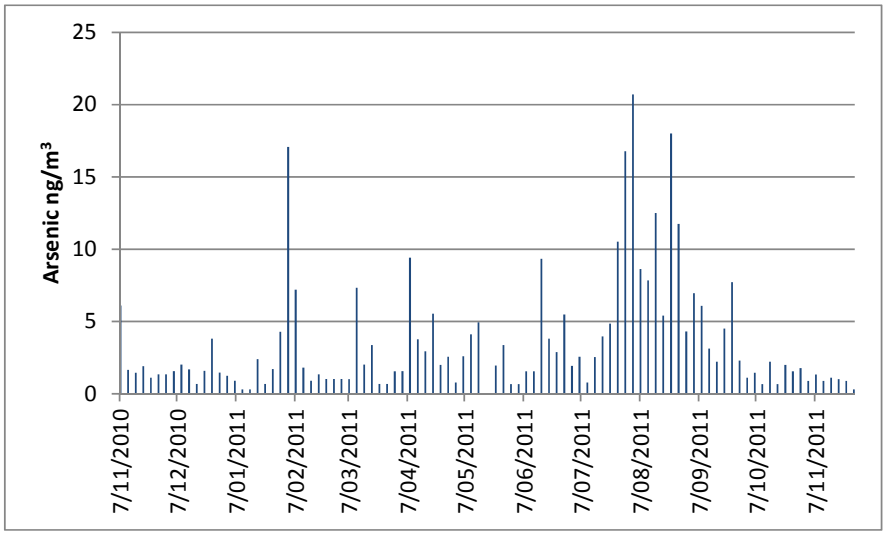


Figure 3.7: Concentration of arsenic (ng/m^3) versus date in the middle of the four day run.

3.5 Concentrations of NO_2

During 2011 hourly average concentrations of NO_2 exceeded 200 µg m^{-3} on 52 occasions. The NES for NO_2 is set at 200 µg m^{-3} with nine allowable exceedences per year. Thus the NES for NO_2 was breached on 43 occasions during 2011. Table 3.3 shows the dates of the exceedences. Figure 3.8 shows no further exceedances occurred after 20 May 2011. Figure 3.9 shows that the 24-hour average NO_2 concentrations measured during this period also exceeded the ambient air quality guideline of 100 µg m^{-3}.

The large number of NO_2 exceedances observed over the three month period, March 2011 to May 2011, is believed to occur as a result of a larger-than-average number of truck movements (plus more congestion) through the intersection during the period when the monitoring started in March. The Wairere Drive 4 laning works that was in progress at the time required large scale removal of soil and relocation in a cleanfill to the north. The transport route for this soil relocation meant that there was up to 290 heavy trucks per hour moving through the Avalon Drive/ Te Rapa Road intersection during peak morning traffic congestion. Waikato Regional Council received reports that traffic gridlock was occurring during this period.

Table 3.3: Breaches of national environmental standard for NO_2 at the intersection of Te Rapa Road and Avalon Drive.

Date	**Time**	**NO_2 (µg/m^3) – hourly average**	**Date**	**Time**	**NO_2 (µg/m^3) – hourly average**
March 2011			**April 2011**		
Thu 3	8 - 9am	210	Fri 1	7 - 8am	216
Tue 8	7 - 8am	345		8 - 9am	201
Wed 9	7 - 8am	273	Fri 8	8 - 9am	223
	8 - 9am	211	Tue 12	7 - 8am	243
Thu 10	6 - 7am	208		8 - 9am	268
	7 - 8am	240	Wed 13	8 - 9am	247
Fri 11	6 - 7am	214		9 - 10am	237
	7 - 8am	292	Thu 14	8 - 9am	208
	8 - 9am	272	Fri 15	8 - 9am	231
Sat 12	7 - 8am	207	Tue 19	8 - 9am	257
Mon 14	7 - 8am	235	Fri 29	8 - 9am	207
	8 - 9am	207	Sat 30	7 - 8 pm	283
Wed 16	7 - 8am	206	**May 2011**		
	8 - 9am	219	Thu 5	8 - 9am	211
Thu 17	7 - 8am	251		9 - 10pm	241
	8 - 9am	227		10 - 11pm	211

Thu 24	7 - 8am	207	Fri 6	11pm - 12am	233
	8 - 9am	238	Tue 10	8 - 9am	222
Tue 29	7 - 8am	223	Wed 11	8 - 9am	209
	8 - 9am	284		9 - 10am	209
Wed 30	6 - 7am	302		10 - 11am	201
	7 - 8am	556	Thu 12	7 - 8am	423
	8 - 9am	251		8 - 9am	488
Thu 31	7 - 8am	341		9 - 10am	205
	8 - 9am	358	Thu 19	6 -7pm	208
	9 - 10am	227		9 - 10pm	242
			Fri 20	9 - 10am	243

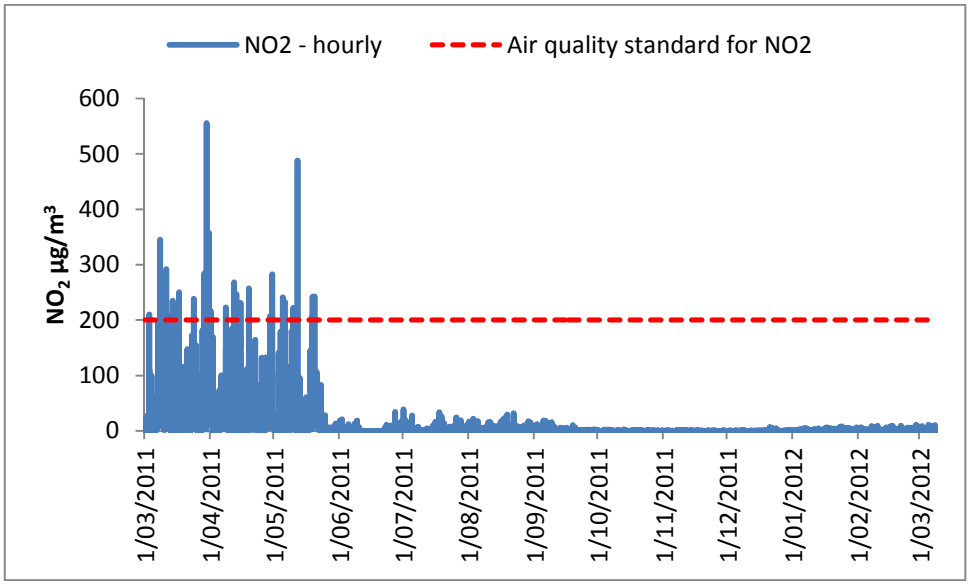


Figure 3.8: Hourly average NO_2 concentrations measured during 2011.

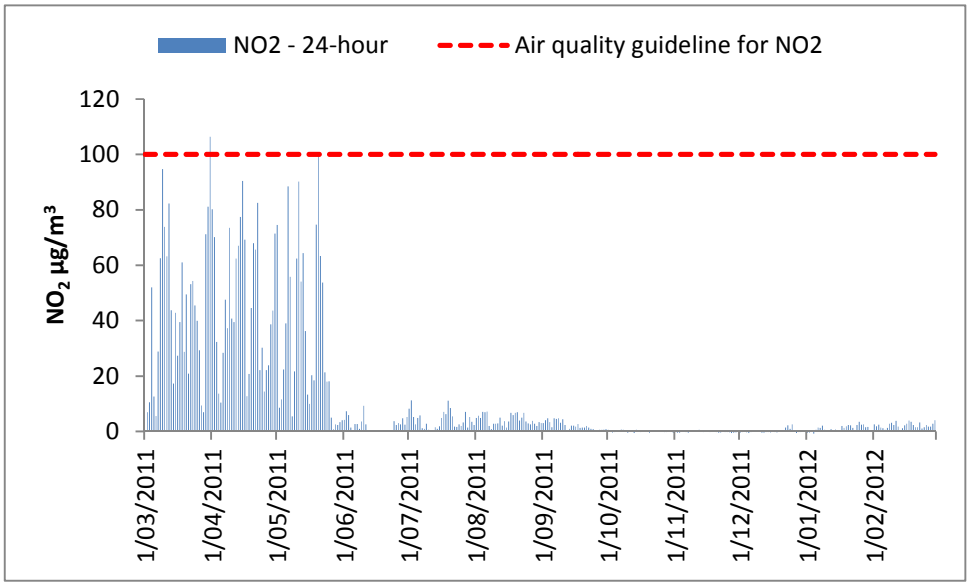


Figure 3.9: 24-hour average NO_2 concentrations measured during 2011.

Figure 3.10 compares hourly and 24-hour average NO_2 concentrations measured during 2011/12 to air quality indicator categories. Both the 24-hour guideline and hourly average NES were breached on 1% of days for the year, although for the 24-hour data this equates to two days compared with 43 occasions with the hourly data. The 24-hour average concentrations were in the alert category 5% of the time compared with 1% for the hourly average data. Figures 3.11 and 3.12 show the distribution of NO_2 concentrations relative to the air quality indicator categories by month of year. With the exception of the March to May 2011 period concentrations of NO_2 were excellent or good. This indicates that NO_2 concentrations are not normally of concern but indicates that problems can arise under roadwork type situations.

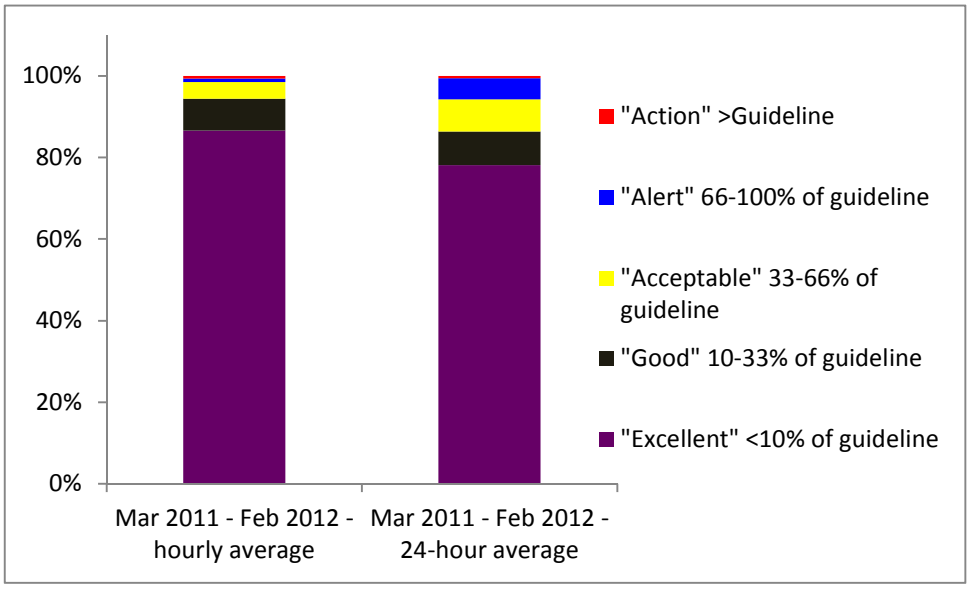


Figure 3.10: Comparison of hourly and 24-hour average NO_2 concentrations to air quality indicator categories.

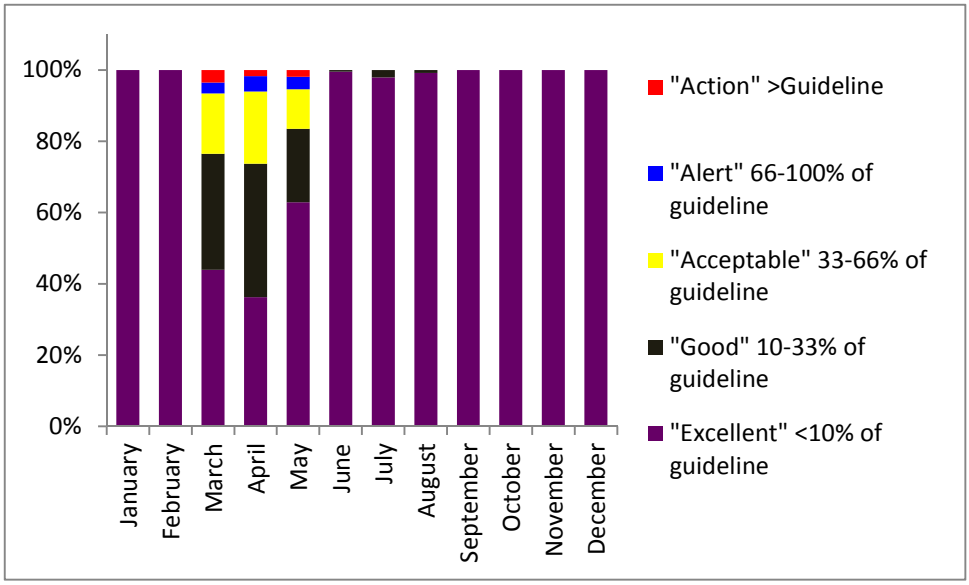


Figure 3.11: Comparison of hourly average NO_2 concentrations each month to air quality indicator categories.

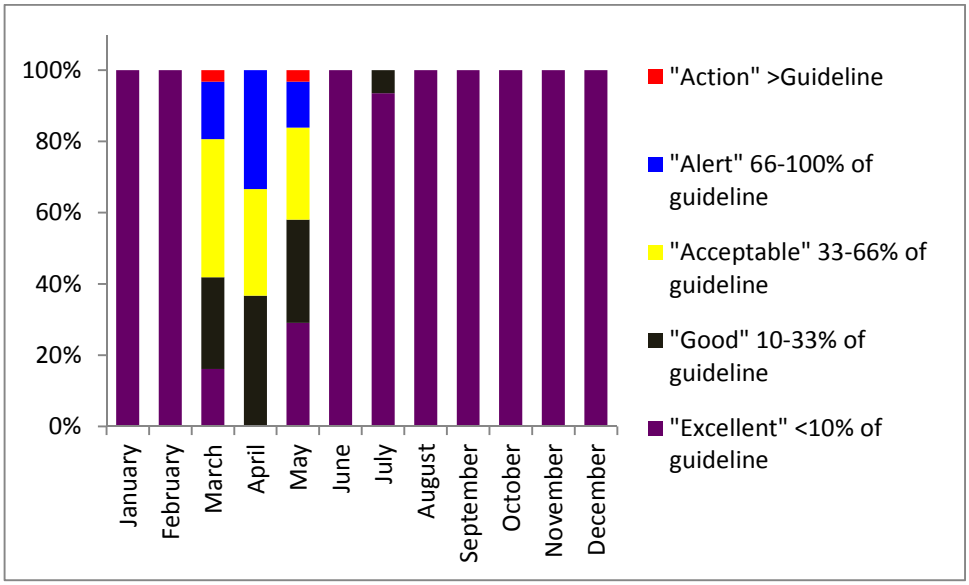


Figure 3.12: Comparison of 24-hour average NO_2 concentrations each month to air quality indicator categories.

3.6 Comparison of meteorological conditions for 2011 to previous years

The frequency and extent of NES breaches from year to year depends largely on the prevalence of meteorological conditions conducive to elevated pollution, in particular low wind speeds, cooler temperatures and temperature inversions. Figure 3.13 compares summary statistics for wind speed and temperature from 1998 to 2010.

An evaluation of meteorological conditions and PM_{10} concentrations in Hamilton from 1998 to 2007 identified 24-hour average wind speed less than 0.74 ms^{-1} as the main meteorological characteristic of elevated PM_{10} concentrations (Wilton, 2007). Figure 3.14 compares the number of days during the winter months when these meteorological conditions occurred from 2000 to 2010 and the number of days each year when PM_{10} concentrations exceeded 50 µg m^{-3}. Results suggest both 2009 and 2010 had a slightly lower prevalence of days when PM_{10} concentrations might typically be elevated but that in 2009 a greater proportion of these experienced high pollution (Figure 3.15).

An alternative but similar approach is to look at the proportion of each grouping of PM_{10} concentrations (10 µg m^{-3} increments) in which the wind speed (24-hour) is less than .74 ms^{-1}. Figure 3.16 shows that these conditions are met on all days when PM_{10} concentrations exceed 50 µg m^{-3} and on most days when the concentrations are between 40 and 50 µg m^{-3}.

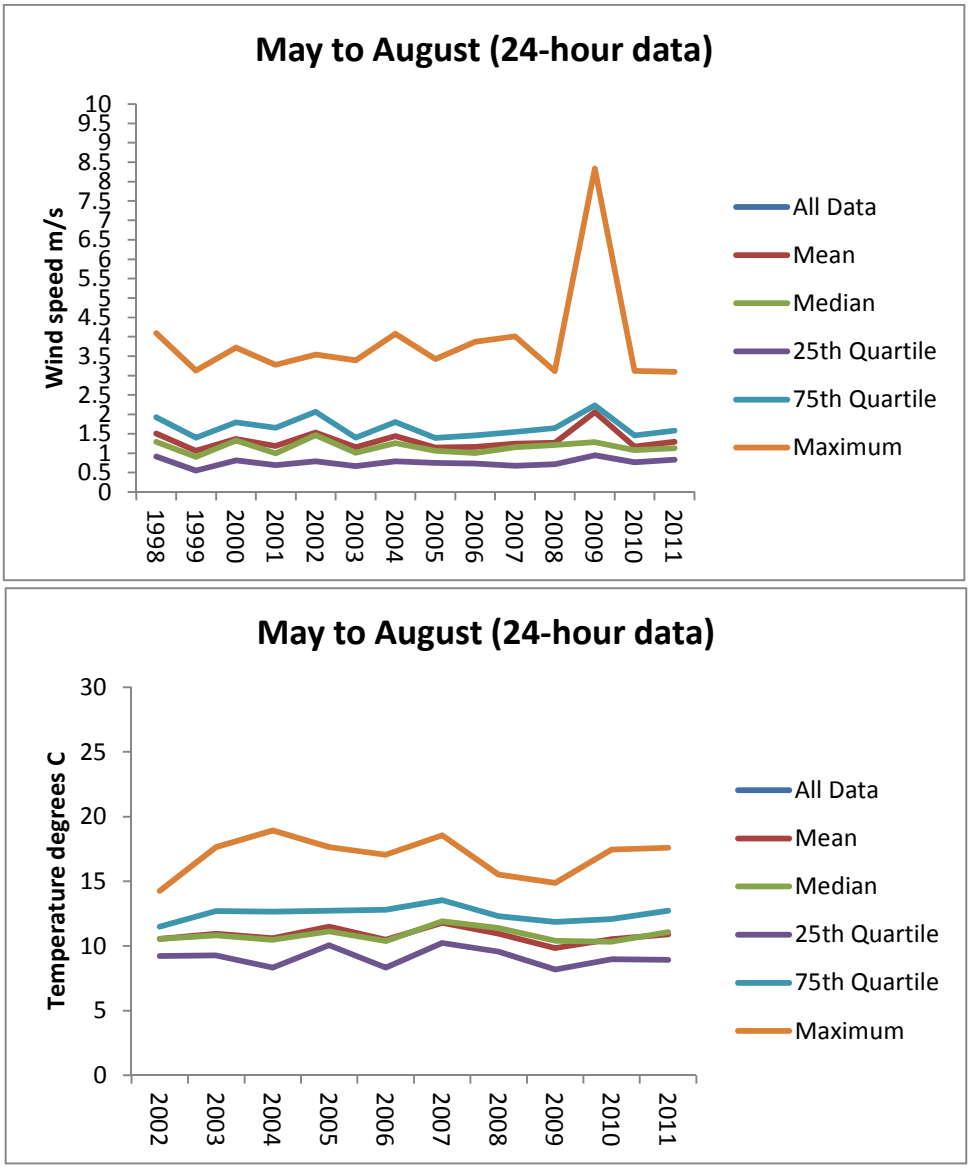


Figure 3.13: Summary wind speed and temperature data from 1999 to 2011 at the Peachgrove Road site.

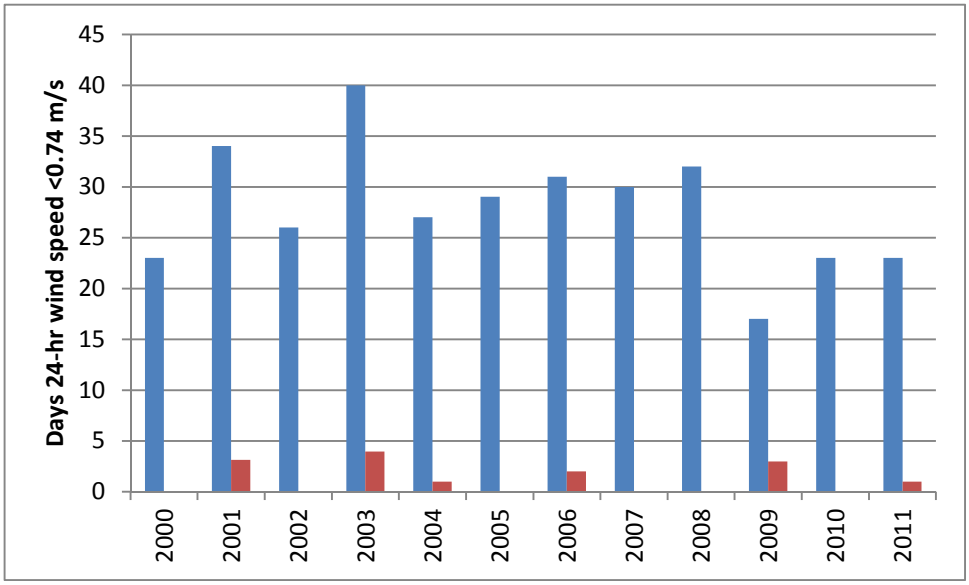


Figure 3.14: Number of days from May to August when the 24-hr average wind speed were less than 0.74 ms^{-1} (blue bar) and number of guideline exceedences per year (red bar).

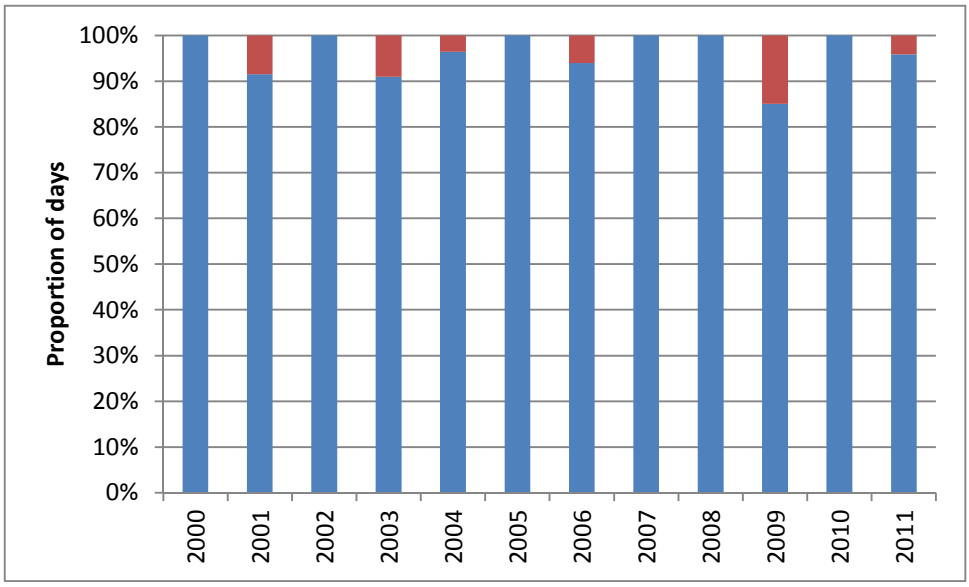


Figure 3.15: Proportion of days when wind speed was less than 0.74 ms^{-1} that PM_{10} concentrations were less than 50 µg m^{-3} (blue bar) and proportion that exceeded 50 µg m^{-3} (red bar).

3.7 Daily variations on high pollution day

Figure 3.12 shows the daily variations in PM_{10} concentrations and meteorological parameters on 19 May when PM_{10} concentrations reached 64 µg m^{-3}. Concentrations of PM_{10} were high throughout the day with a small increase in concentrations around 9am and a more distinct peak around 8pm. Concentrations during the latter period reached 112 µg m^{-3} but dropped off to less than 30 µg m^{-3} by

11pm. The daily wind speed averaged 0.66 ms^{-1} but was particularly low during the evening period (less than 0.5 ms^{-1}).

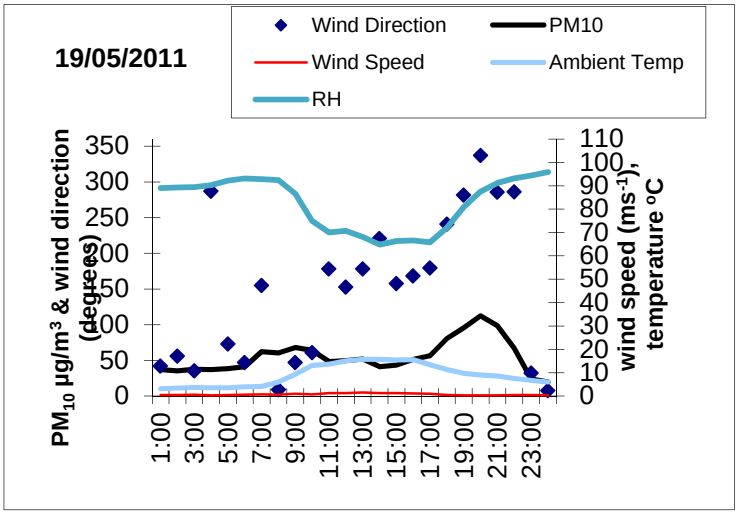


Figure 3.16: Daily variation in PM_{10} concentrations, wind speed, temperature and relative humidity on 19 May 2011 when PM_{10} concentrations reached 64 µg m^{-3}.

4 Tokoroa

4.1 Air Quality Monitoring in Tokoroa

In Tokoroa, monitoring for PM_{10} has been carried out since 2001 at the Billah Street Reserve air quality monitoring site, located west of central Tokoroa. The monitoring site meets the requirements of the "Residential Neighbourhood" site classification as described in the *Good Practice Guideline for Air Quality Monitoring and Data Management 2009',* report (MfE, 2009).

In 1999, some air quality monitoring was carried out in Tokoroa at the South Waikato Council Offices, on the east side of the town. Results of the 1999 monitoring are not included in this air quality monitoring report due to uncertainties surrounding the monitoring method.

A MET ONE series 1020 BAM was used to monitor PM_{10} from 2001 to September 2005 at the Billah Street site. In September 2005 the MET ONE instrument was replaced with a ThermoAndersen FH62 C14 BAM due to unacceptable data loss caused by frequent tape failure from the MET ONE. The FH62 BAM records data at ten minute intervals. Figure 4.1 shows the Tokoroa Airshed and the location of the air quality monitor in Tokoroa.

Figure 4.1: Tokoroa Airshed and air quality monitoring site (Source: Environment Waikato, 2010).

4.2 PM_{10} concentrations in Tokoroa

During 2011 there were 16 days when PM_{10} concentrations exceeded 50 µg m^{-3}. The dates and concentrations reached on these days are shown in Table 4.1. The maximum measured concentration was 73 µg m^{-3} and compares with a maximum of 99 µg m^{-3} measured at the site during 2010 (Table 4.2).

Table 4.1: Dates and concentrations for 2011 exceedences of 50 µg m^{-3} in Tokoroa.

Date	PM_{10} µg m^{-3}	Rank	Date	PM_{10} µg m^{-3}	Rank
16/08/2011	73	1	16/06/2011	58	9
19/05/2011	72	2	20/05/2011	56	10
23/08/2011	72	3	31/05/2011	56	11
21/05/2011	67	4	26/07/2011	54	12
17/07/2011	65	5	1/07/2011	52	13
29/05/2011	60	6	18/07/2011	52	14
5/08/2011	60	7	1/08/2011	51	15
16/07/2011	58	8	18/05/2011	51	16

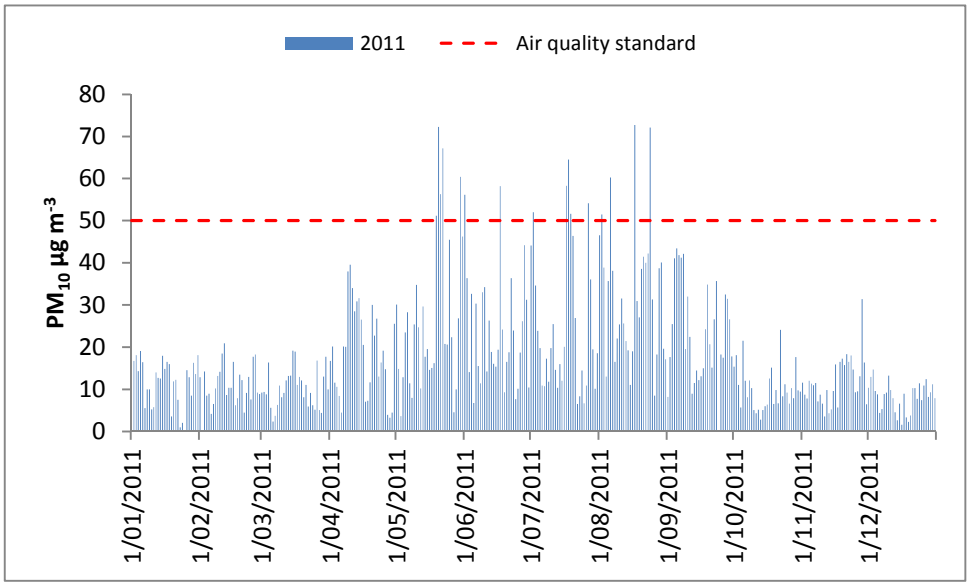


Figure 4.2: Daily winter PM_{10} concentrations measured in Tokoroa during 2011.

It is noted that Met One BAM was changed to an FH62 BAM in September 2005, and a change in baseline readings was observed at that point (Smith, 2006). In 2007 and

2008, site-specific calibration against a gravimetric method was carried out. Comparison of results from the two co-located instruments now suggest that:

- The previous BAM was recording an artificially high baseline reading, because the new instrument is accurate[1] at low PM_{10} concentrations, and
- The new BAM requires a significant upward correction across the mid and upper ranges, in the order of approximately 19% at a PM_{10} concentration of 50 µg m^{-3}. Although site-specific calibration data is only available for the newer instrument, it is also likely that the older BAM would have required a similar range correction to bring its results into line with gravimetric results in Tokoroa (pers comm., Nick Kim, Environment Waikato, 2008).

The net result of these two corrections for all data collected in Tokoroa prior to September 2005 would be to reduce the annual average, but increase the peaks (and the non-compliance frequency).

In this report the approach taken has been to report only calibration-corrected data collected on the newer FH62 BAM during the monitoring years from 2006. Retrospective estimates of air quality in Tokoroa from 2001 to 2005 may form a part of future work involving analysis of trends.

Figure 4.3 shows changes in PM_{10} concentrations relative to air quality indicator categories at the Tokoroa site from 2001 to 2011. Figure 4.4 shows the seasonal variations in the distribution of PM_{10} concentrations for 2011. In May 19% of days resulted in concentrations in the “action” category. August was also notably poor with 13% of days in the “action” category and 29% of days in the “alert” category. The number of days when 50 µg m^{-3} was exceeded, the maximum concentration and the second highest concentration from 2006 to 2011 are shown in Figure 4.5.

[1] The newer BAM is more accurate when compared with the gravimetric reference method.

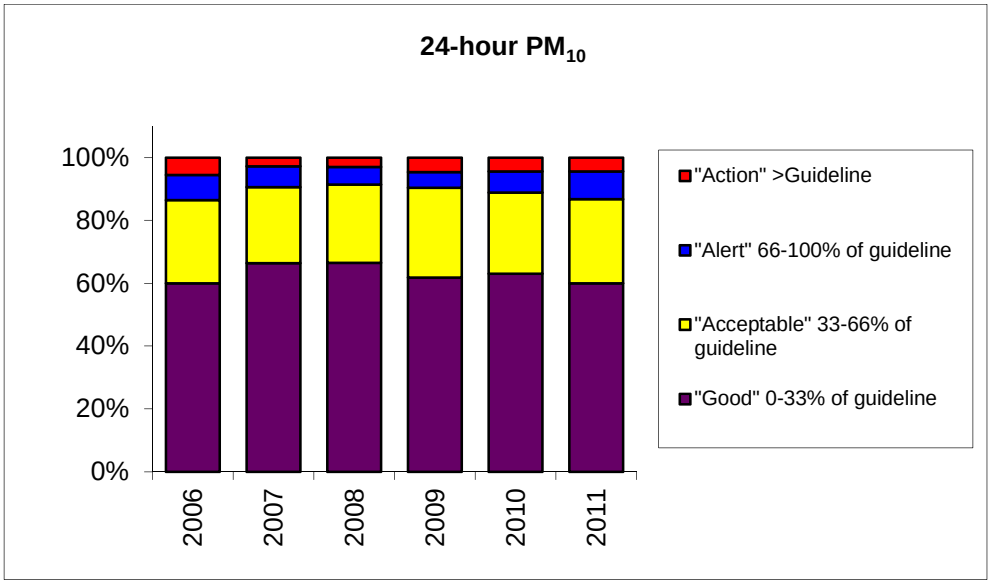


Figure 4.3: Comparison of PM_{10} concentrations measured in Tokoroa from 2006 to 2011 to air quality indicator categories.

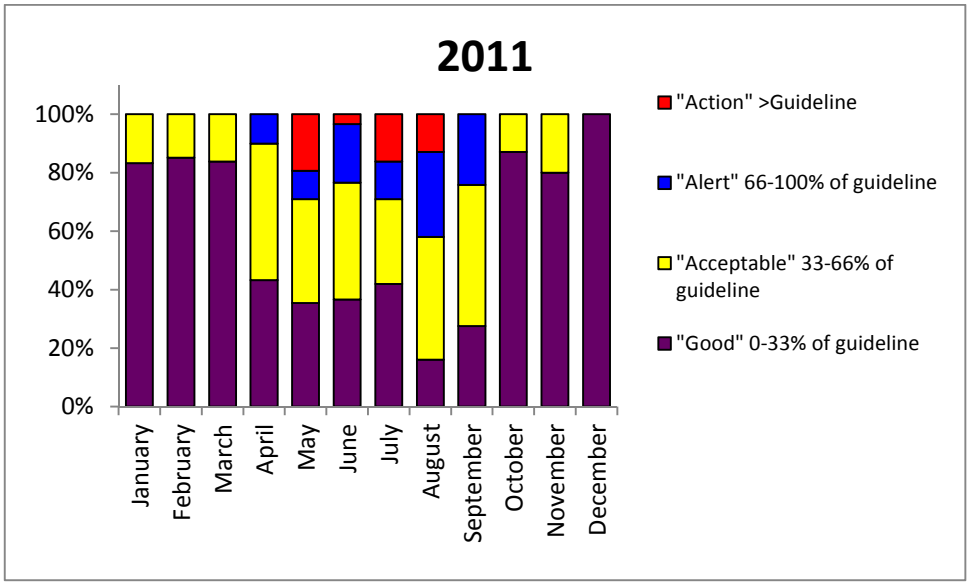


Figure 4.4: Comparison of daily PM_{10} concentrations each month during 2010 to air quality indicator categories.

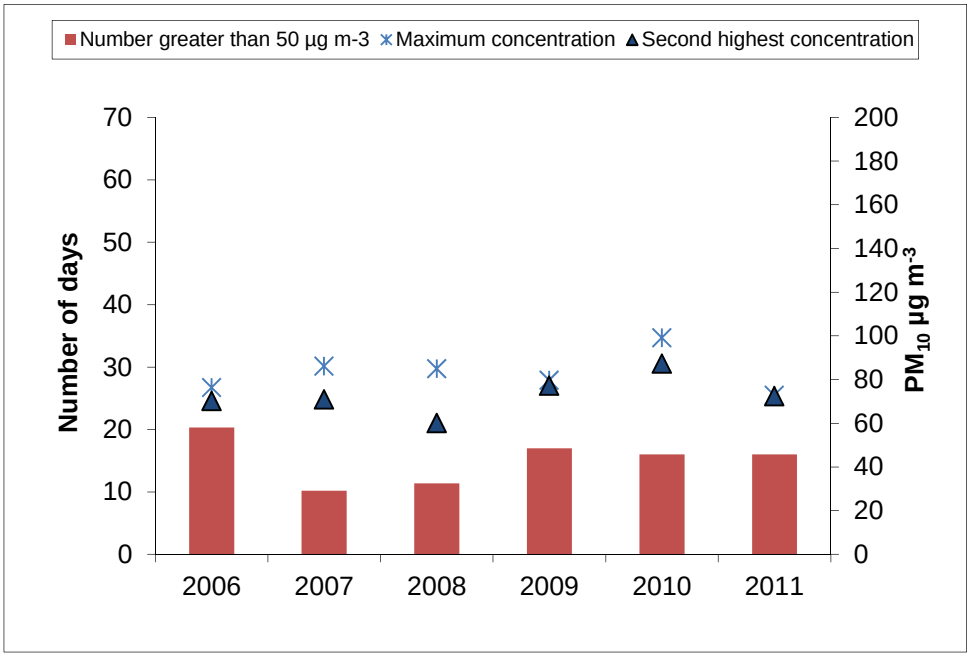


Figure 4.5: Number of days when 50 µg m^{-3} was exceeded, the maximum concentration measured and the second highest concentration from 2006 to 2011.

The annual average PM_{10} concentration for Tokoroa for 2010 was 18 µg m^{-3}. This is similar to other annual average concentrations. Table 4.2 shows the summary statistics for PM_{10} monitoring results.

Table 4.2: Summary of PM_{10} concentrations measured at the Tokoroa monitoring site from 2001 to 2011.

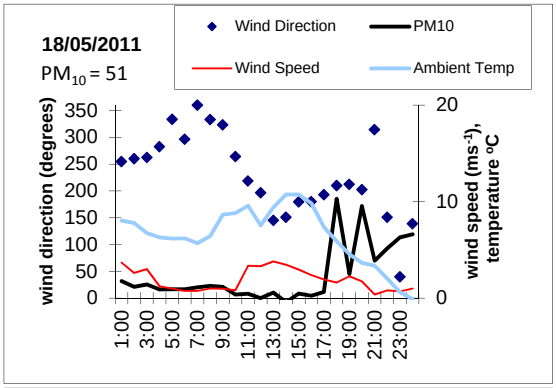
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
"Good" 0-33% of guideline	12%	15%	25%	12%	32%	60%	66%	67%	62%	63%	60%
"Acceptable" 33-66% of guideline	64%	71%	58%	54%	46%	26%	24%	25%	29%	26%	27%
"Alert" 66-100% of guideline	17%	10%	11%	23%	13%	8%	7%	6%	5%	7%	9%
“Action” >Guideline	8%	4%	5%	12%	9%	6%	3%	3%	5%	4%	4%
Percentage of valid data	47%	98%	55%	96%	88%	99%	99%	99%	100%	99%	99%
Annual average (µg m^{-3})	27	24	24	31	25	19	16	17	18	18	18
Measured exceedence	24	15	18	41	33	20	10	11	17	16	16
Second highest PM_{10} concentration (µg m^{-3})	75	70	62	97	89	70	71	60	77	87	72
Annual maximum (µg m^{-3})	66	66	56	92	66	76	86	85	80	99	73
Number of records	173	357	201	351	320	360	360	360	364	360	362

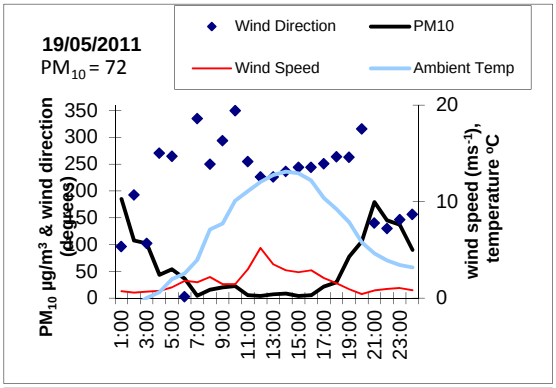
4.3 Daily variations in PM_{10} and meteorology on high pollution days

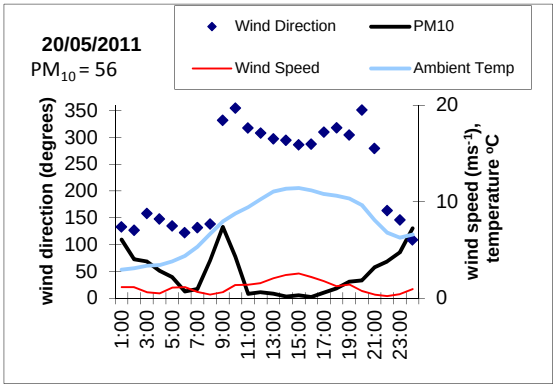
Figure 4.6 shows the variations in meteorological conditions and hourly average PM_{10} concentrations on the 16 days when the 24-hour average PM_{10} measured at Tokoroa exceeded 50 µg m^{-3}.

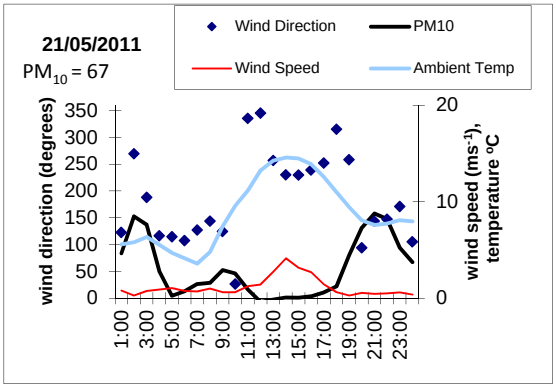
Highest PM_{10} concentrations occurred on 19 May, 6 August and 23 August. On 19 May and 23 August, PM_{10} concentrations showed typical diurnal variations with a decrease in concentrations from midnight to 7am, a small peak around 9am and a more substantial increase in concentrations from 5pm. On 16 August PM_{10} highest PM_{10} concentrations occurred around 9am with evening peak concentrations being slightly lower. On most days

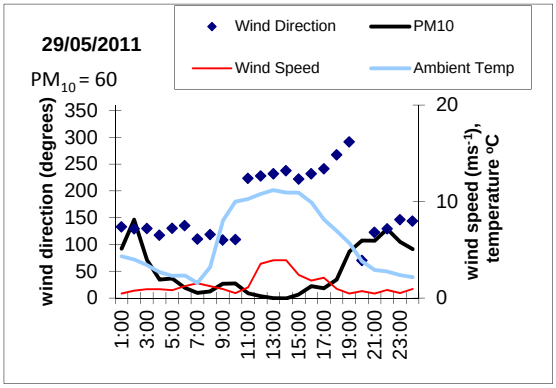
High concentrations typically occur when the wind speeds are low and typically from a south east wind direction.

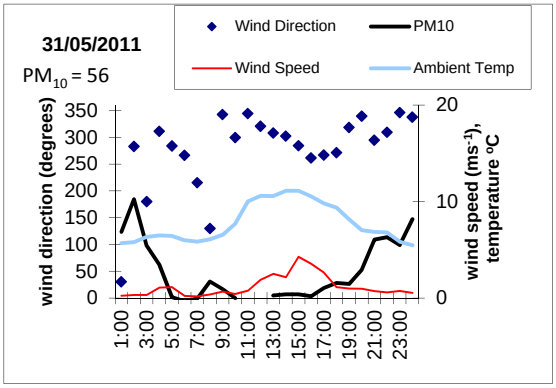

18/05/2011
PM10 = 51
Wind Direction
PM10
Wind Speed
Ambient Temp
wind direction (degrees)
wind speed (ms-1), temperature °C

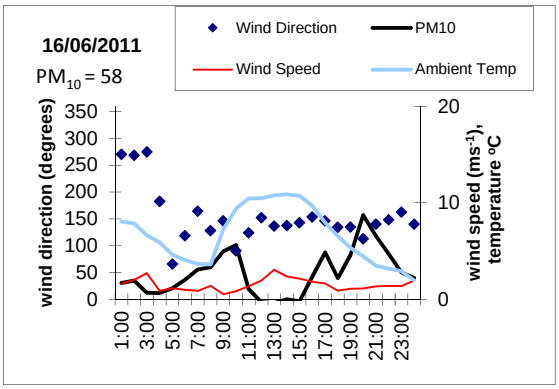

19/05/2011
PM10 = 72
Wind Direction
PM10
Wind Speed
Ambient Temp
PM10 µg/m3 & wind direction (degrees)
wind speed (ms-1), temperature °C

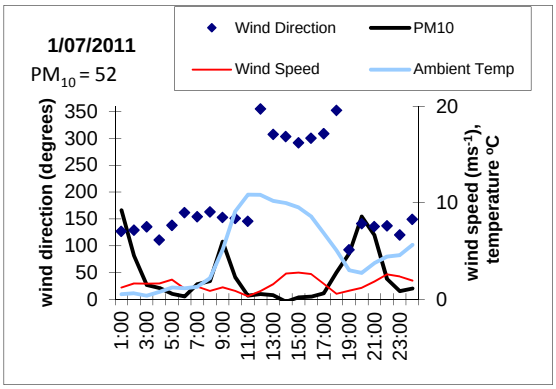

20/05/2011
PM10 = 56
Wind Direction
PM10
Wind Speed
Ambient Temp
wind direction (degrees)
wind speed (ms-1), temperature °C


21/05/2011
PM10 = 67
Wind Direction
PM10
Wind Speed
Ambient Temp
wind direction (degrees)
wind speed (ms-1), temperature °C


29/05/2011
PM10 = 60
Wind Direction
PM10
Wind Speed
Ambient Temp
wind direction (degrees)
wind speed (ms-1), temperature °C


31/05/2011
PM10 = 56
Wind Direction
PM10
Wind Speed
Ambient Temp
wind direction (degrees)
wind speed (ms-1), temperature °C


16/06/2011
PM10 = 58
Wind Direction
PM10
Wind Speed
Ambient Temp
wind direction (degrees)
wind speed (ms-1), temperature °C


1/07/2011
PM10 = 52
Wind Direction
PM10
Wind Speed
Ambient Temp
wind direction (degrees)
wind speed (ms-1), temperature °C

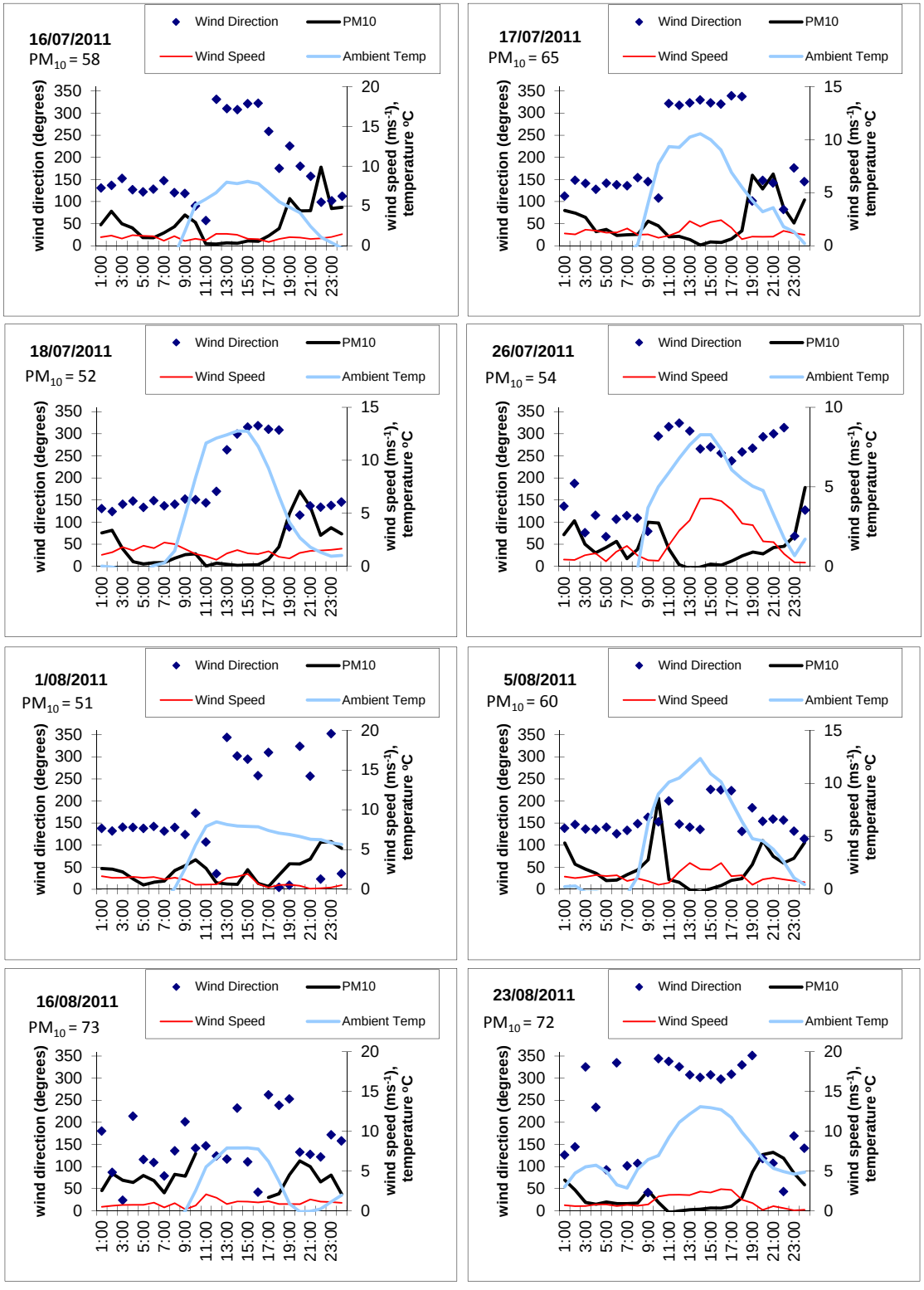


Figure 4.6: Hourly average PM_{10}, wind speed, wind direction and temperature on days when PM_{10} concentrations exceeded the NES at the Tokoroa site.

5 Taupo

5.1 Air Quality Monitoring in Taupo

The air quality monitoring site for Taupo is located at Gillies Avenue Reserve in central Taupo and was established in November 2000. The site meets the requirements of the "Residential Neighbourhood" site classification as described in the '*Good Practice Guideline for Air Quality Monitoring and Data Management 2009'* report (MfE, 2009).

A FH62 C14 BAM has measured PM_{10} concentrations since March 2007. Gravimetric sampling using a Rupprecht and Patashnick Partisol Model 2000 PM_{10} sampler also took place at the Gillies Avenue Site during 2007 and 2008.

Prior to 2005, PM_{10} was monitored in Taupo on a one day in three basis at the Gillies Avenue Reserve site using a Rupprecht and Patashnick Partisol Model 2000 PM_{10} sampler. In January 2006 a FH62 C14 BAM continuous PM_{10} monitoring station was established at Taupo Primary School. The site meets the requirements of the "Residential Neighbourhood" site classification (MfE, 2000).

Operation of the Gillies Avenue Reserve Partisol Model 2000 PM_{10} sampler continued throughout 2006 to March 2007 to evaluate the spatial variation of PM_{10} concentrations between Gillies Avenue and Taupo Primary School.

The maximum recorded 24-hour PM_{10} concentration at the Taupo Primary School site in 2006 was 24.8 µg m^{-3} whereas the maximum recorded 24-hour PM_{10} concentration at the Gillies Avenue Reserve site (based on one day in three Partisol monitoring) was 89 µg m^{-3}. The results from the 2006 Monitoring Report (Smith, 2006) found that the Taupo Primary School site was not a suitable site for compliance with NES Regulation 15, that requires monitoring at the location where contaminant concentrations (or frequency of exceedences) are greatest. The 2006 data reported in this report uses the partisol sampling results for Gillies Avenue. On 17 March 2007 the FH62 C14 BAM was moved from Taupo Primary School back to the Gillies Avenue Reserve site.

Gravimetric sampling using the Partisol Model 2000 PM_{10} sampler also took place at the Gillies Avenue Site during 2008. The sampling regime was approximately one day in three, with a midnight to midnight filter exposure period. The sampling was carried out by the Institute of Geological & Nuclear Sciences (GNS) on behalf of Environment Waikato.

Meteorological instrumentation was installed when the FH62 BAM was installed at the Primary School site in 2006. Wind speed, wind direction, air temperature, and relative humidity data were measured.

Figure 5.1 shows the Taupo Airshed and the location of the monitoring site in Taupo.

Figure 5.1: Taupo Airshed and air quality monitoring site (Source: Environment Waikato, 2010).

5.2 PM_{10} concentrations in Taupo

Average daily PM_{10} concentrations measured at the Taupo Gillies Ave site during 2011 are shown in Figure 5.2. Only one exceedence of 50 µg m^{-3} was recorded during 2011and measured 51 µg m^{-3} on 16 July.

The changes in PM_{10} concentrations relative to air quality indicator categories at the Taupo site from 2006 to 2011 are shown in Figure 5.3. Data are adjusted for gravimetric equivalency only since 2007 so comparison of trends with pre 2006 data are limited[2]. A slight increase in the proportion of 'PM_{10} concentrations in the 'good' category may have occurred since 2007.

[2] For 2006 the gravimetric partisol data from Gillies Ave were used in preference to the BAM primary school data.

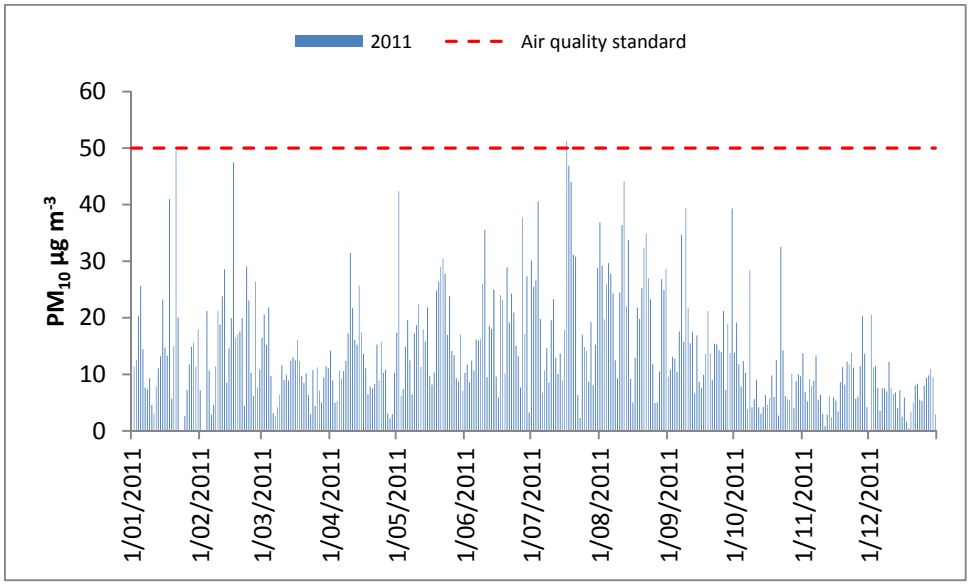


Figure 5.2: Daily winter PM_{10} concentrations measured at Taupo during 2011.

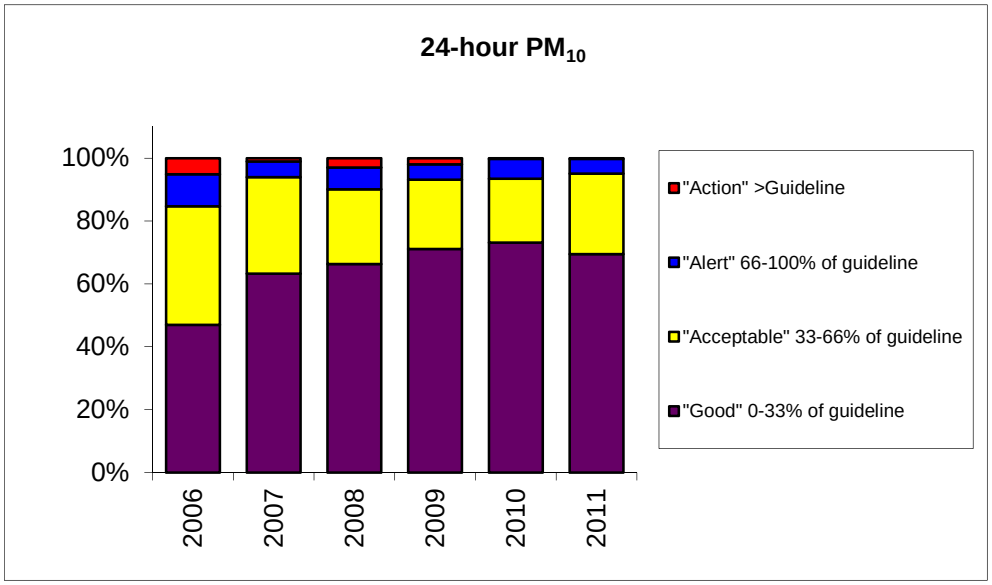


Figure 5.3: Comparison of PM_{10} concentrations measured at the Taupo site from 2001 to 2011 to air quality indicator categories.

Figure 5.4 shows the seasonal variations in the distribution of PM_{10} concentrations for 2011. Figure 5.5 shows the number of days when 50 µg m^{-3} was exceeded, the maximum concentration and the second highest concentration for 2006 to 2011.

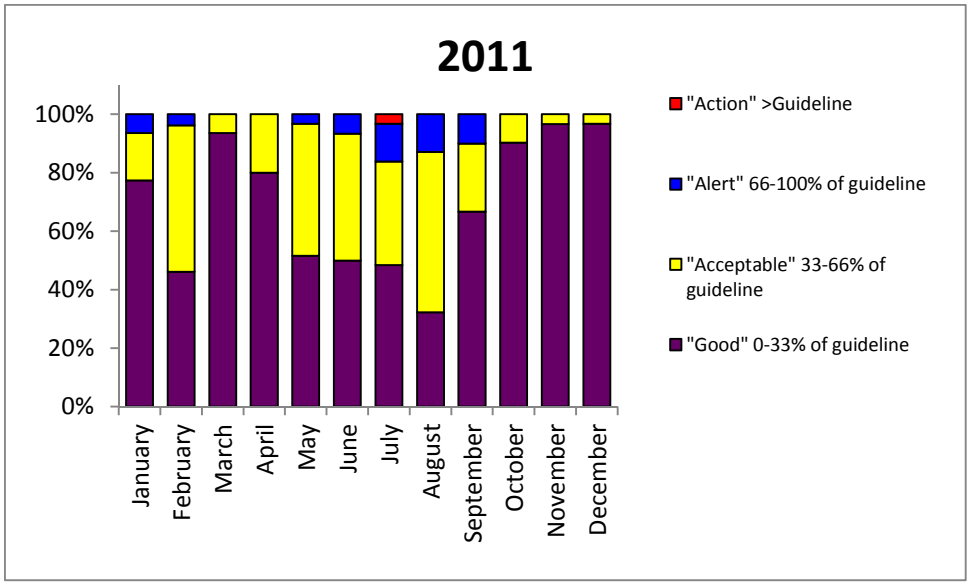


Figure 5.4: Comparison of daily PM_{10} concentrations each month during 2011 to air quality indicator categories.

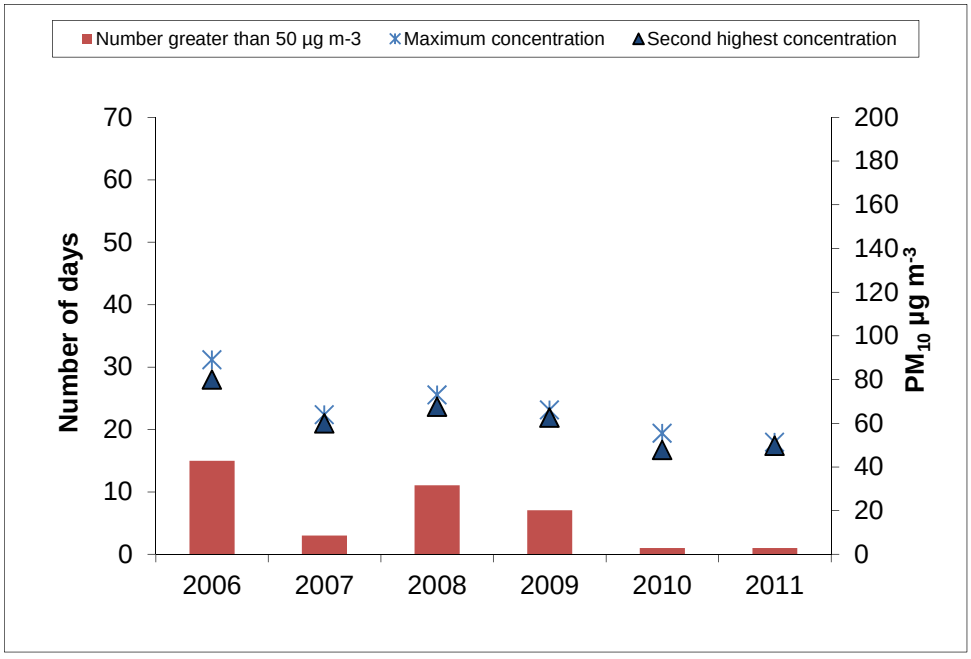


Figure 5.5: Number of days when 50 µg m^{-3} was exceeded, the maximum concentration measured using the BAM and the second highest concentration from 2006 to 2011.

The annual average PM_{10} concentration for 2011 is 14 µg m^{-3}, which was the same as the 2010 annual average but lower than the 2008 annual average PM_{10} concentration of 17 µg m^{-3}. Summary statistics for PM_{10} monitoring results from 2001 to 2011 are shown in Table 5.1. Average and maximum concentrations appear slightly lower during 2010 and 2011. Further investigations would be required to confirm whether the decrease is indicative of a reduction in PM_{10} emissions or occurring as a result of meteorological conditions being less conducive to elevated pollution.

Table 5.1: Summary of PM_{10} concentrations measured at the Taupo monitoring site from 2001 to 2011*.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
"Good" 0-33% of guideline	43%	59%	52%	55%	56%	47%	63%	66%	71%	73%	69%
"Acceptable" 33-66% of guideline	36%	33%	32%	30%	36%	38%	31%	24%	22%	20%	26%
"Alert" 66-100% of guideline	18%	7%	12%	12%	7%	10%	5%	7%	5%	6%	5%
"Action" >Guideline	2%	1%	4%	2%	1%	5%	1%	3%	2%	0%	0%
Percentage of valid data	12%	21%	29%	29%	30%	27%	78%	99%	99%	100%	99%
Annual average (µg m^{-3})	20	17	18	17	16	19	15	17	15	14	14
Exceedences (extrapolated)	7	6	12	6	3	15	3	11	7	1	1
Second highest PM_{10} concentration (µg m^{-3})	45	41	61	55	45	80	60	68	62	48	50
Annual maximum (µg m^{-3})	57	54	62	65	52	89	64	73	66	55	51
Number of records	44	76	106	105	111	98	283	361	363	364	363

*2007 - 2008 data has been updated from that reported in the 2007 and 2008 reports based on a more recent (2009) adjustment factor. 2006 data were gravimetric at Gillies Ave. Data prior to 2006 have not been adjusted for gravimetric equivalency. Note the 2008 monitoring report used a different equation and reported six exceedences of 50 µg m^{-3} for 2007 compared with three exceedences reported here.

5.3 Daily variations in PM_{10} and meteorology on high pollution days

Figure 5.6 shows variations in PM_{10} concentrations and meteorological data on 16 July, when the 24-hour average PM_{10} measured at Taupo exceeded 50µg m^{-3}.

The pattern in PM_{10} concentrations is reasonably typical of high pollution episodes in urban areas of New Zealand. In particular there is a small morning peak in concentrations around 9am followed by a decrease for the majority of the daytime then an increase in concentrations around 6 pm. Concentrations were also elevated during the early morning period (midnight to 3 am) as a result of the evening pollution episode from the previous day.

In Taupo, high PM_{10} concentrations typically occur when the wind is from an easterly or south easterly direction and wind speeds are low. During the daytime the wind shifts to westerly, returning to east/south east during the evening (Wilton & Baynes, 2010). The July 2011 high pollution event was consistent with these wind patterns.

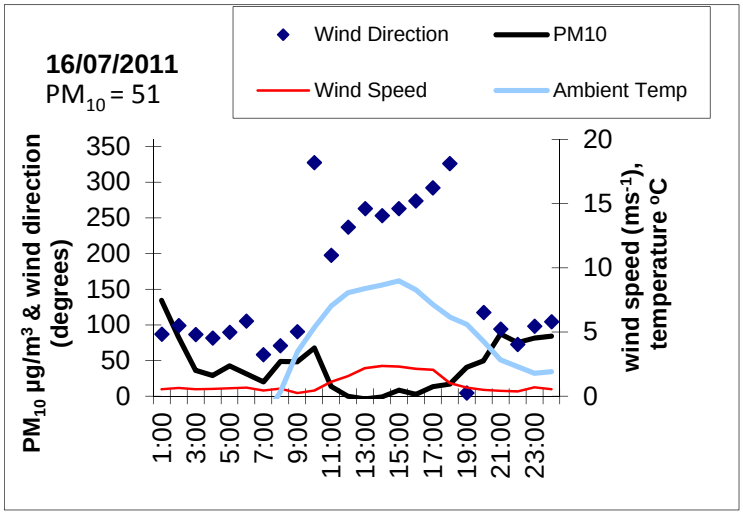


Figure 5.6: Hourly average PM_{10}, wind speed, wind direction and temperature on 16 July when PM_{10} concentrations exceeded 50 µg m^{-3} at Taupo.

6 Te Kuiti

6.1 Air Quality Monitoring in Te Kuiti

The Te Kuiti air quality monitoring sites is located at the Te Kuiti City Council Offices off Queen Street. This site has been used since 2003 and was used during 1998 to monitor PM_{10} (Figure 6.1). Wilton, (2002) provides further descriptions of the air quality monitoring site, including a map and site layout in the *'Air Quality Monitoring Report – Waikato Region*' report. The site meets the requirements of the "Residential Neighbourhood" site classification as described in the '*Good Practice Guideline for Air Quality Monitoring and Data Management 2009'* report (MfE, 2009).

The monitoring method used at the sites is an FH62 C14 BAM.

Figure 6.1: Te Kuiti Airshed and air quality monitoring site (Source: Environment Waikato, 2010).

6.2 PM_{10} Concentrations in Te Kuiti

Figure 6.2 shows daily average PM_{10} concentrations measured in Te Kuiti during 2011. There was only one exceedence of 50 µg m^{-3} which occurred on 9 December 2011 and reached 51 µg m^{-3}. This is an abnormal exceedence for Te Kuiti as concentrations do not normally exceed 50 µg m^{-3} outside of the winter months. The number of exceedences in Te Kuiti had been reasonably consistent since 2007 at around 3-4 per year with the exception of 2006 when there were seven exceedences of 50 µg m^{-3}. During 2011 there were no winter time exceedences of 50 µg m^{-3}.

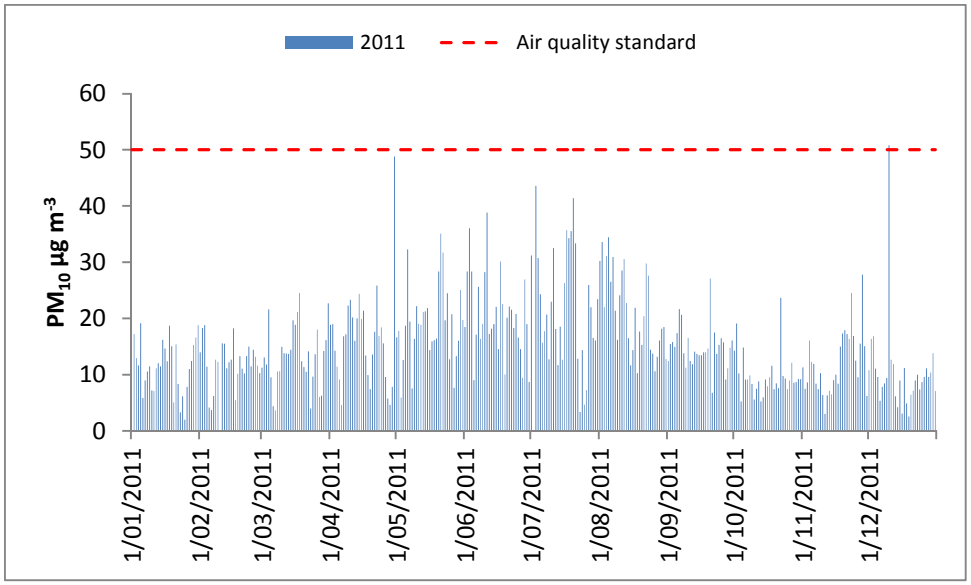


Figure 6.2: Daily winter PM_{10} concentrations measured at the Te Kuiti site during 2011.

A comparison of PM_{10} concentrations to air quality indicator categories from 2003 to 2011 in Te Kuiti is shown in Figure 6.3. Figure 6.4 shows the seasonal variations in the distribution of PM_{10} concentrations for 2011 and Figure 6.5 shows the number of days when 50 µg m^{-3} was exceeded, the maximum concentration and the second highest concentration from 2006 to 2011.

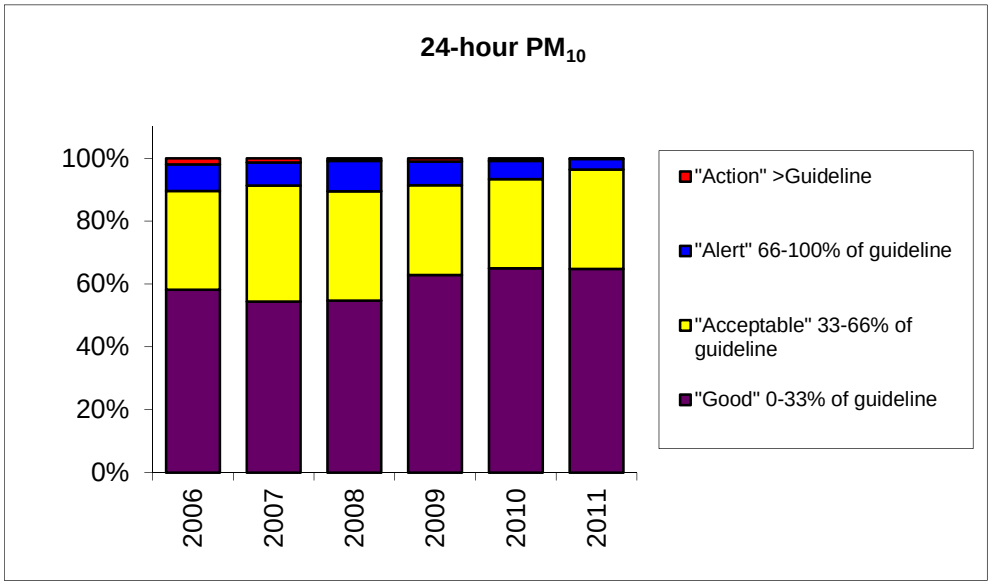


Figure 6.3: Comparison of PM_{10} concentrations measured at the Te Kuiti site from 2003 to 2011 to air quality indicator categories.

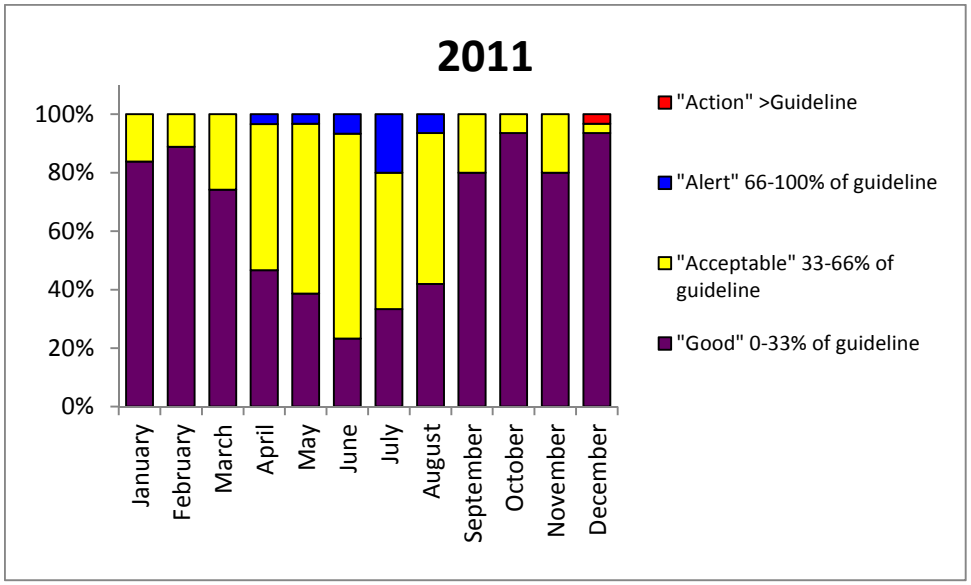


Figure 6.4: Comparison of daily PM_{10} concentrations each month during 2011 to air quality indicator categories.

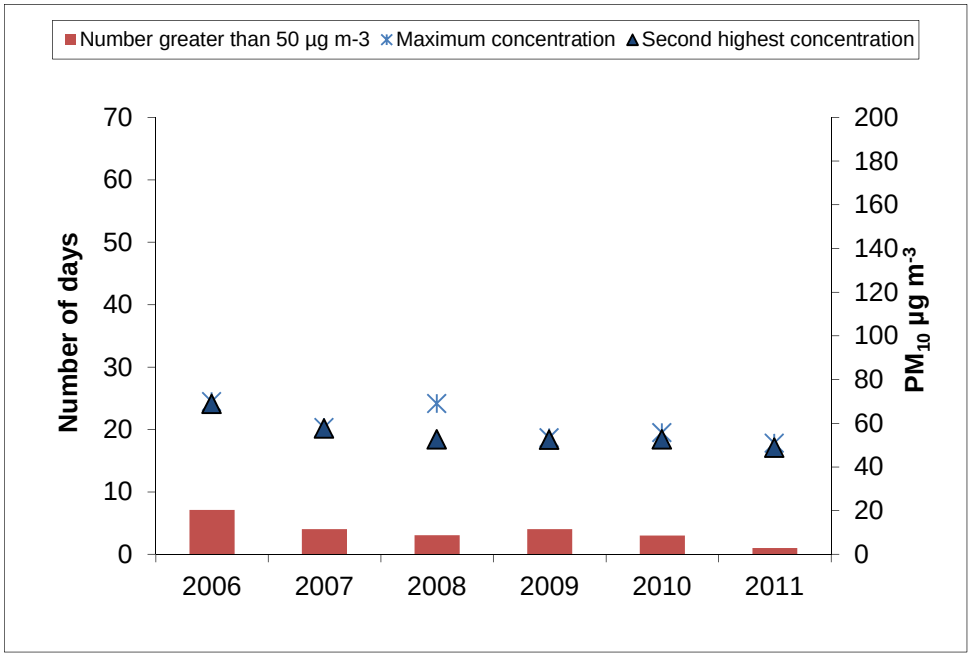


Figure 6.5: Number of days when 50 µg m^{-3} was exceeded, the maximum concentration measured and the second highest concentration from 2006 to 2011.

In 2011 the annual average PM_{10} concentration in Te Kuiti was 15 µg m^{-3}. Table 6.1 shows that PM_{10} concentrations in Te Kuiti had been reasonably consistent from 2003 to 2009 but that slightly lower values in 2010 and 2011 may reflect some improvement. It is uncertain whether this occurs as a result of a decrease in emissions or because of meteorological conditions. The highest peak (24-hour average) concentration was measured in 2006 along with the greatest number of exceedences.

Table 6.1: Summary of PM_{10} concentrations measured at the Te Kuiti monitoring site from 2003 to 2011.

	2003	2004	2005	2006	2007	2008	2009	2010	2011
"Good" 0-33% of guideline	48%	51%	59%	58%	54%	55%	63%	65%	65%
"Acceptable" 33-66% of guideline	32%	40%	34%	31%	37%	35%	29%	28%	32%
"Alert" 66-100% of guideline	17%	8%	7%	9%	7%	10%	8%	6%	3%
"Action" >Guideline	2%	1%	1%	2%	1%	1%	1%	1%	0%
Percentage of valid data	63%	95%	92%	99%	79%	99%	99%	99%	99%
Annual average (µg m^{-3})	18	18	17	18	17	18	17	16	15
Exceedences	5	5	2	7	4	3	4	3	1
Second highest concentration	56	56	52	69	58	53	52	53	49
Annual maximum (µg m^{-3})	59	61	54	70	58	69	53	56	51
Number of records	229	346	337	363	287	361	360	360	363

6.3 Daily variations in PM_{10} and meteorology on 9 December when PM_{10} concentrations exceeded 50 µg m^{-3}.

Figure 6.5 shows hourly variations in PM_{10} concentrations and meteorological variables on 9 December when the 24-hour average PM_{10} concentration exceeded 50 µg m^{-3}. This pattern is not typical of an urban PM_{10} pollution event with concentrations elevated between 4pm and 7pm. The wind direction during this time was westerly. It is likely a localised source of PM_{10} (e.g., outdoor rubbish fire) caused the high concentrations measured on 9 December.

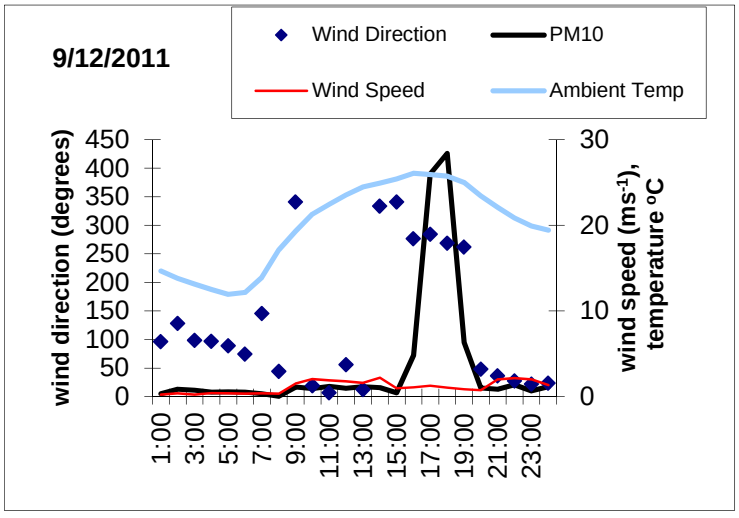


Figure 6.6: Hourly average PM_{10}, wind speed, wind direction, and temperature on 9 December when PM_{10} concentrations exceeded 50 µg m^{-3} at Te Kuiti.

7 Matamata

7.1 Air Quality Monitoring in Matamata

Matamata is situated approximately 41 km east of Hamilton. Air quality monitoring in Matamata commenced in June 2005 at the air quality monitoring site located at the Playcentre grounds on Farmers Road (Figure 7.1). The site meets the requirements of the 'Residential Neighbourhood' site classification as described in the *'Good Practice Guideline for Air Quality Monitoring and Data Management 2009'* report (MfE, 2009).

A FH62 C14 BAM measures PM_{10} concentrations at the Matamata Playcentre. Meteorological data are also collected, including wind speed and direction, ambient air temperature and relative humidity. The site was installed by Watercare Services Limited and is operated and maintained by Environment Waikato staff. The BAM continuously measures PM_{10} data and it is logged at ten minute intervals.

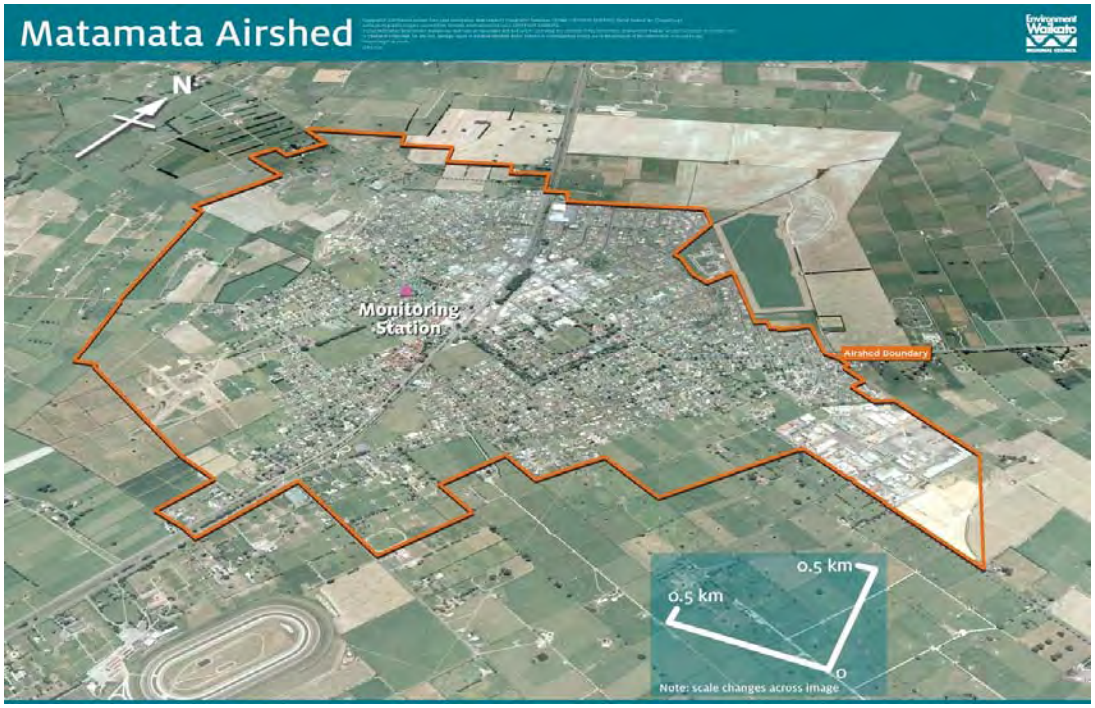


Figure 7.1: Matamata Airshed and air quality monitoring site (Source: Environment Waikato, 2010).

7.2 PM_{10} concentrations in Matamata

Daily average PM_{10} concentrations measured at Matamata during 2011 are shown in Figure 7.2. The maximum measured PM_{10} concentration was 31 µg m^{-3} and was measured on16 July. Previous winter time maximums have been around 34-36 µg m^{-3}.

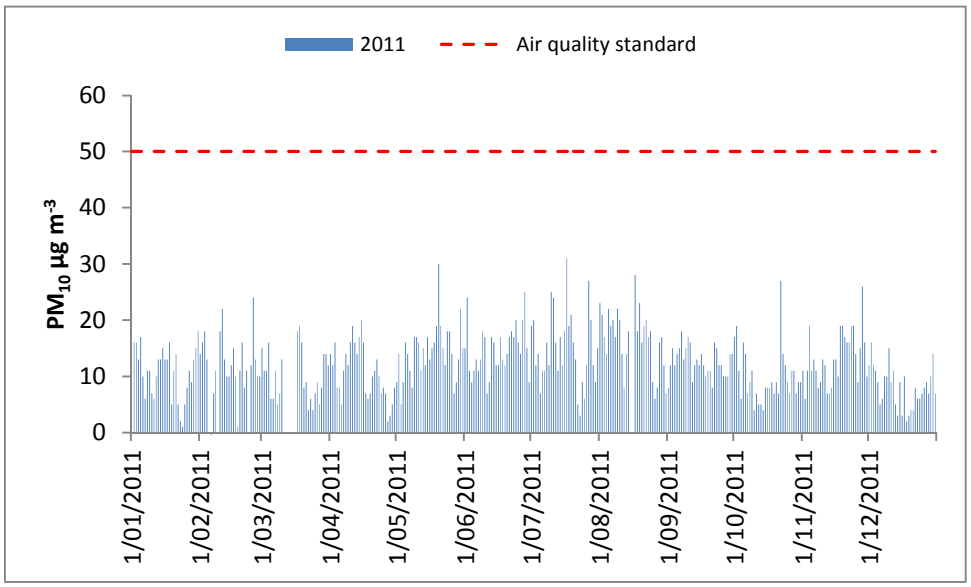


Figure 7.2: Daily winter PM_{10} concentrations measured at the Matamata site during 2011.

Figure 7.3 shows concentrations of PM_{10} measured at the Matamata air quality monitoring site almost all less than 66% of the NES. Figure 7.4 shows the seasonal variations in the distribution of PM_{10} concentrations for 2011. The number of days when 50 µg m^{-3} was exceeded, the maximum concentration and the second highest concentration from 2006 to 2011 are shown in Figure 7.5. The highest PM_{10} concentration measured during 2009 was an anomaly in that it occurred as a result of the Australian dust storm.

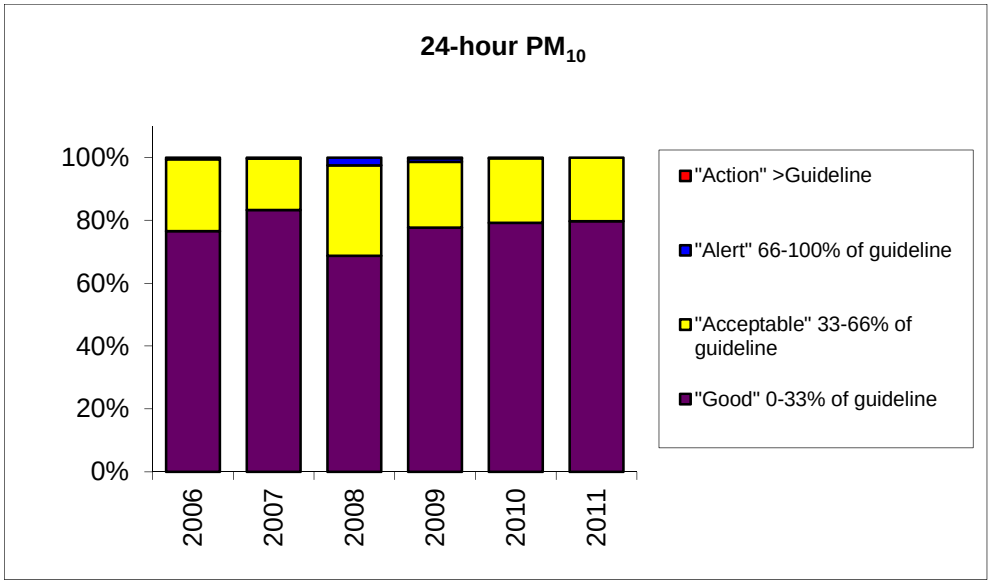


Figure 7.3: Comparison of PM_{10} concentrations measured at the Matamata site from 2006 to 2011 to air quality indicator categories.

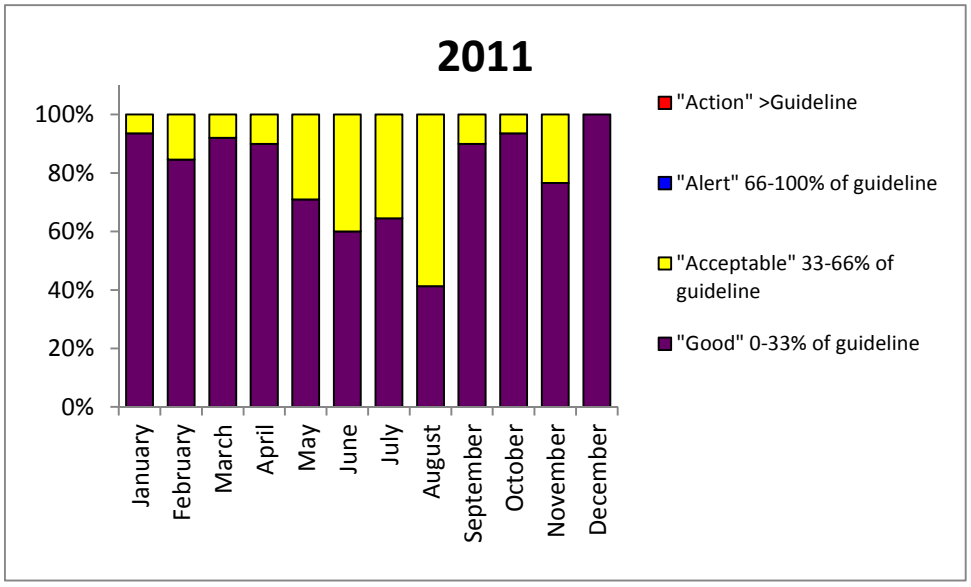


Figure 7.4: Comparison of daily PM_{10} concentrations each month during 2011 to air quality indicator categories.

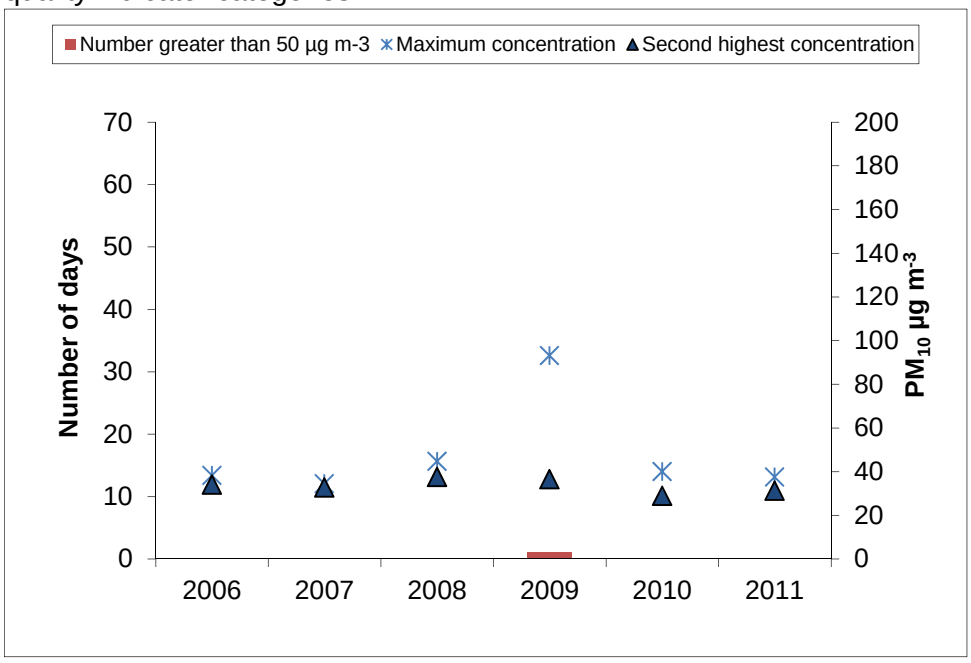


Figure 7.5: Number of days when 50 µg m^{-3} was exceeded, the maximum concentration and the second highest concentration from 2006 to 2011.

The annual average PM_{10} concentration for Matamata for 2011 is 12 µg m^{-3}. Summary statistics for PM_{10} monitoring results are shown in Table 7.1.

Table 7.1: Summary of PM_{10} concentrations measured at the Matamata monitoring site from 2005 to 2010.

	2005	2006	2007	2008	2009	2010	2011
"Good" 0-33% of guideline	81%	77%	83%	69%	78%	79%	80%
"Acceptable" 33-66% of guideline	18%	23%	16%	29%	21%	20%	20%
"Alert" 66-100% of guideline	1%	1%	0%	2%	1%	0%	0%
"Action" >Guideline	0%	0%	0%	0%	0%	0%	0%
Percentage of valid data	51%	99%	79%	100%	98%	99%	97%
Annual average (µg m^{-3})	12	13	12	15	13	13	12
Exceedences	0	0	0	0	1	0	0
Second highest concentration	34	34	33	38	36	29	30
Annual maximum (µg m^{-3})	36	38	34	45	93	40	31
Number of records	187	362	287	364	359	361	359

7.3 Daily variations in PM_{10} and meteorology on 16 July 2011

Daily variations in PM_{10} concentrations and meteorological variables on 16 July 2011 when the highest PM_{10} concentration of 31 µg m^{-3} (24-hour average) was recorded are shown in Figure 7.6. Elevated PM_{10} concentrations occur during the early evening under low wind speeds and a variable wind direction.

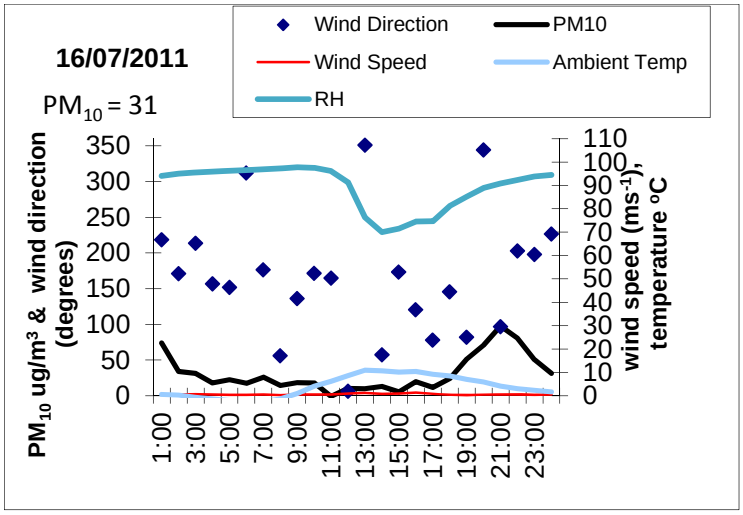


Figure 7.6: Hourly average PM_{10}, wind speed, wind direction, temperature and humidity on 16 July when the 24-hour average PM_{10} concentration was 31 µg m^{-3} at Matamata.

8 Putaruru

8.1 Air Quality Monitoring in Putaruru

Putaruru is located 65 kilometres southeast of Hamilton and is close to Lake Arapuni on the Waikato River. It is situated mid way between Tokoroa and Tirau on State Highway One, in the South Waikato District and has a population of around 3000 people. Putaruru occupies a flat to gently undulating site, and to the east the land rises to the Mamaku Range.

A monitoring site was established at the Bowling Club on Arapuni Street in Putaruru, in July 2006 (Figure 8.1). The map reference for the site is NZMS260 T15:533-457. Daily concentrations of PM_{10} have been measured since the site was established. Data is adjusted for gravimetric equivalency.

A FH62 C14 BAM measures PM_{10} concentrations at Putaruru (Figure 8.2).

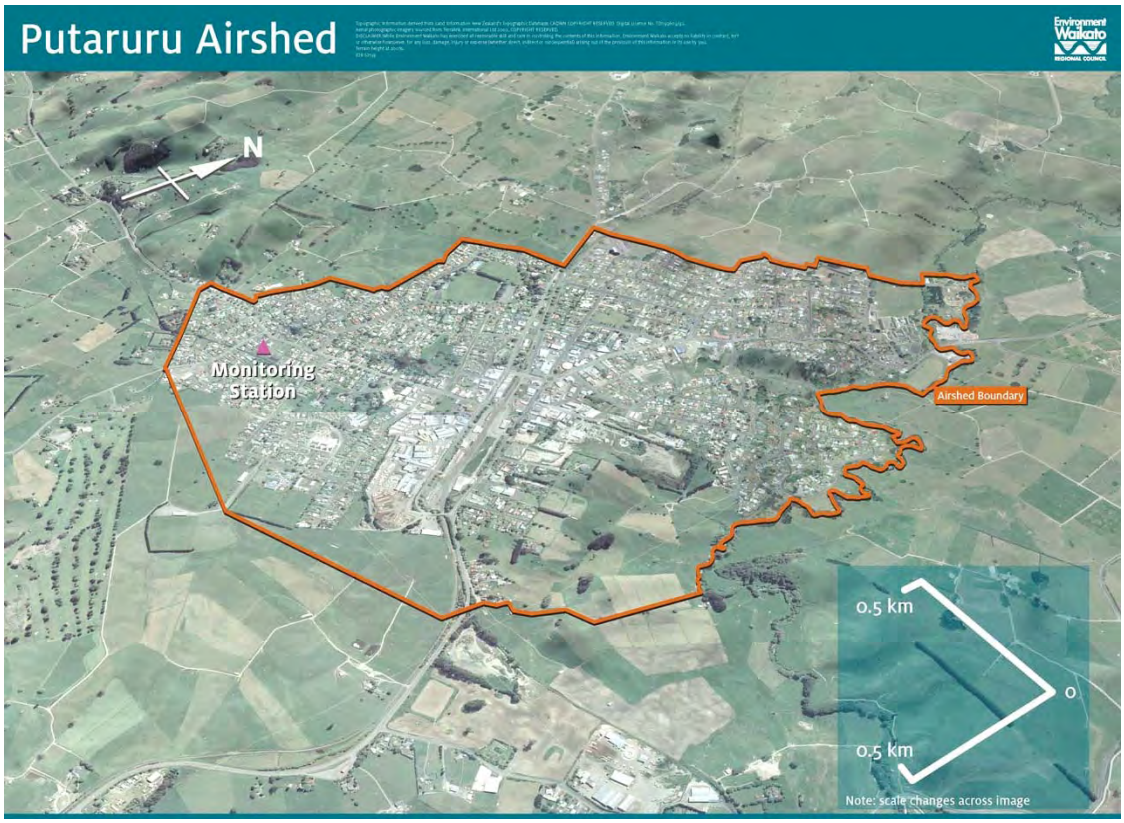


Figure 8.1: Putaruru Airshed and air quality monitoring site (Source: Environment Waikato, 2010).

Figure 8.2: Putaruru air quality monitor (Source: Environment Waikato, 2009).

8.2 PM_{10} Concentrations in Putaruru

Daily average PM_{10} concentrations measured at Putaruru during 2011 are shown in Figure 8.3. The maximum concentration of 54 µg m^{-3} was recorded on 1 May. This was the only measured exceedence of 50 µg m^{-3} (24-hour average) and does not constitute a breach of the NES, which allows one exceedence of 50 µg m^{-3} per year.

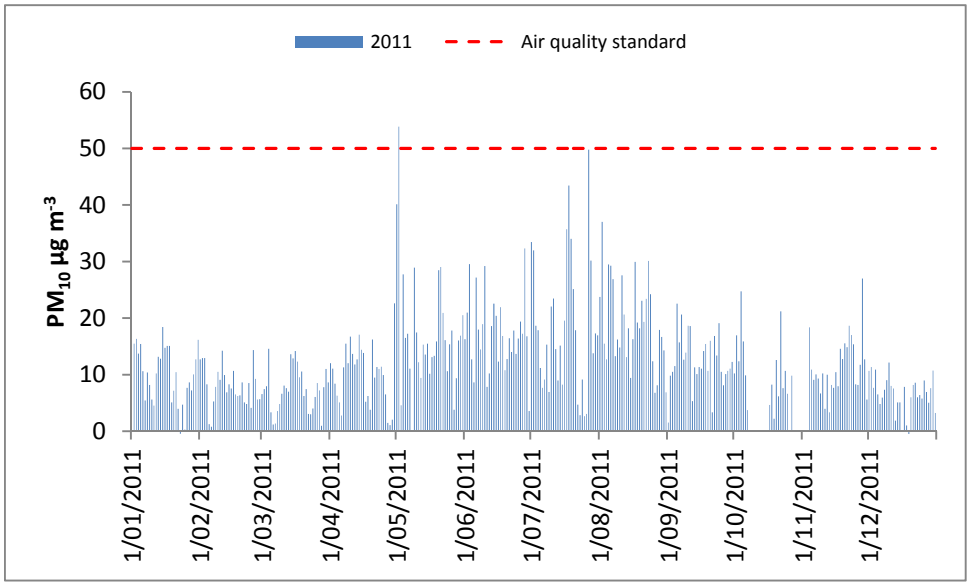


Figure 8.3: Daily winter PM_{10} concentrations measured at the Putaruru site during 2011.

Figure 8.4 compares PM_{10} concentrations measured at Putaruru from 2006 to 2011 to the MfE (2000) air quality indicator categories. Figure 8.5 shows seasonal

variations in the distribution of PM_{10} concentrations for 2011. No data were presented for October because there were insufficient data collected during this month to be representative. Like most urban areas of New Zealand the most degraded air quality occurs during the months May to August.

Figure 8.6 shows the number of days when 50 µg m^{-3} was exceeded, the maximum concentration and the second highest concentration from 2006 to 2011. The greatest number of exceedences and the highest PM_{10} concentrations occurred during 2008; however it is worth noting that in 2008, two of the four recorded exceedances were in summer (February) and came about as a result of dust created by roadworks during the unusual drought conditions.

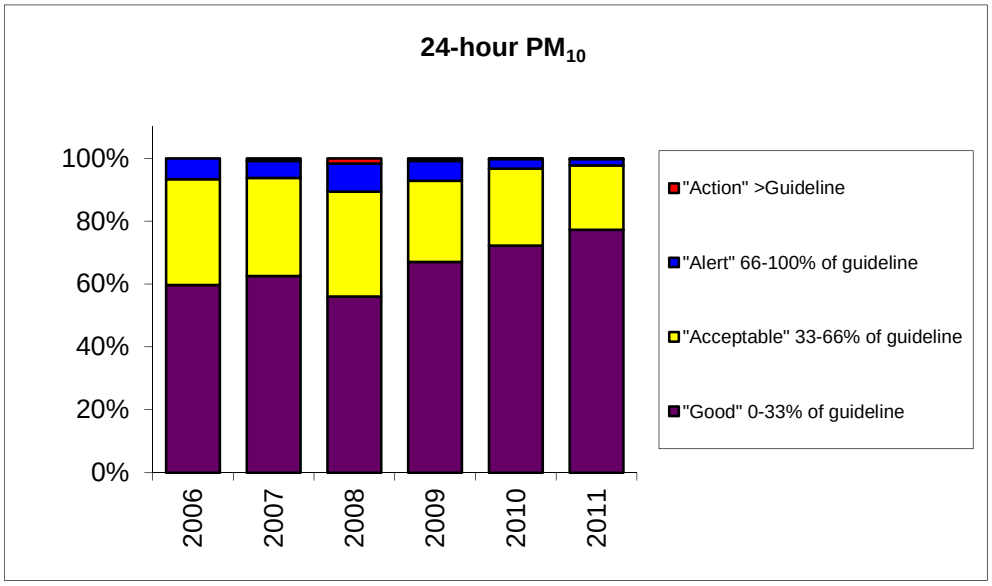


Figure 8.4: Comparison of PM_{10} concentrations measured at the Putaruru site from 2006 to 2010 to air quality indicator categories.

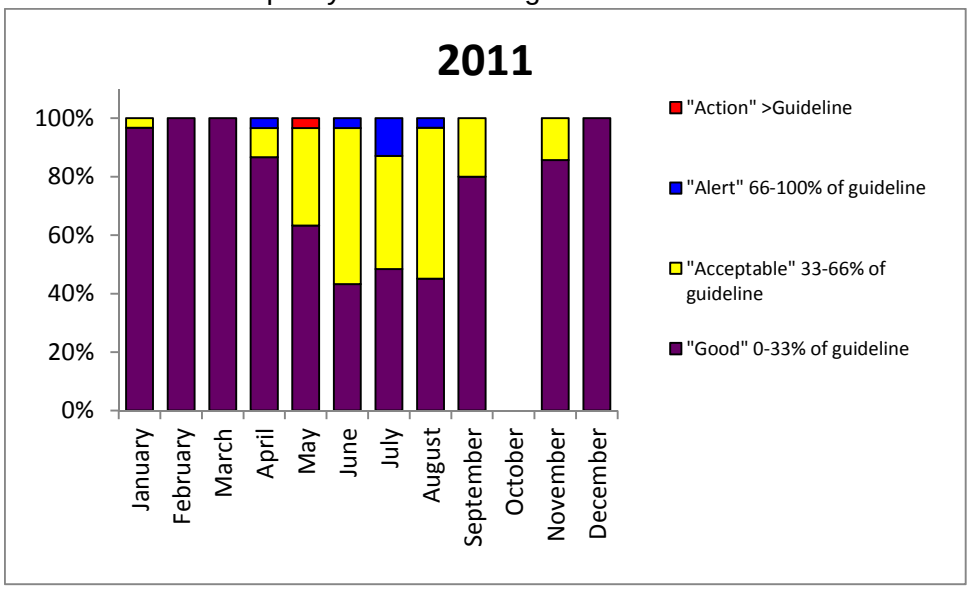


Figure 8.5: Comparison of daily PM_{10} concentrations for 2011 to air quality indicator categories.

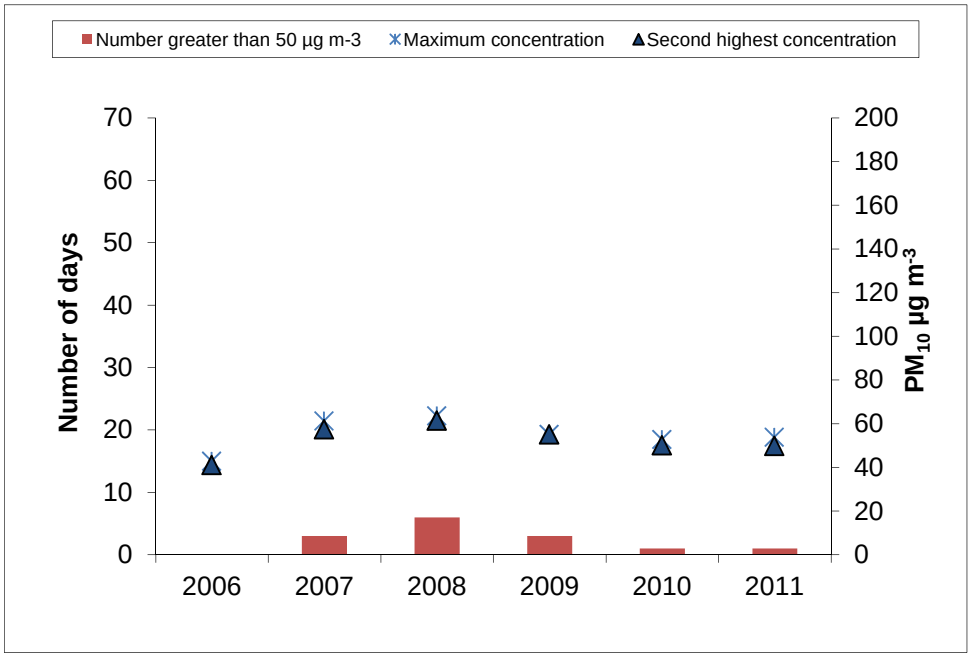


Figure 8.6: Number of days when 50 µg m^{-3} was exceeded, the maximum concentration and the second highest concentration from 2006 to 2011.

The annual average PM_{10} concentration for Putaruru for 2010 was 13 µg m^{-3}. This compares with an annual average PM_{10} guideline of 20 µg m^{-3} (MfE, 2002). Summary statistics for PM_{10} monitoring results are shown in Table 8.1.

Table 8.1: Summary of PM_{10} concentrations measured at the Putaruru monitoring site from 2006 to 2010.

	2006	2007	2008	2009	2010	2011
"Good" 0-33% of guideline	60%	62%	56%	67%	72%	77%
"Acceptable" 33-66% of guideline	34%	31%	33%	26%	25%	20%
"Alert" 66-100% of guideline	7%	5%	9%	6%	3%	2%
"Action" >Guideline	0%	1%	2%	1%	0%	0%
Percentage of valid data	45%	100%	100%	100%	99%	95%
Annual average (µg m^{-3})	n/a	16	18	15	14	13
Exceedences	0	3	4	3	1	1
Second highest concentration	41	57	61	55	50	50
Annual maximum (µg m^{-3})	43	61	64	55	53	54
Number of records	166	365	365	364	363	347

9 Ngaruawahia

9.1 Air Quality Monitoring in Ngaruawahia

Ngaruawahia is located 19 kilometres north west of Hamilton and is situated at the junction of the Waikato and Waipa Rivers in the central Waikato basin. To the west of the town the land is hilly, rising to the Hakarimata Range.

In 2008 a monitoring site was established at Herschel Street, about 50 metres away from the corner of Ellery Street and Herschel Street in Ngaruawahia (Figure 9.1).

A ThermoAndersen FH62 C14 BAM measures PM_{10} concentrations at Ngaruawahia (Figure 9.2).

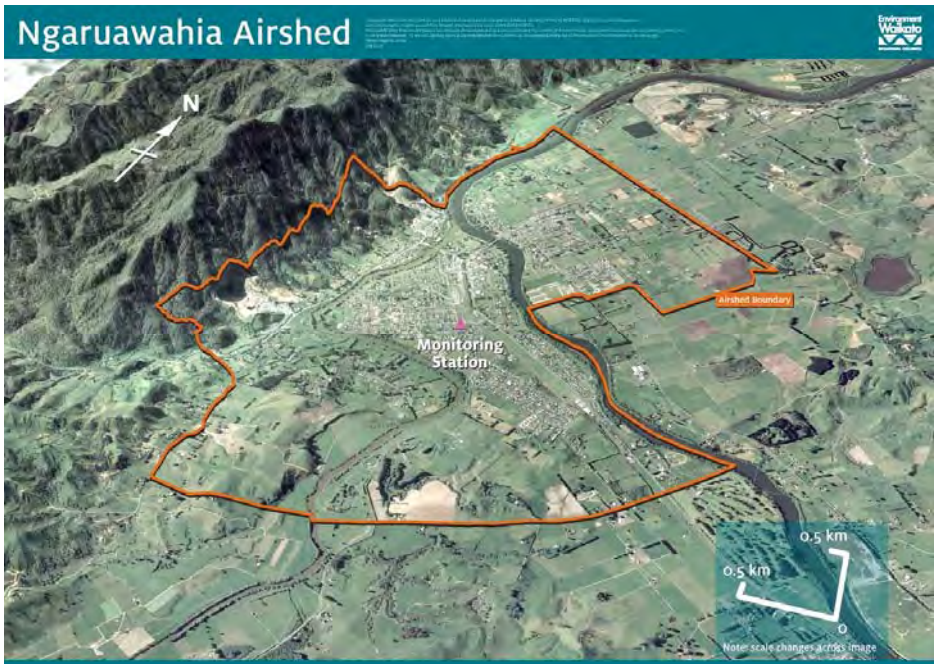


Figure 9.1: Ngaruawahia Airshed and monitoring site (Source: Environment Waikato, 2010).

Figure 9.2: Ngaruawahia air quality monitor (Source: Environment Waikato, 2009).

9.2 PM_{10} Concentrations in Ngaruawahia

Figure 9.3 shows 24-hour average PM_{10} concentrations measured at the Ngaruawahia site during 2011.

The maximum measured PM_{10} concentration in Ngaruawahia during 2011 was 44 µg m^{-3} (24-hour average) and was measured on 21 July. This is similar to the winter maximum concentration for 2009 of 43 µg m^{-3} but less than the 2010 winter maximum of 29 µg m^{-3}. Air quality data for Ngaruawahia is not adjusted for gravimetric equivalency.

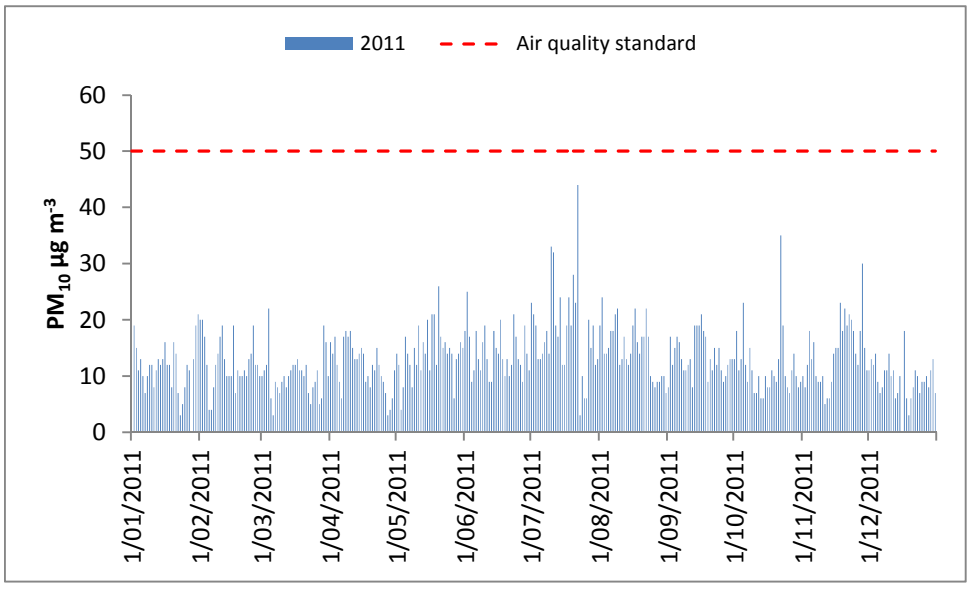


Figure 9.3: Daily winter PM_{10} concentrations measured at the Ngaruawahia site during 2011.

Figure 9.4 shows that during 2011, 98% of the PM_{10} concentrations measured at Ngaruawahia were within the 'acceptable' and 'good' air quality indicator categories (MfE, 2000). Seasonal variations in the distribution of PM_{10} concentrations are shown in Figure 9.5. Figure 9.1 compares the maximum and second highest PM_{10} concentrations and the number of days when 50 µg m^{-3} was exceeded from 2008 to 2010. The one exceedence of 50 µg m^{-3} measured at this site (2009) occurred as a result of the Australian dust storms.

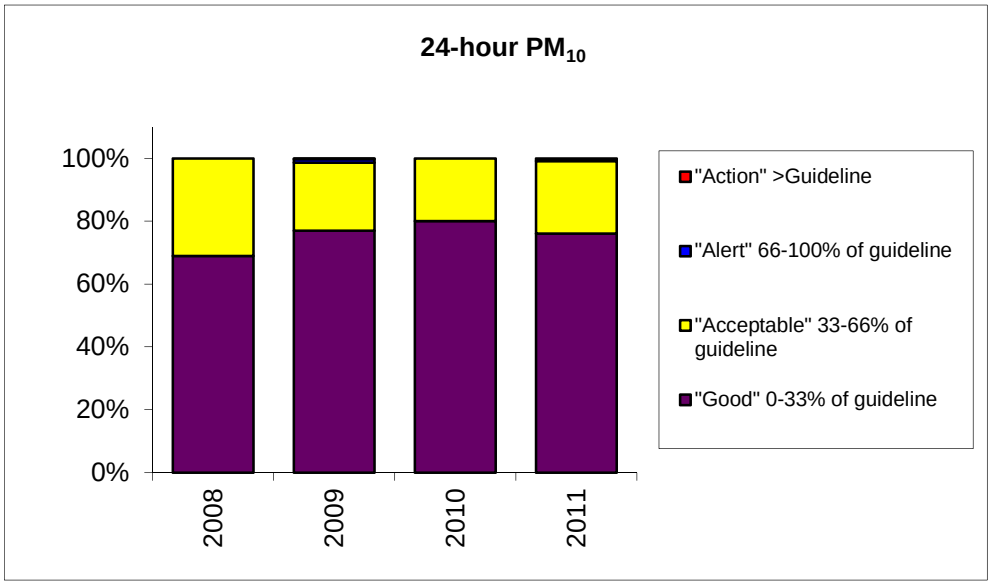


Figure 9.4: Comparison of PM_{10} concentrations measured at the Ngaruawahia site from 2008 – 2011 to air quality indicator categories.

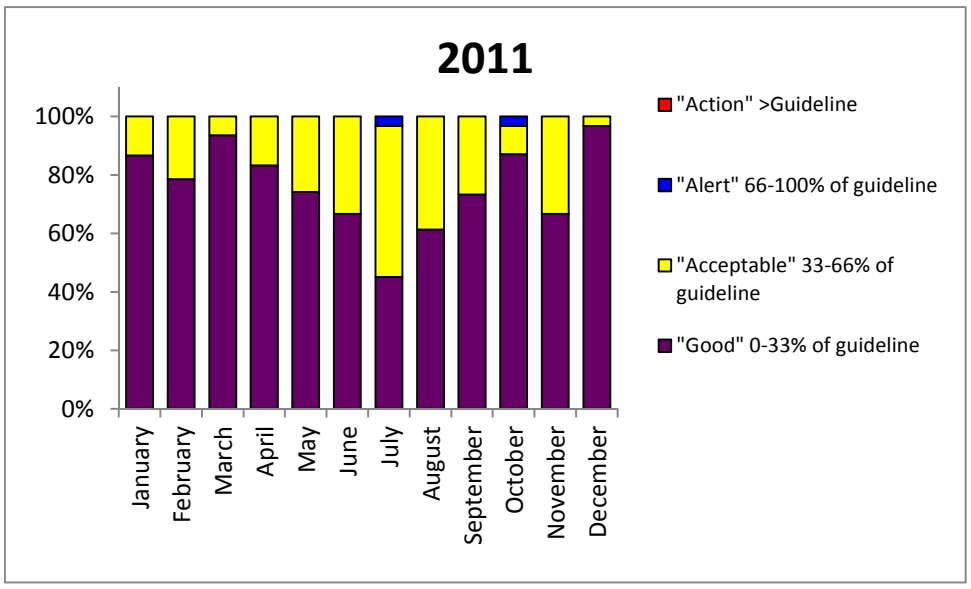


Figure 9.5: Comparison of daily PM_{10} concentrations each month during 2011 to air quality indicator categories.

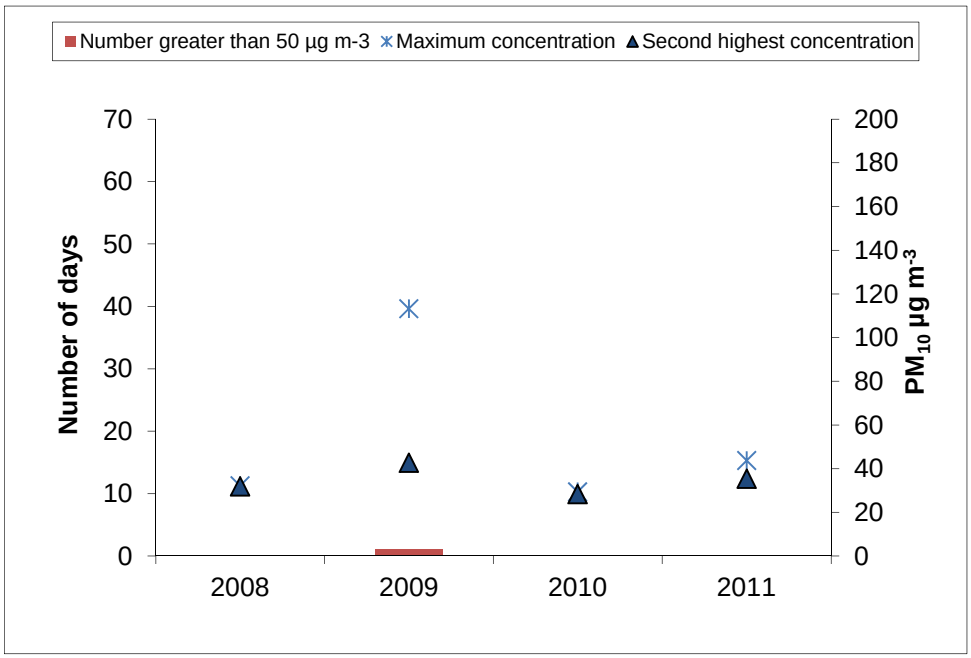


Figure 9.6: Number of days when 50 µg m^{-3} was exceeded, the maximum concentration and the second highest concentration from 2008 to 2011.

The annual average PM_{10} concentration for Ngaruawahia for 2011 was 13 µg m^{-3}. Summary statistics for PM_{10} monitoring results are shown in Table 9.1.

Table 9.1: Summary of PM_{10} concentrations measured at the Ngaruawahia monitoring site from 2008 to 2011.

	2008	2009	2010	2011
"Good" 0-33% of guideline	69%	77%	80%	76%
"Acceptable" 33-66% of guideline	31%	22%	20%	23%
"Alert" 66-100% of guideline	0%	1%	0%	1%
"Action" >Guideline	0%	0%	0%	0%
Percentage of valid data	65%	100%	97%	99%
Annual average (µg m^{-3})	14	14	13	13
Measured exceedences	0	1	0	0
Second highest concentration	32	43	28	35
Annual maximum (µg m^{-3})	32	113	29	44
Number of records	237	364	355	363

10 Waihi

10.1 Air Quality Monitoring in Waihi

Waihi is located 66 kilometers north west of Hamilton and is situated on the Ohinemuri River, a tributary of the Waihou River. The town occupies flat to gently undulating land. To the north and north-west are the lower hills of the Coromandel Range, and to the south-west and south are the Waitawheta hills.

Figure 10.1 shows the monitoring site at Grey Street, Waihi, around 50 meters north of the corner of Dobson Street and Grey Street. Daily concentrations of PM_{10} have been measured since the site was established in 2008.

A Sequential Partisol Sampler is used to measure PM_{10} concentrations at Waihi (Figure 10.2).

Figure 10.1: Waihi Airshed and air quality monitoring site (Source: Environment Waikato, 2010).

Figure 10.2: Waihi air quality monitor (Source: Environment Waikato, 2009).

10.2 PM_{10} concentrations in Waihi

No exceedences of 50 µg m^{-3} were measured at the air quality monitoring site in Waihi during 2011. The maximum PM_{10} concentrations measured at Waihi during 2011 was 43 µg m^{-3}. This compares with a maximum of 45 µg m^{-3} during 2010.

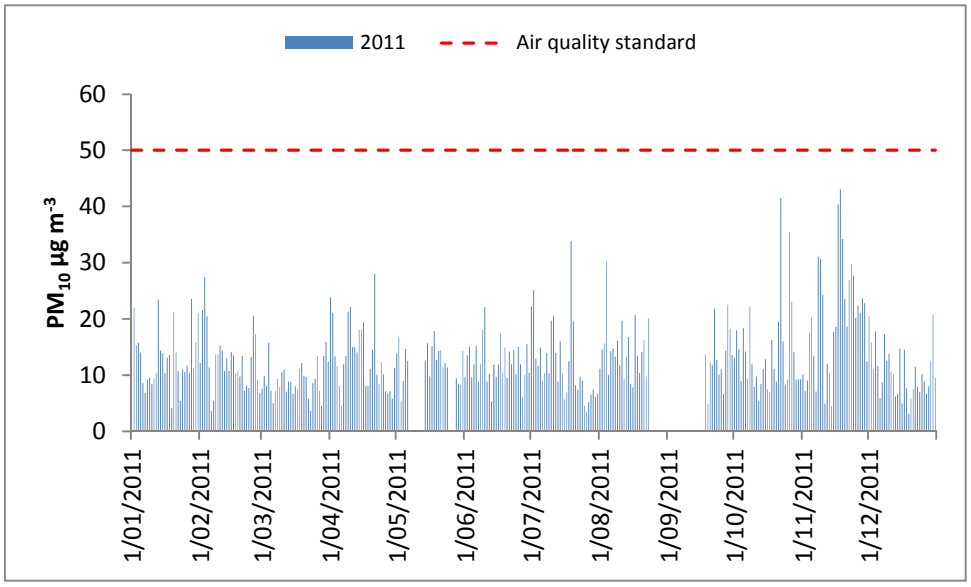


Figure 10.3: Daily winter PM_{10} concentrations measured at the Waihi site during 2011.

Figure 10.4 shows 2011 concentrations of PM_{10} relative to air quality indicator categories at Waihi. Figure 10.5 shows seasonal variations in the distribution of PM_{10} concentrations. Note data for May, August and September was not presented because of missing data during these months. Figure 10.6 shows the number of days when 50 µg m^{-3} was exceeded, the maximum concentration and the second highest concentration from 2008 to 2011.

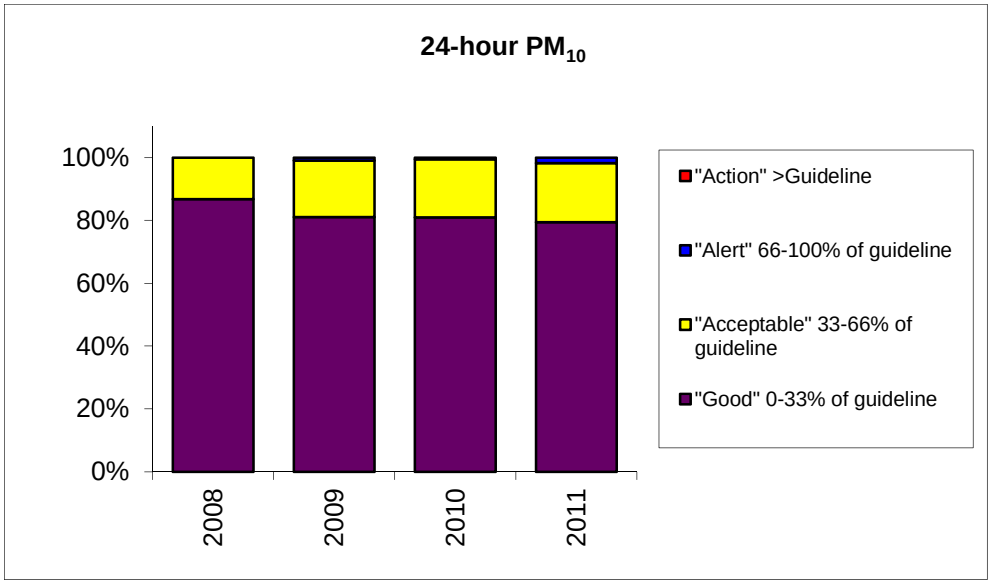


Figure 10.4: Comparison of PM_{10} concentrations measured at the Waihi site from 2008 to 2011 to air quality indicator categories.

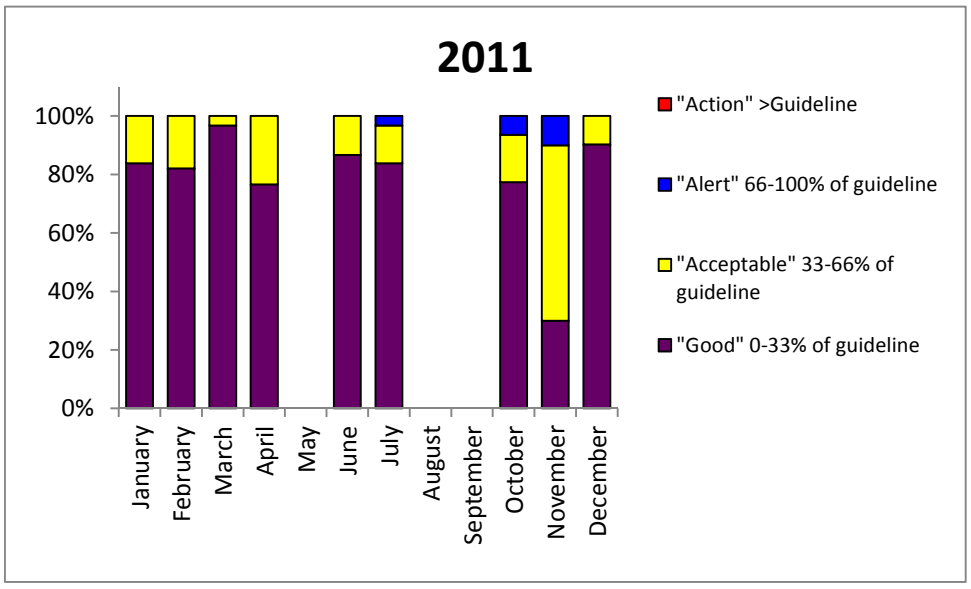


Figure 10.5: Comparison of daily PM_{10} concentrations during 2011 to air quality indicator categories.

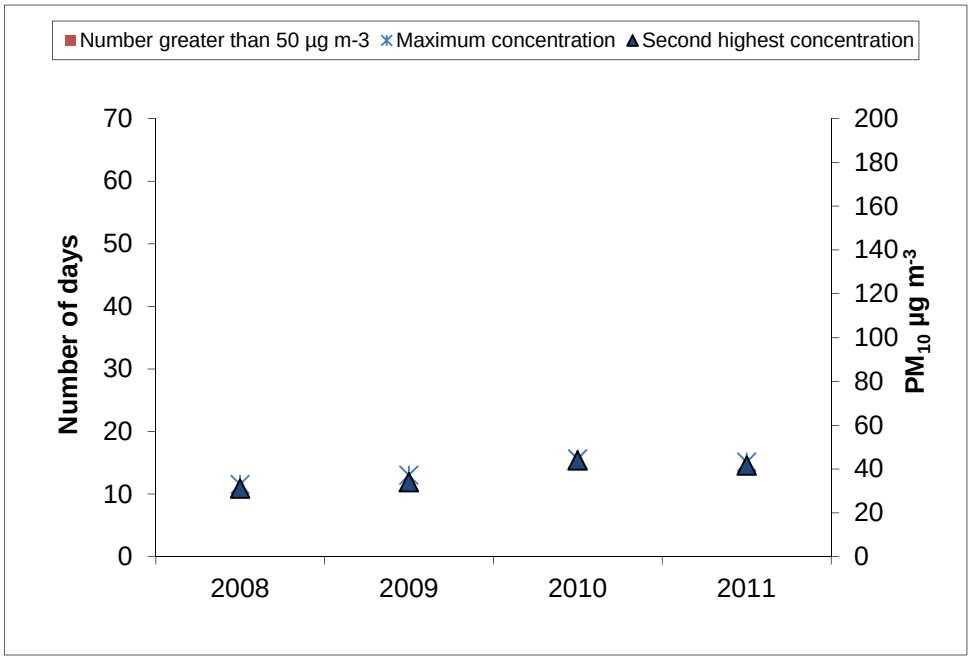


Figure 10.6: Number of days when 50 µg m^{-3} was exceeded, the maximum concentration and the second highest concentration from 2008 to 2011.

The estimated annual average PM_{10} concentration for Waihi for 2011 is 13 µg m^{-3}. Table 10.1 shows the summary statistics for PM_{10} monitoring results from 2008 to 2011.

Table 10.1: Summary of PM_{10} concentrations measured at the Waihi monitoring site from 2008-2011.

	2008	2009	2010	2011
"Good" 0-33% of guideline	87%	81%	81%	79%
"Acceptable" 33-66% of guideline	13%	18%	19%	19%
"Alert" 66-100% of guideline	0%	1%	1%	2%
"Action" >Guideline	0%	0%	0%	0%
Percentage of valid data	84%	87%	96%	90%
Annual average (µg m^{-3})	12	12	12	13
Measured exceedences	0	0	0	0
Second highest concentration	31	34	44	42
Annual maximum (µg m^{-3})	33	37	45	43
Number of records	308	317	351	330

11 Turangi

11.1 Air Quality Monitoring in Turangi

Turangi is located on the banks of the Tongariro River near the southern end of Lake Taupo and is 50 kilometres south west of Taupo. Turangi has a population of around 3500 and is the second largest population centre in the Taupo District. It is near the edge of the Kaimanawa Ranges.

A monitoring site was established at 16 Ohuanga Road, Turangi (Figure 11.1) in April 2009. Daily and hourly average PM_{10} concentrations are measured at the site using a FH 62 BAM.

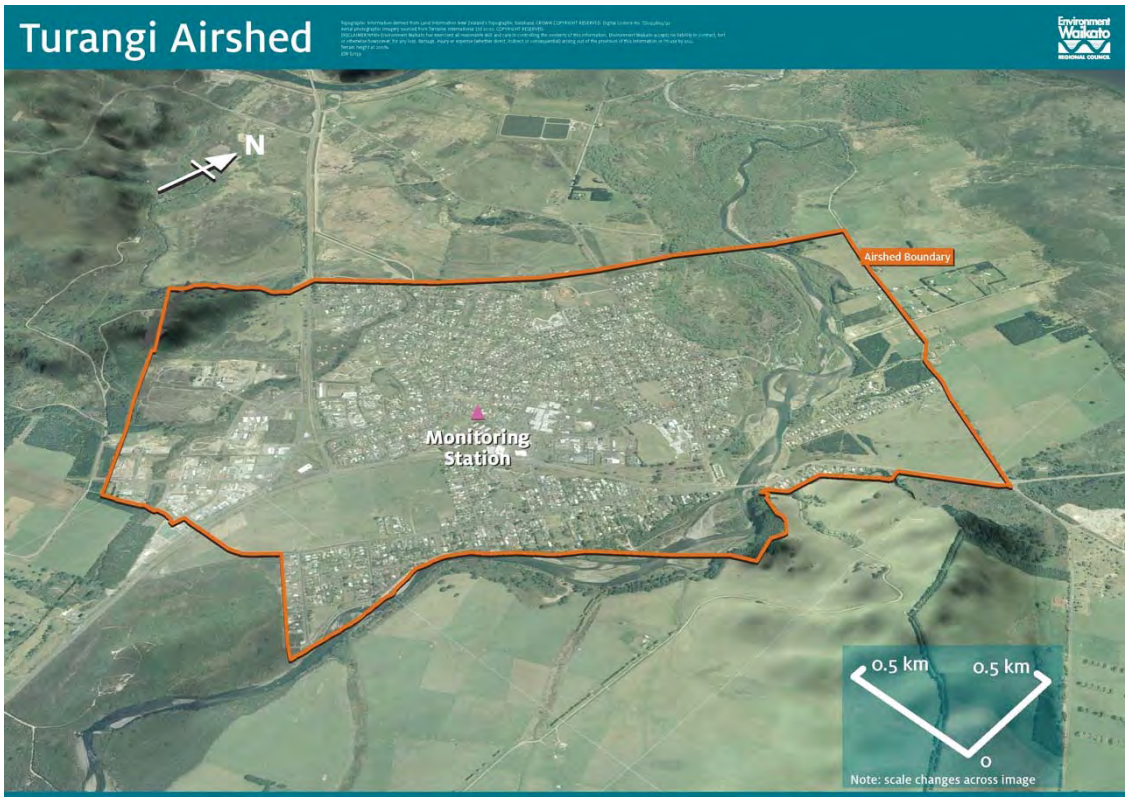


Figure 11.1: Turangi Airshed and air quality monitoring site (Source: Environment Waikato, 2010).

Figure 11.2: Turangi air quality monitor (Source: Environment Waikato, 2010).

11.2 PM_{10} Concentrations in Turangi

The maximum PM_{10} concentration in Turangi was 33 µg m^{-3} (24-hour average) and was recorded on 2 July. No exceedences of 50 µg m^{-3} were measured at Turangi during 2011. Monitoring data was not available for January and part of February 2011 due to relocation of the monitoring station a distance of about 20 metres within the existing site location.

Daily average PM_{10} concentrations measured at the Turangi site during 2011 are shown in Figure 11.3.

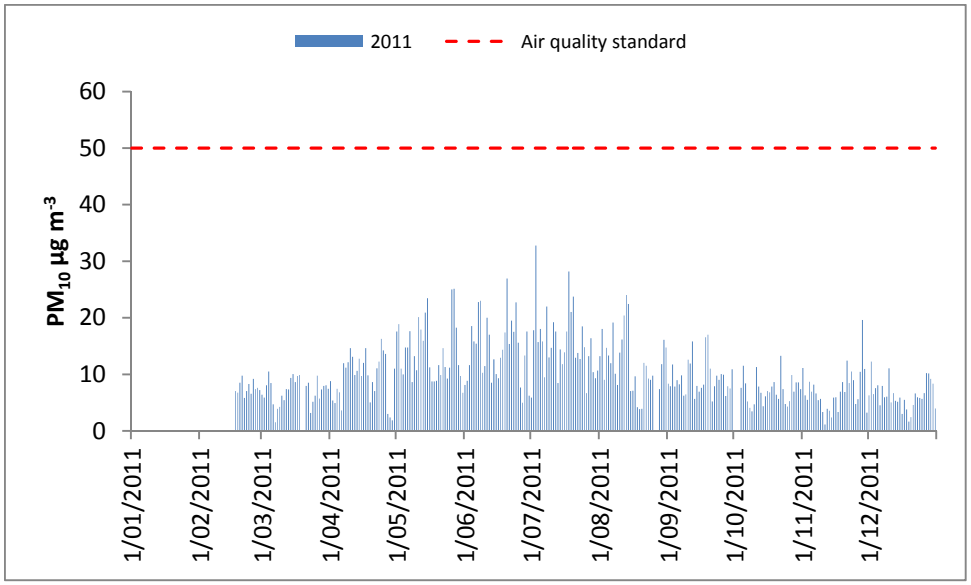


Figure 11.3: Daily winter PM_{10} concentrations measured at the Turangi site for 2011.

Figure 11.4 shows concentrations of PM_{10} relative to air quality indicator categories at Turangi from 2009 to 2011. In 2011, 87% of days experienced PM_{10} concentrations within the 'good' category. On all other days PM_{10} was within the "acceptable" category.

Seasonal variations in the distribution of PM_{10} concentrations for 2011 are shown in Figure 11.5. Figure 11.6 shows no exceedences of 50 µg m^{-3} from 2009 to 2011 and the maximum concentration and the second highest concentration for each year.

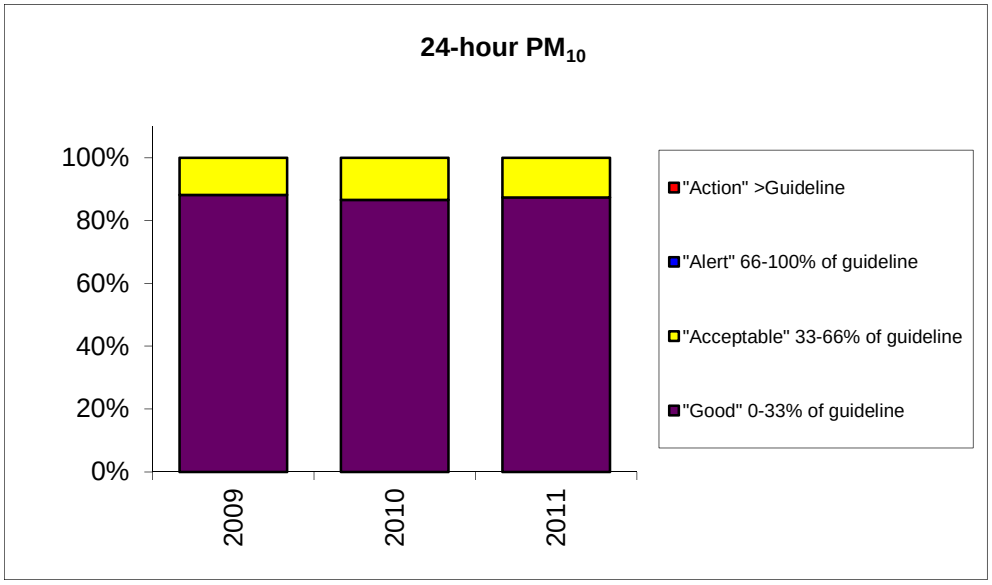


Figure 11.4: Comparison of PM_{10} concentrations measured at the Turangi site in 2011 to air quality indicator categories.

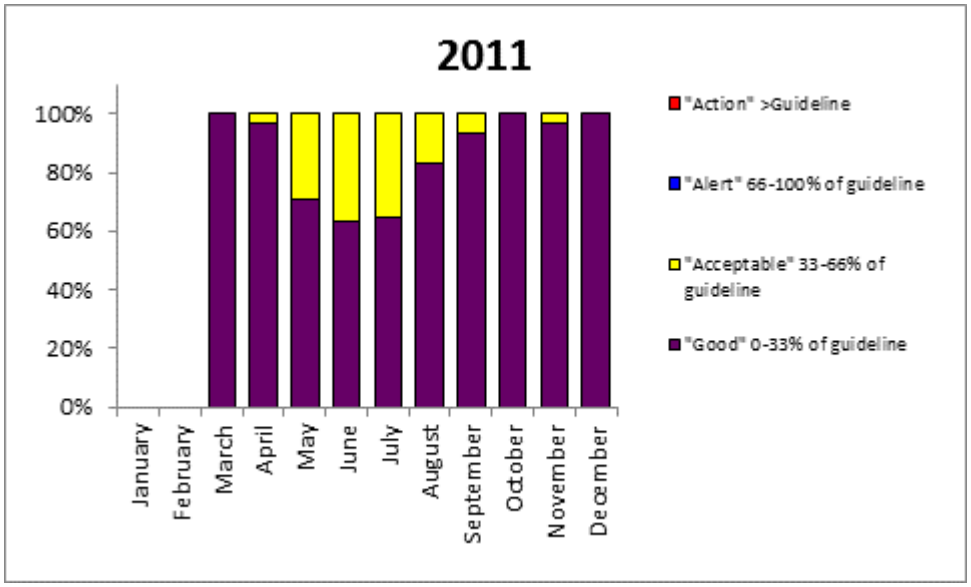


Figure 11.5: Comparison of daily PM_{10} concentrations for 2011 to air quality indicator categories.

The annual average PM_{10} concentration for Turangi for 2011 is 10 µg m^{-3}. Table 11.1 shows summary statistics for PM_{10} monitoring results from 2009 to 2011.

Table 11.1: Summary of PM_{10} concentrations measured at the Turangi monitoring site from 2009 to 2011.

	2009	2010	2011
"Good" 0-33% of guideline	88%	87%	87%
"Acceptable" 33-66% of guideline	12%	13%	13%
"Alert" 66-100% of guideline	0%	0%	0%
"Action" >Guideline	0%	0%	0%
Percentage of valid data	79%	84%	85%
Annual average (µg m^{-3})	9	10	10
Measured exceedences	0	0	0
Second highest concentration	25	30	28
Annual maximum (µg m^{-3})	25	32	33
Number of records	288	305	312

12 Concentrations of radon

Radon is a radioactive gas, occurring naturally as the decay product of radium and is considered to be a health hazard due to its radioactivity. Its most stable (and thus most abundant) isotope, ^{222}Rn, has a half life of 3.8 days. Radon emanates naturally from the ground all over the world, wherever traces of uranium or thorium can be found, and particularly in regions with soils containing granite or shale, which have a higher concentration of uranium. Up to 48% of estimated annual radiation dose is due to radon (http://www.nrl.moh.govt.nz/publications/1988-6.pdf).

The FH62 C14 Continuous Ambient Particulate Monitor (BAM) measures the mass concentration of suspended particulate matter (e.g., TSP, PM_{10}, $PM_{2.5}$, PMC and PM_1) by use of beta attenuation. In addition, the ambient radioactive influence of ^{222}Rn gas (alpha particle emission) is measured as a refinement step toward better sensitivity at lower ambient particulate concentrations. This nominal "radon record" is recorded (at 10 minute intervals), and archived, but usually ignored.

A comparison of the radon data (Table 1) recorded over a period of four to six months between February 2011 to July 2011 by the seven FH62 BAMs located in the Waikato Region were compared with duplicate, co-located (Figure 1) Accustar AT-100 radon detector badges.

Table 12.1: Comparison of radon data recorded by BAMs with co-located radon detection badges.

Location	Exposure Period (days)	BAM Reading (pCi/L) Mean	BAM Reading (pCi/L) Max	Radon Badge[1] (pCi/L)
Tokoroa	149	0.04	0.30	<0.4
Taupo	147	0.02	0.17	0.4
Matamata	171	0.10	0.87	<0.4
Te Kuiti	163	0.09	0.59	0.4
Ngaruawahia	169	0.06	0.65	0.5
Putaruru	134	0.08	0.82	<0.4
Turangi	149	0.01	0.14	<0.4
Hamilton[2]	161	–	–	<0.4
Waihi[2]	122	–	–	<0.4

1. <0.4 is below the detection limit
2. No BAM available for comparative data collection

Radon readings of between 0.4 to 0.5 pCi/L were determined for detection badges located at Taupo, Te Kuiti and Ngaruawahia. Detection badges located at all other locations were below the detection limit of 0.4 pCi/L. The mean BAM readings (averaged over the four to six month period that the badges were exposed) were all

well below 0.4 pCi/L with the highest mean reading of 0.1 pCi/L determined in Matamata. The highest 10 minute BAM reading was also determined in Matamata with a maximum reading of 0.87 pCi/L obtained.

The readings are consistent with the average outdoor radon level of 0.4 pCi/L in the US (www.epa.gov/radon/healthrisks.html) and are well below the US indoor guideline of 4 pCi/L (www.epa.gov/radon/healthrisks.html).

Figure 12.1: Duplicate radon detection badges co-located at an FH62 BAM monitoring site.

13 Summary

During 2011 concentrations of PM_{10} were measured at air quality monitoring sites in Hamilton, Tokoroa, Taupo, Te Kuiti, Matamata, Putaruru, Ngaruawahia, Waihi and Turangi. Monitoring of arsenic, nitrogen dioxide, benzene, toluene and xylenes were measured in Hamilton and concentrations of radon were measured in Tokoroa, Taupo, Te Kuiti, Matamata, Putaruru, Ngaruawahia, and Turangi.

The NES for PM_{10} was breached in Tokoroa. All other towns were compliant with the NES although one exceedence of 50 µg m^{-3} was measured in Hamilton, Putaruru, Te Kuiti and Taupo. The maximum measured PM_{10} concentrations, number of exceedences of 50 µg m^{-3} and the annual average PM_{10} concentration at all sites are shown in Table 13.1. More than one exceedence of the 50 µg m^{-3} constitutes a breach of the NES. The annual average concentration for each location is also shown and can be compared with an annual average guideline of 20 µg m^{-3} (MfE, 2002).

Table 13.1: Summary of PM_{10} monitoring results for 2011.

	Maximum measured concentration µg m^{-3-}	Measured exceedences	Number of NES breaches	Annual Average
Hamilton	64	1	0	14 µg m^{-3}
Tokoroa	73	16	15	18 µg m^{-3}
Taupo	51	1	0	14 µg m^{-3}
Te Kuiti	51	1	0	15 µg m^{-3}
Matamata	31	0	0	12 µg m^{-3}
Putaruru	54	1	0	13 µg m^{-3}
Ngaruawahia	44	0	0	13 µg m^{-3}
Waihi	43	0	0	13 µg m^{-3}
Turangi	33	0	0	10 µg m^{-3}

Concentrations of NO_2 were measured in Hamilton from March 2011 to March 2012. A total of 52 exceedences of 200 µg m^{-3} (hourly average) were measured during a three month period when road works increased traffic congestion in this area. The NES for NO_2 was breached on 43 occasions during this time. No exceedences were measured following the completion of the road works.

In Hamilton, concentrations of benzene were within the guideline of 3.6 µg m^{-3} although concentrations at several sites had increased relative to recent years. The highest annual concentration was measured at the Greenwood Street monitoring site and was 3.5 µg m^{-3} which is close to the 2010 benzene guideline. Concentrations of toluene, xylene and arsenic were well within acceptable levels. Concentrations of radon at all monitoring sites were within acceptable levels.

References

Fisher, G., Rolfe, K., Kjellstrom, T., Woodward, A., Hales, S., Sturman, A., Kingham, S., Peterson, J., Shrestha, R., King, D., 2002. *Health effects due to motor vehicle air pollution in New Zealand*. Report to the Ministry of Transport.

Ministry for the Environment, 2009, *Good Practice Guide for Air Quality Monitoring and Data Management 2009*, Publication number: ME 933, Ministry for the Environment : Wellington.

Ministry for the Environment, 2002, *Ambient Air Quality Guidelines, May 2002,* Ministry for the Environment.

Ministry for the Environment, 2004, *National Environmental Standards for Air Quality,* Ministry for the Environment, Wellington.

Smith, J., 2006, *Air Quality Monitoring Report 2006*, Environment Waikato Report.

Smith, J. and Lee, K., 2003. Soil as a source of dust and implications for human health. *Advances in Agronomy*, Vol. 80, p 1-32.

Stevenson, C. and Narsey, H., 1999. *Benzene and Other Toxic Organics* Report prepared for the Ministry of Health.

Wilton, E and Baynes, M, 2008, *Air Quality Monitoring 2007 for Hamilton, Tokoroa, Taupo,Te Kuiti, Matamata and Putaruru*, Environment Waikato Report.

Wilton, E and Baynes, M, 2009, *Air Quality Monitoring 2008 for Hamilton, Tokoroa, Taupo,Te Kuiti, Matamata, Putaruru, Nguaruwahia, Waihi*, Environment Waikato Report.

Wilton, E and Baynes, M, 2010, *Air Quality Monitoring 2009 for Hamilton, Tokoroa, Taupo,Te Kuiti, Matamata, Putaruru, Nguaruwahia, Waihi, and Turangi*, Environment Waikato Report.

Appendices

The appendices to this report are the Excel spreadsheets of raw data and indicator calculations and are compiled in separate documents (Waikato Regional Council Doc 2177562, Doc 2177565, Doc 2132524, Doc 2081906 and Doc 1918318), which may be obtained on request from the Waikato Regional Council.