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Ambient air quality monitoring report for the Waikato Region – 1998 to 2020

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Executive summary

Although air pollution is a complex mixture of contaminants and particles generated from both natural sources and human created sources such as home heating, traffic and industrial discharges, the majority of health effects in New Zealand are associated with particulate matter less than 10 micrometres in size – commonly known as PM_{10}. It is also a good indicator of the sources and effects of other air pollutants. However, while PM_{10} levels pose a risk to human health, it is now well established internationally, that the finer particle range, referred to as $PM_{2.5}$, provides better evidence of effects on human health and is more indicative of the problem source, which is combustion related.

While wood and coal burners used for home heating dominate the health impacts associated with PM_{10} in every location in New Zealand except Auckland, vehicle emissions are also sources of air pollutants that have adverse health effects. Exhaust emissions include fine particulate matter, volatile organic compounds (such as benzene) and the gases carbon monoxide and nitrogen oxides. In New Zealand, motor vehicle emissions are the main source of nitrogen dioxide (NO_2) in urban areas.

The National Environmental Standards for Air Quality (NESAQ) sets a maximum concentration limit for PM_{10} of 50 $\mu g/m^3$ as a 24-hour average with one allowable exceedance per 12-month period and a 1-hour average limit for NO_2 of 200 $\mu g/m^3$ with nine allowable exceedances per 12-month period. There is currently no New Zealand based guideline or standard applicable to $PM_{2.5}$ and consequently the World Health Organisation (WHO) guidelines have been used for reporting of $PM_{2.5}$ concentrations. The WHO guidelines for $PM_{2.5}$ were updated in 2021 and include a 24-hour average guideline of 15 $\mu g/m^3$ and an annual average guideline of 5 $\mu g/m^3$. Data are also reported against the WHO 2005 guidelines (25 $\mu g/m^3$ for 24—hour and 10 $\mu g/m^3$ for annual $PM_{2.5}$) as these guidelines were relevant at the time monitoring was carried out. The WHO 2021 annual average guideline for NO_2 of 10 $\mu g/m^3$ as well as the WHO 2005 annual average guideline of 40 $\mu g/m^3$ have also been used for assessment purposes.

A total of 14 out of 20 gazetted airsheds in the Waikato region have been monitored for PM_{10} over the period 1998 to 2020 with monitoring of $PM_{2.5}$ in Tokoroa since 2015. Monitoring of benzene in Hamilton and nitrogen dioxide (NO_2) in Cambridge, Hamilton, Te Awamutu and Taupō has also occurred over this reporting period.

Te Kuiti, Taupō and Putaruru airsheds, after earlier breaches of the PM_{10} standard, have been identified as meeting compliance with the NES since 2016, 2018 and 2019 respectively with an improving trend identified in Te Kuiti and Taupō which have mainly been attributed to reductions in emissions from home heating sources.

An improving trend in PM_{10} concentrations has been identified in the Tokoroa airshed attributed mainly to reductions in emissions from home heating sources. Despite this, the 24-hour PM_{10} and $PM_{2.5}$ concentrations continue to exceed the NES and WHO standard and guideline multiple times during the winter season. The annual average concentrations also exceed the WHO guidelines. Domestic home heating has been identified as the primary source of PM_{10} and $PM_{2.5}$ in the Tokoroa airshed and there is evidence of arsenic and lead contamination from the burning of treated and painted wood.

The last breach of the NES 24-hour average PM_{10} standard in Hamilton occurred in 2013. Since then, both the 24-hour average and annual average PM_{10} concentrations have complied with the NES standard and WHO guidelines. There is evidence of an improving trend at the Ohaupo Road station, the site more impacted on by vehicle emissions, but there is no statistically significant change identified for the Claudelands station.

Benzene concentrations, as indicators of traffic related emissions, have complied with the Ministry for the Environment guideline at all traffic monitoring sites within Hamilton and have

been steadily improving since 2003. However, while the 1-hour average NO_2 concentrations recorded in Hamilton have met the NES 1-hour standard since 2011, the New Zealand Transport Agency's nine passive NO_2 monitoring sites in Hamilton all exceed the WHO 2021 annual average guideline compared to only two sites typically exceeding the WHO 2005 annual average guideline. Exceedances of the WHO 2021 annual average guideline have also been identified at passive NO_2 sites in Taupō, Te Awamutu and Cambridge.

Trend analyses undertaken for the 12 passive NO_2 sites monitored by NZTA in Hamilton, Cambridge, Te Awamutu and Taupō has identified only one site (Hamilton) with a worsening trend and five sites with an improving trend (four in Hamilton and one in Te Awamutu).

While wood burners for domestic home heating have been identified as the main source of poor air quality in all airsheds, traffic sources in Hamilton have been identified as significant contributors to poor air quality in localised areas close to busy traffic routes and intersections.

With the continued significant non-compliance against the NES and WHO standards and guidelines for PM_{10} and $PM_{2.5}$ in Tokoroa, in addition to the recent introduction of $PM_{2.5}$ monitoring in Hamilton, Te Kuiti and Taupo and the imminent introduction of long and short term $PM_{2.5}$ standards in New Zealand it is likely that actions such as the clean heat incentives and education campaigns already implemented in Tokoroa will need to be increased and also extended to other airsheds where it is anticipated that the new $PM_{2.5}$ standards will also not be met. Consideration will also need to be given to the South Waikato and Waitomo districts that have been identified as having had significant increases in social deprivation. While there will be increased challenges in converting to clean heat sources and changing behaviours, there will also be greater health benefits realised as a result of the higher vulnerability of people living in those areas.

Population growth, particularly in Hamilton City and Waikato District is anticipated to contribute to worsening air quality arising from increased traffic emissions along key traffic routes which could be mitigated through a shift to electric vehicles. However, EVs can still produce significant particulate emissions from tyre wear, brake pads and resuspension of roadside dust so it will still be important to limit the flow of vehicles through built up urban centres and in close proximity to sensitive receptors such as early childhood centres and schools where appropriate setbacks and the use of vegetation could be used as a means of mitigating air pollution exposure.

Climate change could result in an improvement in wintertime air quality as a result of reduced woodburner impacts. However, it is less clear how air quality will be impacted at other times of the year as a result of other air pollutant sources. For example, drier, windier weather in springtime or summer and or changes in prevailing wind directions could result in more dust impacts on air quality. Wildfires may also be more frequent as well as increasing prevalence of hayfever and thunderstorm asthma events arising from changes in sources of airborne pollen.

1 Introduction

1.1 Background

New Zealand (and the Waikato region) enjoys good air quality most of the time due to the country's long narrow shape, exposure to strong eastward winds, and typically low population density. However, during the winter months when temperature inversions form on cold, still days, air pollutants can become trapped close to the ground leading to poor air quality in some towns and cities.

Air quality within towns and cities can be affected by a number of activities including natural causes such as sea spray, pollen and volcanic activity and human created causes such as home heating, traffic, and industrial discharges.

Although air pollution is a complex mixture of contaminants and particles, the majority of health effects in New Zealand are associated with particulate matter less than 10 micrometres in size – commonly known as PM_{10}. It is also a good indicator of the sources and effects of other air pollutants. However, while PM_{10} levels pose a risk to human health, it is now well established internationally, that the finer particle range, referred to as $PM_{2.5}$, provides better evidence of effects on human health.

The Health and Air Pollution in New Zealand Study (Kuschel et al., 2012) identified that domestic fires (open fires and wood and coal burners used for home heating) are the main source of PM_{10} resulting in health impacts in every location in New Zealand except Auckland.

Emissions from motor vehicles are also sources of air pollutants that have adverse health effects. Exhaust emissions include fine particulate matter, volatile organic compounds (such as benzene) and the gases carbon monoxide and nitrogen oxides. Nitrogen dioxide emissions can occur directly from combustion processes and as a result of the conversion of nitric oxide gas (also produced from combustion processes) reacting in the atmosphere in the presence of ozone. In New Zealand, motor vehicle emissions are the main source of nitrogen dioxide in urban areas.

Other gases (such as ozone and sulphur dioxide) and secondary particulate (sulphates and nitrates) can form in the atmosphere from reactions involving some of these primary emissions. Sulphur dioxide is typically associated with combustion of fuels containing high levels of sulphur such as coal from industry and heavy fuel oils used in shipping. However, natural sources can often be significant in New Zealand. Such sources can include emissions of SO_2 and H_2S gas from the Central Plateau volcanic zone and marine phytoplankton activity involving release of dimethyl sulphide as a gaseous precursor via methane sulphonic acid (MSA) to secondary sulphate (Davy & Trompetter, 2017a). On average across NZ, it is estimated that around 0.7 to 1 ug/m^3 of particulate matter is formed from ammonium nitrate which will likely come from a combination of urban and agricultural sources which could represent up to 2% contribution of a PM_{10} exceedance (Davy & Trompetter, 2017b).

1.2 Regulatory requirements and assessment criteria

In New Zealand, monitoring and management of air quality is undertaken within defined air quality management areas referred to as airsheds. Airshed boundaries are officially identified by regional councils and approved and made public by the Ministry for the Environment (MfE).

Regional councils have a responsibility to monitor and manage outdoor air quality under the Resource Management Act 1991 (RMA). The National Environmental Standards for Air Quality (NESAQ) are mandatory environmental regulations made under the RMA that:

- direct regional councils to focus on monitoring of PM_{10} as the main contaminant of concern and on managing the main source of PM_{10} emissions, namely woodburners used for domestic home heating;
- include ambient air quality standards for PM_{10}, carbon monoxide, nitrogen dioxide, sulphur dioxide and ozone for protecting human health;
- require regional councils to monitor air quality if it is likely that the ambient air quality standard for a contaminant will be breached in an airshed;
- requires regional councils to ensure any air discharge consent authorisations will not result in airshed breaches of these standards;
- state that an airshed is classified as polluted if it has more than one PM_{10} exceedance per 12-month period;
- state that an airshed ceases to be polluted when the PM_{10} standard has not been breached in the airshed for five years; and
- requires offsets for expanding or newly establishing industry which discharge significant amounts of PM_{10} in to a polluted airshed. Existing industries authorised to discharge to air at current levels are exempt from this requirement. The 'offset rule' of the NESAQ effectively acts as a disincentive to industry establishing or expanding within a polluted airshed as it drives additional cost on to the price of doing business.

The air quality standard for PM_{10} is 50 micrograms per cubic metre of air (50 $\mu g/m^3$) averaged over a 24-hour period (from midnight to midnight), with one allowable exceedance per 12-month period. The standards for PM_{10}, carbon monoxide, nitrogen dioxide, sulphur dioxide and ozone along with averaging periods and number of allowable exceedances are provided in Table 1.1. A breach of the standards occurs when more than the allowable number of exceedances occurs within the specified period.

Table 1.1 National Environmental Standards for Air Quality.

Contaminant	Standard Concentration	Standard Averaging period	Allowable exceedances per year
Carbon monoxide	10 mg/m^3	8-hour	1
Particles (PM_{10})	50 $\mu g/m^3$	24-hour	1
Nitrogen dioxide	200 $\mu g/m^3$	1-hour	9
Sulphur dioxide	350 $\mu g/m^3$	1-hour	9[a]
Sulphur dioxide	570 $\mu g/m^3$	1-hour	0[a]
Ozone	150 $\mu g/m^3$	1-hour	0

a. Note that the 1-hour average concentration of sulphur dioxide can exceed 350 $\mu g\ m^{-3}$ up to 9 times within any 12-month period but can never exceed a 1-hour average of 570 $\mu g\ m^{-3}$.

For the assessment of other air contaminants not included under the NESAQ, the National Ambient Air Quality guidelines (MfE, 2002) and the World Health Organisation (WHO) guidelines are used. It is important to note that in September 2021, the WHO guidelines were updated from the previous 2005 guidelines and while the monitoring period relevant to this report occurred prior to these changes, the monitoring results throughout this report are compared to both the 2005 and the 2021 WHO guidelines. A subset of ambient air quality guidelines relevant to WRC's air quality monitoring programme are provided in Table 1.2.

Table 1.2 Ambient air quality guidelines.

Contaminant	Guideline Concentration	Guideline Averaging period	Source
Toluene	190 µg/m^3	Annual	MfE, 2000
Total xylenes	950 µg/m^3	Annual	MfE, 2000
Ethylbenzene	1000 µg/m^3	Annual	US EPA RC
Benzene (year 2002)	10 µg/m^3	Annual	MfE, 2002
Benzene (year 2010)	3.6 µg/m^3	Annual	MfE, 2002
Particles (PM_{10})	50 µg/m^3	24-hour	MfE, 2002/ WHO 2005
Particles (PM_{10})	45 µg/m^3	24-hour	WHO 2021
Particles (PM_{10})	20 µg/m^3	Annual	MfE, 2002/ WHO 2005
Particles (PM_{10})	15 µg/m^3	Annual	WHO, 2021
Particles ($PM_{2.5}$)	25 µg/m^3	24-hour	WHO, 2005
Particles ($PM_{2.5}$)	15 µg/m^3	24-hour	WHO, 2021
Particles ($PM_{2.5}$)	10 µg/m^3	Annual	WHO, 2005
Particles ($PM_{2.5}$)	5 µg/m^3	Annual	WHO, 2021
Nitrogen dioxide	100 µg/m^3	24-hour	MfE, 2002/ WHO 2005
Nitrogen dioxide	25 µg/m^3	24-hour	WHO, 2021
Nitrogen dioxide	40 µg/m^3	Annual	WHO, 2005
Nitrogen dioxide	10 µg/m^3	Annual	WHO, 2021

1.3 Monitoring objectives

Ambient air quality monitoring has been carried out in the Waikato region by the Waikato Regional Council (WRC) since 1998. The US EPA define ambient air monitoring as the systematic, long-term assessment of pollutant levels by measuring the quantity and types of certain pollutants in the surrounding, outdoor air.

The objectives of Waikato Regional Council's ambient air quality monitoring programme are to:

1. Determine compliance with national ambient air quality standards and guidelines.
2. Identify trends in ambient air quality and sources contributing to poor air quality.
3. Provide information to support the implementation of our regional plan and regional policies on air quality, including consent processing and consented and permitted activity compliance.

1.4 Airsheds and contaminants monitored

There are 20 airsheds in the Waikato region that have been officially gazetted by MfE for monitoring and management purposes (refer to Figure 1.1). To date, a total of 14 of these airsheds have been monitored for PM_{10}. A combination of long-term monitoring and short-term surveys are undertaken as described below:

- Long-term monitoring is undertaken for airsheds that are either currently classified as polluted, have previously been classified as polluted or have indicated potential to breach the standards and be classified as polluted. The five airsheds that fall within this criteria are Hamilton, Putaruru, Taupo, Tokoroa and Te Kuiti.
- A shorter term "rolling" survey is undertaken for airsheds that have not yet been monitored. In these cases, WRC's monitoring stations are moved to new locations subject to the airshed having had no exceedances of the 24-hour average PM_{10} standard over a short term (3 to 6 years) monitoring period and/ or where no worsening trend has been identified.

Figure 1.1 Map of Waikato Region indicating the 20 urban centres that have been gazetted as airsheds.

A summary of the air quality parameters monitored and the respective monitoring periods for each airshed is provided in Table 1.3. A full list of parameters monitored is provided but only those in bold have been included for analysis in this report due to availability of a sufficient dataset covering consecutive years.

Table 1.3 Air quality parameters monitored (only parameters in bold have been included in this report).

Airshed	Parameter Monitored	Monitoring Period
Hamilton	**PM_{10}, $PM_{2.5}$, NO_2**, CO, SO_2, O_3, **BTEX**, heavy metals, PAHs & **meteorology**	29/05/1998 to current
Tokoroa	**PM_{10}, $PM_{2.5}$,** NO_2, SO_2, BTEX & **meteorology**	29/03/2001 to current[1]
Taupo	**PM_{10}, NO_2,** & **meteorology**	3/11/2000 to current
Te Kuiti	**PM_{10}, $PM_{2.5}$** & **meteorology**	13/05/2003 to current[2]
Putaruru	**PM_{10}**	18/07/2006 to current
Turangi	**PM_{10}**	11/03/2009 to 30/10/2018
Cambridge	**PM_{10} & NO_2**	28/05/2013 to 17/08/2016[3]
Te Awamutu-Kihikihi	**PM_{10} & NO_2**	27/06/2013 to 26/10/2016[4]
Morrinsville	**PM_{10}**	28/05/2015 to current
Thames	**PM_{10}**	13/04/2016 to current
Waihi	**PM_{10}**	31/01/2008 to 7/01/2012
Ngaruawahia	**PM_{10}**	31/08/2007 to 3/04/2013
Matamata	**PM_{10} & meteorology**	20/06/2005 to 18/04/2013[5]
Huntly	**PM_{10}, NO_2, SO_2** & meteorology	2001 to current[6]

1. Short term PM_{10} monitoring in Tokoroa also from 19/02/1999 to 30/11/1999 but not included in this analysis.
2. Short term PM_{10} monitoring in Te Kuiti also from 21/04/1998 to 5/11/1998 but not included in this analysis.
3. Passive NO_2 monitoring in Cambridge by NZTA covers period 2007 to current.
4. Passive NO_2 monitoring in Te Awamutu by NZTA covers period 2010 to current.
5. Meteorology in Matamata continues to current.
6. Monitoring by Genesis Energy.

Hamilton is the Waikato region's main urban area, with a population of 160,911 (2018 Census). The airshed (refer to Figure 1.2) extends across both the eastern and western sides of the Waikato River. The main source of poor air quality is domestic home heating but traffic can also be a significant source of poor air quality especially in the vicinity of busy intersections (Golder Associates, 2020). Hamilton currently has two active ambient particulate monitoring stations operated by WRC and a number of localised traffic monitoring sites operated by WRC and NZTA. The main ambient air quality monitoring station is at the Claudelands Event Centre on Heaphy Terrace on the eastern side of Hamilton. The Ohaupo Road station (also referred to as the Bloodbank Station) is a secondary air quality monitoring station, more influenced by localised traffic and industry sources. It is next to the NZ Blood Service at the Waikato Hospital on the corner of Ohaupo Road and Lorne Street on the western side of Hamilton. From November 1997 to October 2013, the main ambient air quality monitoring station was located on Peachgrove Road on the eastern side of Hamilton on land owned by Electricity Corp NZ. The station was decommissioned in October 2013 because the property changed ownership to allow for development of a Countdown supermarket.

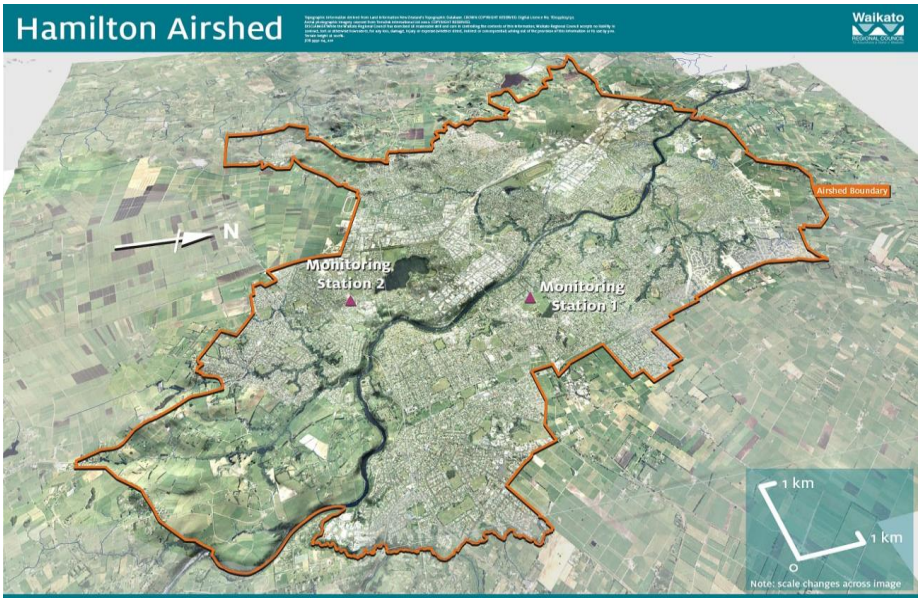


Figure 1.2 Hamilton, airshed with monitoring stations identified by pink triangle.

Taupō, with a population of 37,203 (2018 Census), is the Waikato region's second largest urban area after Hamilton. It is located within the Taupō Volcanic Zone at the northeastern end of Lake Taupō (refer to Figure 1.3). The main source of poor air quality is domestic home heating (Wilton, 2015a). Due to its location within the Taupō Volcanic zone, there will be a larger contribution from volcanic/geothermal activity at times. The surrounding pumice soils are also likely to contribute to a higher summertime dust source. Taupō's one active ambient air quality and meteorological monitoring station, located at Gillies Avenue Reserve, was established in November 2000.

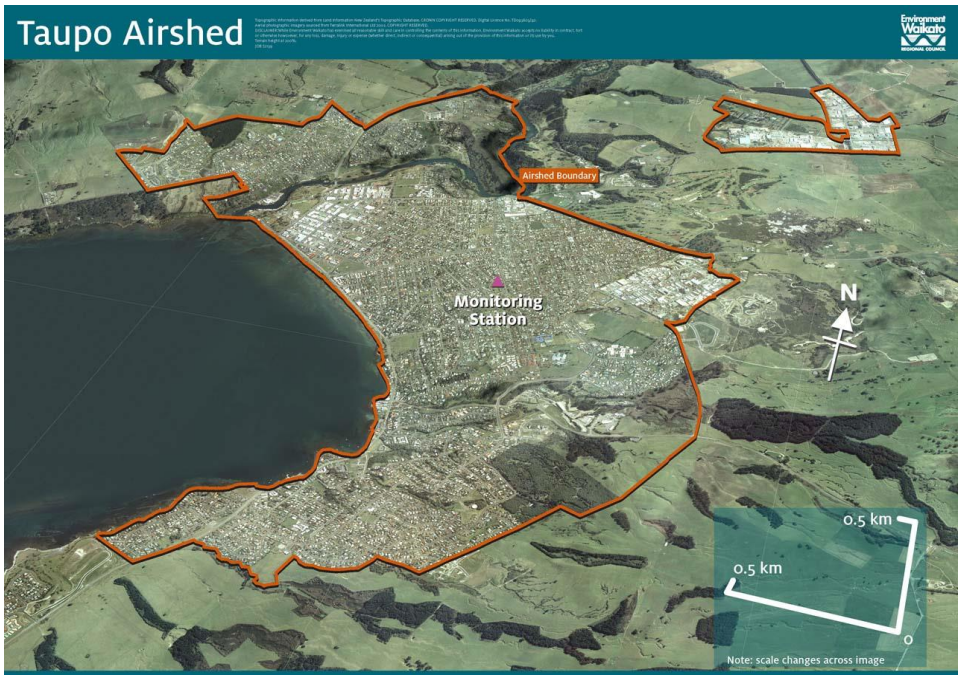


Figure 1.3 Taupo airshed with monitoring station identified by pink triangle with separate industrial area identified to the northeast.

Tokoroa is located mid-way between Hamilton and Taupō on State Highway One (refer to Figure 1.4), close to the foot of the Mamaku Ranges with a population of 13,578 (2018 Census). The main source of poor air quality is domestic home heating (Wilton, 2019). Tokoroa's one active ambient air quality and meteorological monitoring station is located at the Billah Street Reserve and was established in March 2001. In April 2015, the station was shifted (within the same site) to a new enclosure 25 metres from its previous location because of concern about potential

impacts from the lime dosing process used on site by South Waikato District Council for treating drinking water at the Billah Street reservoir.

Figure 1.4 Tokoroa airshed with monitoring station identified by pink triangle.

Te Kuiti is located approximately 78km south of Hamilton within a confined valley that is aligned along an approximately southeasterly to northwesterly direction (refer to Figure 1.5). The town is located within the Waitomo District and has a population of 4,572 (2018 Census). The main source of poor air quality is domestic home heating but there are also three significant industrial sources including a lime processing plant and two woodfired combustion plants associated with two separate sawmilling operations (Wilton, 2015b). Te Kuiti's ambient air quality monitoring and meteorological station was established at the Waitomo District Council offices on Queen Street in May 2003.

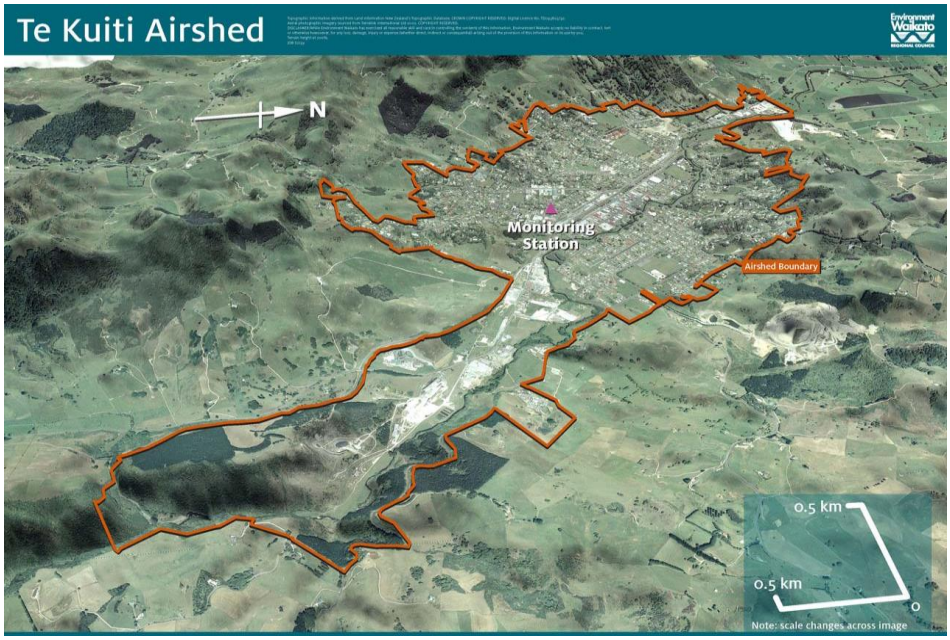


Figure 1.5 Te Kuiti airshed with monitoring station identified by pink triangle.

Putaruru is located 65 kilometres southeast of Hamilton and is close to Lake Arapuni on the Waikato River (refer to Figure 1.6). It is situated midway between Tokoroa and Tirau on State Highway One, in the South Waikato District and has a population of 4,314 (2018 Census). Putaruru occupies a flat to gently undulating site, and to the east the land rises to the Mamaku

Range. The main source of poor air quality is domestic home heating (Wilton, 2015b). Putaruru's ambient air quality monitoring station was established at the Bowling Club on Arapuni Street, in July 2006.

Figure 1.6 Putaruru airshed with monitoring station identified by pink triangle.

Turangi, at the southern end of Lake Taupō, has a population of 3,444 (2018 Census). The main source of poor air quality is domestic home heating (Wilton, 2006). Due to its location within the Taupo Volcanic zone, at times volcanic/geothermal activity has been identified as contributing to PM_{10} concentrations. Turangi's ambient air quality monitoring station was established at the Turangi Fire Station on Ohuanga Road in March 2009 (refer to Figure 1.7).

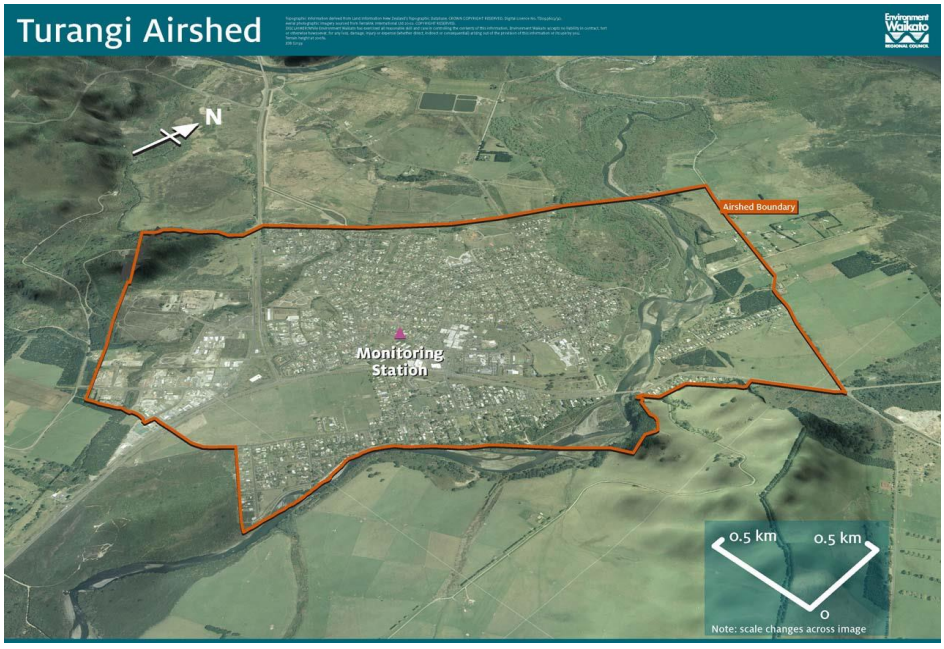


Figure 1.7 Turangi airshed with monitoring stations identified by pink triangle.

Cambridge, approximately 23km southeast of Hamilton, has a population of 18,180 (2018 Census). The airshed extends across both the eastern and western sides of the Waikato River (refer to Figure 1.8). The main source of poor air quality is expected to be domestic home heating (Kuschel et al., 2012). PM_{10} was monitored in Cambridge at an ambient air quality monitoring station located at Leamington Domain on Scott Street from May 2013 to August 2016. NZTA have been monitoring NO_2 at the intersection of Victoria St and Queen St since 2007.

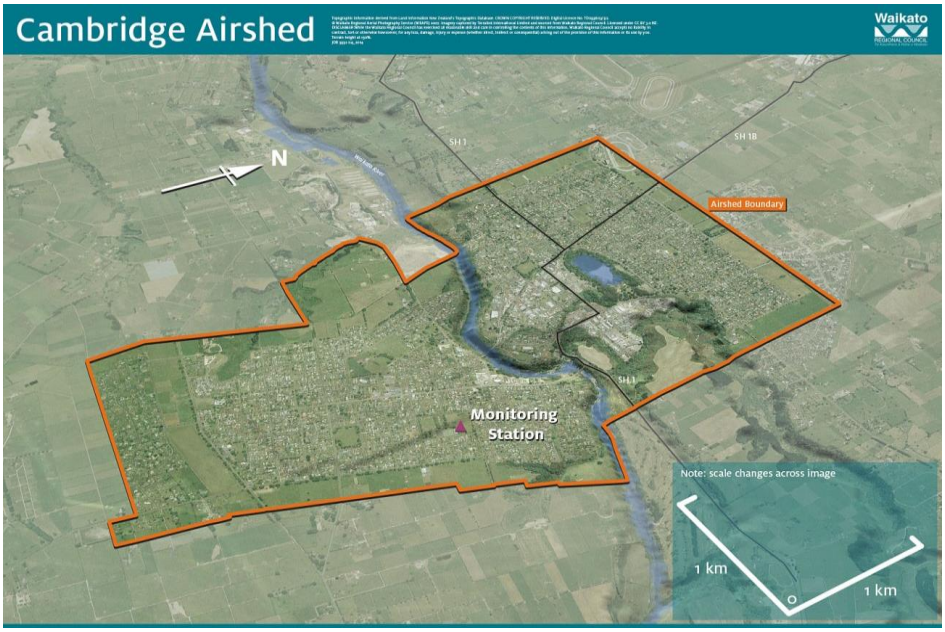


Figure 1.8 Cambridge airshed with monitoring stations identified by pink triangle.

Te Awamutu, approximately 30km south of Hamilton, has a population of 12,198 (2018 Census). The main source of poor air quality is likely to be home heating but there are also significant industrial emissions associated with the Fonterra dairy factory which has milk powder driers and gas and coal fired boilers (Wilton, 2006). PM_{10} was monitored in Te Awamutu at an ambient air quality monitoring station located at Albert Park on Albert Park Drive from June 2013 to October 2016 (refer to Figure 1.9). NZTA have been monitoring NO_2 at the intersection of Ohaupo Road and Albert Drive since 2010.

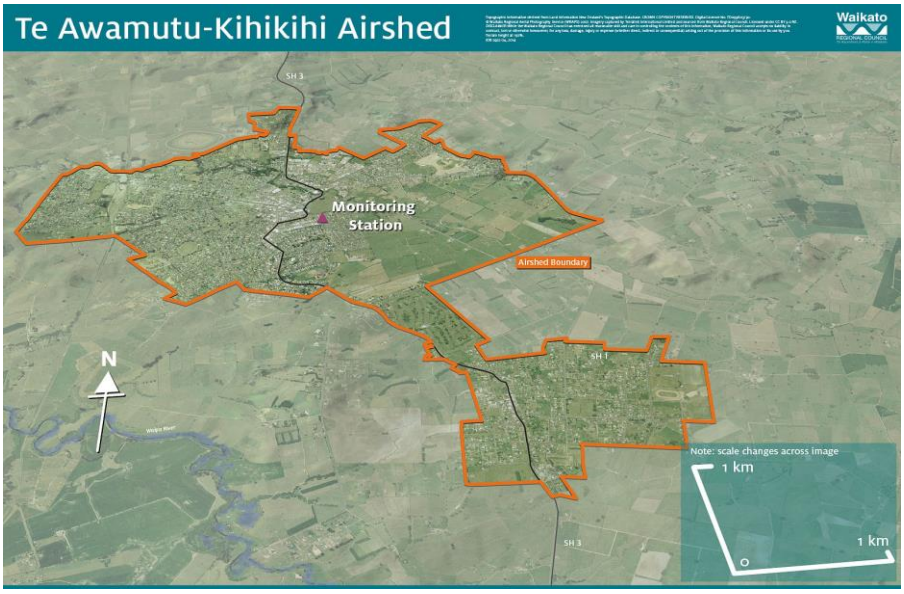


Figure 1.9 Te Awamutu-Kihikihi airshed with monitoring stations identified by pink triangle.

Morrinsville, approximately 30km northeast of Hamilton, has a population of 7,761 (2018 Census). The main source of poor air quality is domestic home heating (Wilton, 2016). Morrinsville's ambient air quality monitoring station was established at Morrinsville College in the vicinity of North Street in May 2015 (refer to Figure 1.10).

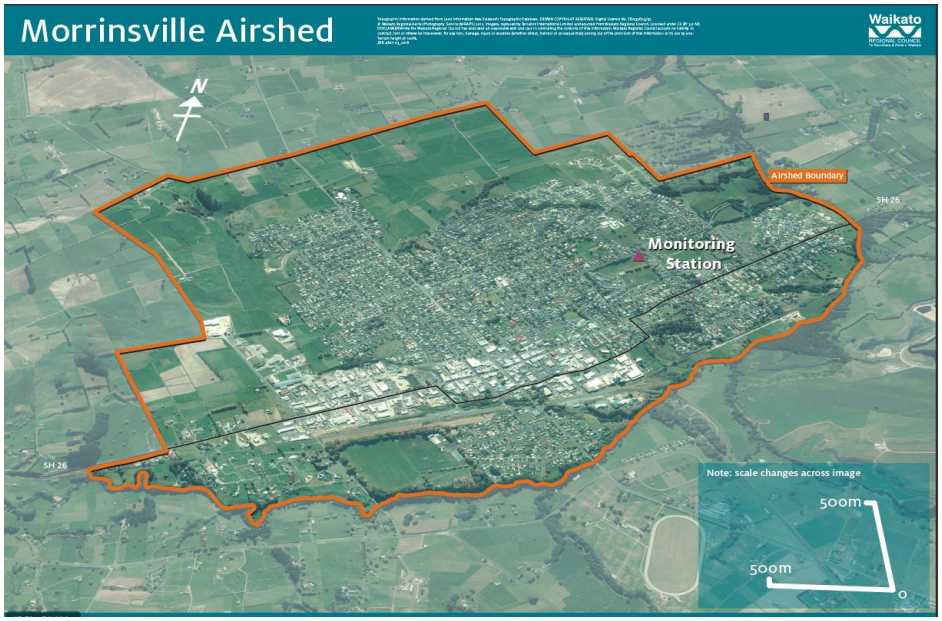


Figure 1.10 Morrinsville airshed with monitoring stations identified by pink triangle.

Waihi is approximately 65 km northeast of Hamilton. It has has a population of 5,403 (2018 Census). The main source of poor air quality is domestic home heating (Smith & Wilton, 2007). Air quality was monitored in Waihi at the residential monitoring site on Grey Street from January 2008 to March 2012, when the station was disestablished (refer to Figure 1.11). A sequential partisol 2025i was used for daily monitoring of PM_{10}.

Figure 1.11 Waihi airshed with monitoring stations identified by pink triangle.

Matamata is approximately 42 km east of Hamilton near the western base of the Kaimai Ranges. It has a population of 7,806 (2018 Census). The main source of poor air quality is domestic home heating (Smith & Wilton, 2007). Air quality was monitored in Matamata at the residential PM_{10} monitoring site at the playcentre grounds on Farmers Road from June 2005 to April 2013 (refer to Figure 1.12). Monitoring of meteorology has been continued at the site.

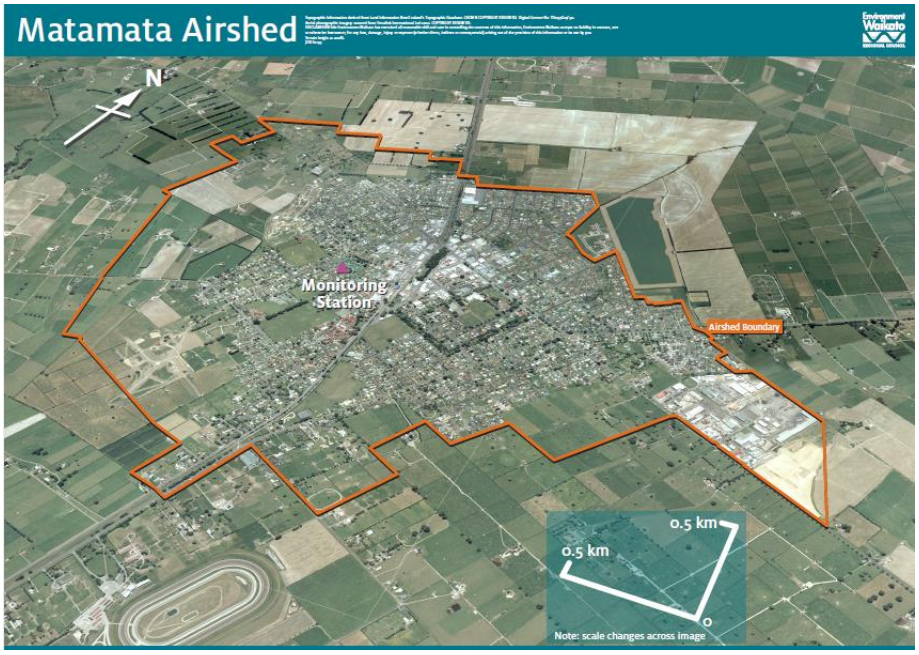


Figure 1.12 Matamata airshed with monitoring stations identified by pink triangle.

Ngaruawahia is approximately 15 km northwest of Hamilton. It has has a population of 6,621 (2018 Census). The main source of poor air quality is domestic home heating (Wilton, 2006). Air quality was monitored in Ngaruawahia at the residential PM_{10} monitoring site at the Ngaruawahia Bowling Club on Herschel Street from May 2008 to April 2013, when the site was disestablished (refer to Figure 1.13).

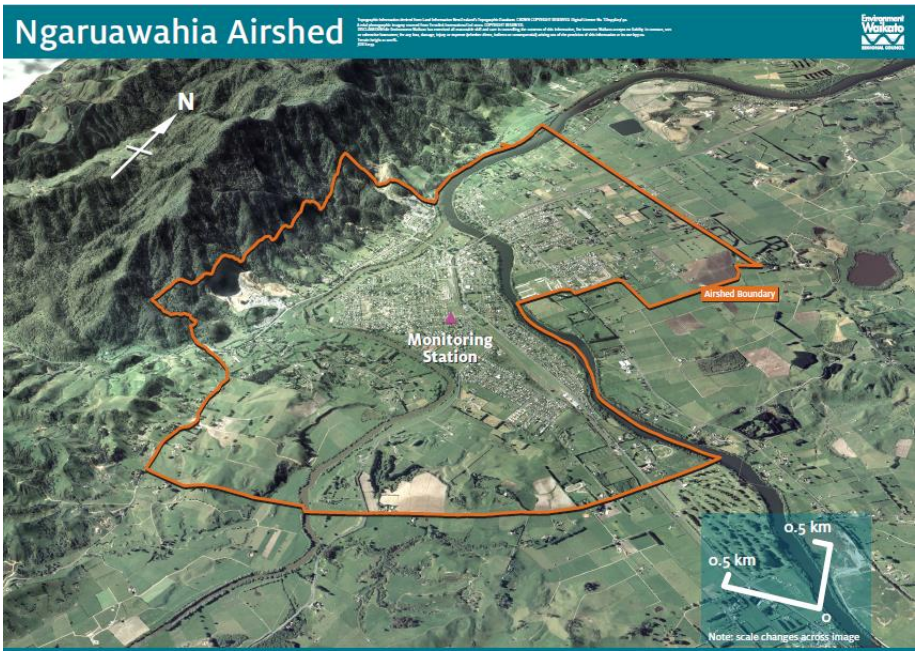


Figure 1.13 Ngaruawahia airshed with monitoring stations identified by pink triangle.

Thames is located at the southeastern end of the Firth of Thames on the banks of the Kauaeranga River (refer to Figure 1.14). Most of the urban area occupies a coastal strip of flat land at the western base of the Coromandel Range. Thames has a population of 7,293 (2018 Census). The main source of poor air quality is domestic home heating (Wilton & Baynes, 2010). Thame's ambient air quality monitoring station was established at Thames High School in the vicinity of Richmond Street in March 2016.

Figure 1.14 Thames airshed with monitoring stations identified by pink triangle.

Huntly is approximately 25 km northwest of Hamilton. It has a population of 7,905 (2018 Census). The main source of poor air quality is domestic home heating (Wilton & Baynes, 2010). Air quality has been monitored in Huntly by Genesis Energy since 2001 at four separate stations, two of which are located within the airshed at the i-Site centre on SH1 and Croft Terrace, and two stations located outside the airshed boundary in rural areas (refer to Figure 1.15).

Figure 1.15 **Huntly airshed with monitoring stations identified by pink triangles (rural/background stations to the north of the airshed identified in bottom image).**

2 Methodology

2.1 PM_{10} & $PM_{2.5}$ monitoring

There are many different ways of measuring particulate concentrations in air and each method can provide varying levels of accuracy. One of the most common methods used by Regional Councils around New Zealand over the period 1998 to 2020 has been the Beta Attenuation Monitor (BAM). In the Waikato region, the Thermo-Scientific FH62 BAM has been the main instrument used for monitoring particulate concentrations in addition to Thermo-Scientific Sequential Partisols. A tapered element oscillating microbalance (TEOM) was also used for a period in Hamilton. However, the more recent development and availability of optical based particulate monitoring instruments that have US-EPA equivalent status has resulted in a recent shift to use of Teledyne API T640x monitors.

The following provides details of the four main methodologies available for monitoring of particulate matter that have either US-EPA reference or equivalence status for purposes of regulatory ambient air quality monitoring. Each of the four methods requires the use of a size-selective inlet which cuts off particle sizes with greater than 10 microns or 2.5 microns aerodynamic diameter for PM_{10} or $PM_{2.5}$ monitoring respectively.

1. Filter based instrumentation such as the Sequential Partisol are a type of gravimetric method used to measure particles by drawing air at a known flow rate through a pre-weighed filter for 24 hours. Particles in air are collected on the filter which is then weighed in a laboratory and reported as micrograms per cubic metre. Partisols operate a cassette system that contains multiple filters that can automatically be changed at a pre-determined time. While this method provides a direct measurement of mass and has US-EPA reference status, the laboratory "turn around" time for obtaining particulate concentrations means that there can be limitations around the ability to report PM_{10} exceedances within the one-month timeframe required by the NES-AQ. There is also no ability to identify variation in particle concentrations throughout the day.

2. Beta attenuation monitors (BAM) measure particle concentrations continuously in air. Sampled air is drawn through a filter which collects particles. A beam of beta radiation (electrons) is passed through the filter and measured on the other side of the filter by a detector. As the mass of particles on the filter increases the beta count is reduced. The relationship between the decrease in count and particle mass is calculated according to a known equation (Beer-Lambert law). The heating of the inlet to reduce relative humidity in the sample (and thus the water content), may lead to a loss of semi-volatile material and therefore this method can underestimate particulate concentrations. These instruments include a radiation source which is typically carbon 14, krypton 85 or promethium 147. This method has US-EPA equivalence status which is accepted for compliance purposes under the NESAQ.

3. The tapered element oscillating microbalance (TEOM) measures particle concentrations in air continuously. Sampled air is drawn through a filter which collects particles. The filter sits on top of a hollow tapered element which vibrates at a known frequency (oscillates). The frequency of oscillation changes by an amount proportional to the mass of particles deposited on the filter. Because the sample air is heated to a high temperature the semi-volatile fraction of the particle mass can be destroyed. For this reason, TEOMs can underestimate particulate concentrations. Fitting a TEOM with a FDMS (filter dynamics measuring system) can overcome this problem. This method has US-EPA equivalence status which is accepted for compliance purposes under the NESAQ.

4. Optical instruments use the loss of light due to scattering and absorption by the particles over a sample path length. Some of these instruments are capable of measuring the particle concentrations as a count as well as apportioning it to a size category. The counts then need to be converted into a mass by calculation using a range of assumptions on the nature of the particles sampled. The Teledyne T640x measures particles optically using a polychromatic light source combined with a 90° scattered light detection system. This instrument is capable of monitoring PM_{10} and $PM_{2.5}$ simultaneously. The T640x also has very little heating, no sample filter and instantaneous measurement and therefore will retain and measure more of the semi-volatile aerosol component of mass compared with other methods. While this method has US-EPA equivalence status, it is not currently identified as an approved method for compliance purposes under the NESAQ. If there is insufficient heating on the inlet to optical instruments then even high humidity during foggy days can influence the particulate concentrations being measured.

Refer to table 2.1 for a detailed summary of monitoring instruments used at each of the air quality stations within the Waikato region over the period 1998 to 2020.

PM_{10} and $PM_{2.5}$ data from the BAM monitors are recorded and logged by iQuest iRIS 320 dataloggers and telemetered hourly to Waikato Regional Council and stored in the hydrotel database. Subsequent data processing and archiving is undertaken in the WISKI database.

Over the period 2006 to 2010, several air quality monitoring stations in the Waikato region had Thermo Sequential Partisol gravimetric samplers run in conjunction with existing BAM and TEOM instruments in order to determine the need to apply site-specific corrections to the BAM and TEOM PM_{10} data. As a result, it was determined that site-specific corrections were required for PM_{10} data collected at Hamilton (Peachgrove Rd) Tokoroa, Taupō and Putaruru. Monitoring data has therefore been adjusted accordingly, at those sites. Table 2.2 provides details of the formulae used for applying the corrections. Additional assessments using a sequential partisol were undertaken in Tokoroa in 2014 and 2016 and indicated that the applied correction factor for BAM PM_{10} data for Tokoroa was still valid. No corrections are applied to the $PM_{2.5}$ data.

Table 2.1 Summary of PM_{10} and $PM_{2.5}$ monitoring instruments used in the Waikato region.

Station	Location	Instrument
Claudelands	Claudelands Event Centre, Heaphy Tce, Hamilton	Thermo FH62 BAM (PM_{10}), Thermo 5014i BAM ($PM_{2.5}$) & Teledyne-API T640x (PM_{10} & $PM_{2.5}$)
Bloodbank/ Ohaupo Rd	Waikato Hospital, Ohaupo Road, Hamilton	Thermo FH62 BAM (PM_{10})
Peachgrove Rd	ECNZ, Peachgrove Road, Hamilton	Rupprecht & Patashnick TEOM 1400A (PM_{10}), Thermo Sequential Partisol 2025i (PM_{10})
Billah Street	Billah St Reserve, Billah St, Tokoroa	Thermo FH62 BAM (PM_{10}), Thermo 5014i BAM ($PM_{2.5}$), Met-One BAM, Teledyne-API T640x (PM_{10} $PM_{2.5}$) & Thermo Sequential Partisol 2025i (PM_{10})
Bowling Club	Bowling Club, Arapuni St, Putaruru	Thermo FH62 BAM (PM_{10}) & Thermo Sequential Partisol 2025i (PM_{10})
Gillies Avenue	Gillies Ave Reserve, Taupō	Thermo FH62 BAM (PM_{10}) & Thermo Sequential Partisol 2025i (PM_{10})

Waitomo DC	Waitomo District Council, Queen St, Te Kuiti	Thermo FH62 BAM (PM_{10}) & Teledyne-API T640x (PM_{10} & $PM_{2.5}$)
Firestation	Fire Station, Ohuanga Rd, Turangi	Thermo FH62 BAM (PM_{10})
Morrinsville College	Morrinsville College, North St, Morrinsville	Thermo 5014i BAM (PM_{10})
Thames	Thames High School, Richmond St, Thames	Thermo 5014i BAM (PM_{10})
Matamata	Playcentre grounds on Farmers Road	Thermo FH62 BAM (PM_{10})
Ngaruawahia	Ngaruawahia Bowling Club on Herschel Street	Thermo FH62 BAM (PM_{10})
Waihi	Grey Street, Waihi	Thermo Sequential Partisol 2025i (PM_{10})
Huntly	Ralph Rd, Frost Rd, Pukekapia Rd, i-Site Centre, SH1, Croft Tce, Huntly	Thermo FH62 BAM (PM_{10})

Table 2.2 Site-specific corrections applied to BAM and TEOM PM_{10} data.

Station	Correction factor
Tokoroa	Corrected $PM_{10} = 10^{(1.09945 \log BAM - 0.08595)}$
Taupō	Corrected $PM_{10} = 1.255BAM - 1.538$
Putaruru	Corrected $PM_{10} = 1.106BAM - 2.38$
Hamilton (Peachgrove Rd)	Corrected PM10 = 1.19975 x RawTEOM - 3.9182

2.2 BTEX monitoring

Motor vehicles are the main sources of the volatile organic compounds benzene, ethyl-benzene, toluene and xylenes (BTEX) in urban areas. BTEX pollutants are typically monitored using a passive sampling methodology where passive samplers containing activated carbon are attached to a power pole, in proximity to a busy street or intersection and are exposed for a certain period to the ambient air. The BTEX compounds are adsorbed to the carbon over this period and can then be analysed in a laboratory at the end of the exposure period.

Passive sampling for BTEX has been undertaken in Hamilton at eight sites over the period 2003 to 2020 using 3M Passive axial diffusion samplers. Two of the eight sites have been located on Peachgrove Road adjacent to Countdown supermarket and Hamilton Intermediate School. The other six sites have been located at the intersections of Bridge Street/ Grey Street, Claudelands Road/ Victoria Street, Tristram Street/ London Street, Greenwood Street/ Massey Road, Ohaupo Road/ Lorne Street and Wairere Road/ Clyde Street (refer to Figure 2.1).

Figure 2.1 Map of passive BTEX sites in Hamilton.

The method used is as described in Stevenson and Narsey (1999) with passive axial samplers being deployed for periods of three months. The BTEX compounds are extracted from the samplers using carbon disulphide and then analysed using Gas Chromatography Mass Spectrometry 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 BTEX monitoring in New Zealand and is significantly more cost effective than the radial passive sampler method recommended by the Ministry for the Environment's ambient air quality guidelines (MfE 2002).

Validation of this axial sampler method with the MfE recommended method was undertaken in 2010 by Waikato Regional Council. It was determined that the accuracy of the 3M passive axial samplers is likely to be sufficient for monitoring purposes provided the deployment duration is not excessive (Mathieson, 2010).

2.3 Nitrogen dioxide monitoring

Nitrogen dioxide (NO_2) is one of the air contaminants from motor vehicles and monitoring of NO_2 can provide an indication of the potential impact of this source. Monitoring of NO_2 in Hamilton, compliant with the requirements of the NESAQ, has been conducted by Waikato Regional Council over limited periods on Peachgrove Road, Te Rapa Road and Ohaupo Road. This monitoring has been undertaken using an Ecotech Serinus 40 NO_2/NO_x analyser which measures NO_2 continuously using gas phase chemiluminescence. The continuous analysers are operated in accordance with AS3580.5.1:2011 and are a reference method used to determine compliance with the NESAQ.

NO_2 was monitored using a continuous analyser in Hamilton at Waikato Regional Council's Peachgrove Road monitoring station from January 1998 to December 1999 and from May to August 2003. This was classified as a residential peak monitoring site in accordance with the Ministry for the Environment’s air quality monitoring site classifications.

Further NO_2 monitoring was undertaken in Hamilton at the corner of Wairere Drive and Te Rapa Road from 1 March 2011 to 29 February 2012. This intersection was selected on the basis of it having been identified as a busy traffic site.

More recent continuous NO_2 monitoring has been undertaken for short periods using a continuous analyser in Hamilton at the Ohaupo Road monitoring station close to the intersection with Lorne Street. This intersection was selected on the basis of it having been identified as a busy traffic site. Monitoring has occurred at this location over the following periods:

- 5 April 2013 to 3 October 2013
- 1 June 2014 to 9 September 2014
- 1 June 2020 to current

The NZ Transport Agency (NZTA) undertakes passive NO_2 monitoring in Hamilton, Te Awamutu, Taupō and Cambridge with contributory funding from Waikato Regional Council on an annual basis. This monitoring is carried out using NO_2 passive diffusion tubes containing triethanolamine (TEA) which react with NO_2 to form nitrite ions. Triplicate tubes are installed on street light poles adjacent to roadways and after one month exposure, taken to a laboratory where the NO_2 reactant is analysed spectrophotometrically according to the harmonised method AEA/ENV/R/2504 Issue 1a.

This method does not permit direct assessment of NO_2 concentrations against the NESAQ one-hour average standard as it only provides monthly averages. However, it does allow an indicative comparison with the 2005 World Health Organisation (WHO) annual exposure guideline of 40 $\mu g/m^3$ and the more recent 2021 WHO annual exposure guideline of 10 $\mu g/m^3$. The results are therefore useful as a screening method rather than a regulatory method, for which continuous monitors are used.[1]

NO_2 is monitored using passive samplers by NZTA at eight busy traffic sites and one background residential site in Hamilton and at one busy traffic site each in Cambridge, Te Awamutu and Taupō. The locations of monitoring sites are provided in Table 2.3 and Figures 2.2 to 2.3.

Table 2.3 Site locations for passive NO_2 monitoring.

Airshed	Location	Monitoring period
Hamilton	Cambridge Rd/Morrinsville Rd	2007 to current
Hamilton	Bridge St/Cobham Dr	2010 to current
Hamilton	Brooklyn Rd/Peachgrove Rd	2010 to current
Hamilton	Victoria St/Ulster St	2010 to current
Hamilton	Greenwood St/Killarney Rd	2010 to current
Hamilton	Lorne St/Ohaupo Rd	2007 to current
Hamilton	Avalon Dr/Grandview Rd	2007 to current
Hamilton	Seamer Place	2011 to current
Hamilton	Te Rapa Rd/Ann Michele St	2010 to current
Cambridge	Victoria St/Queen St	2007 to current
Te Awamutu	Ohaupo Rd/Albert Drive	2010 to current
Taupo	Tongariro St/Norman Smith St	2007 to current

[1] Ambient air quality (nitrogen dioxide) monitoring network report 2007 – 2009, NZTA

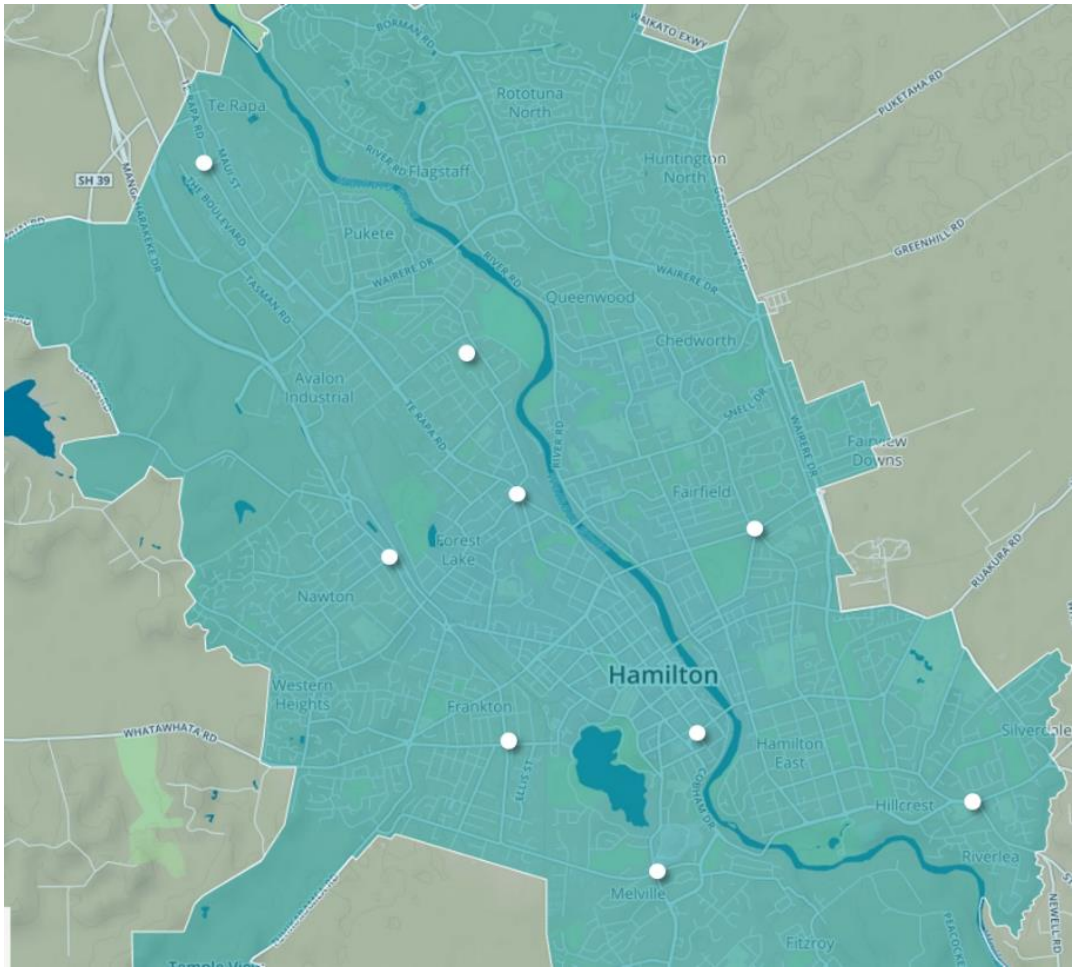


Figure 2.2 Map of passive NO_2 monitoring sites in Hamilton.

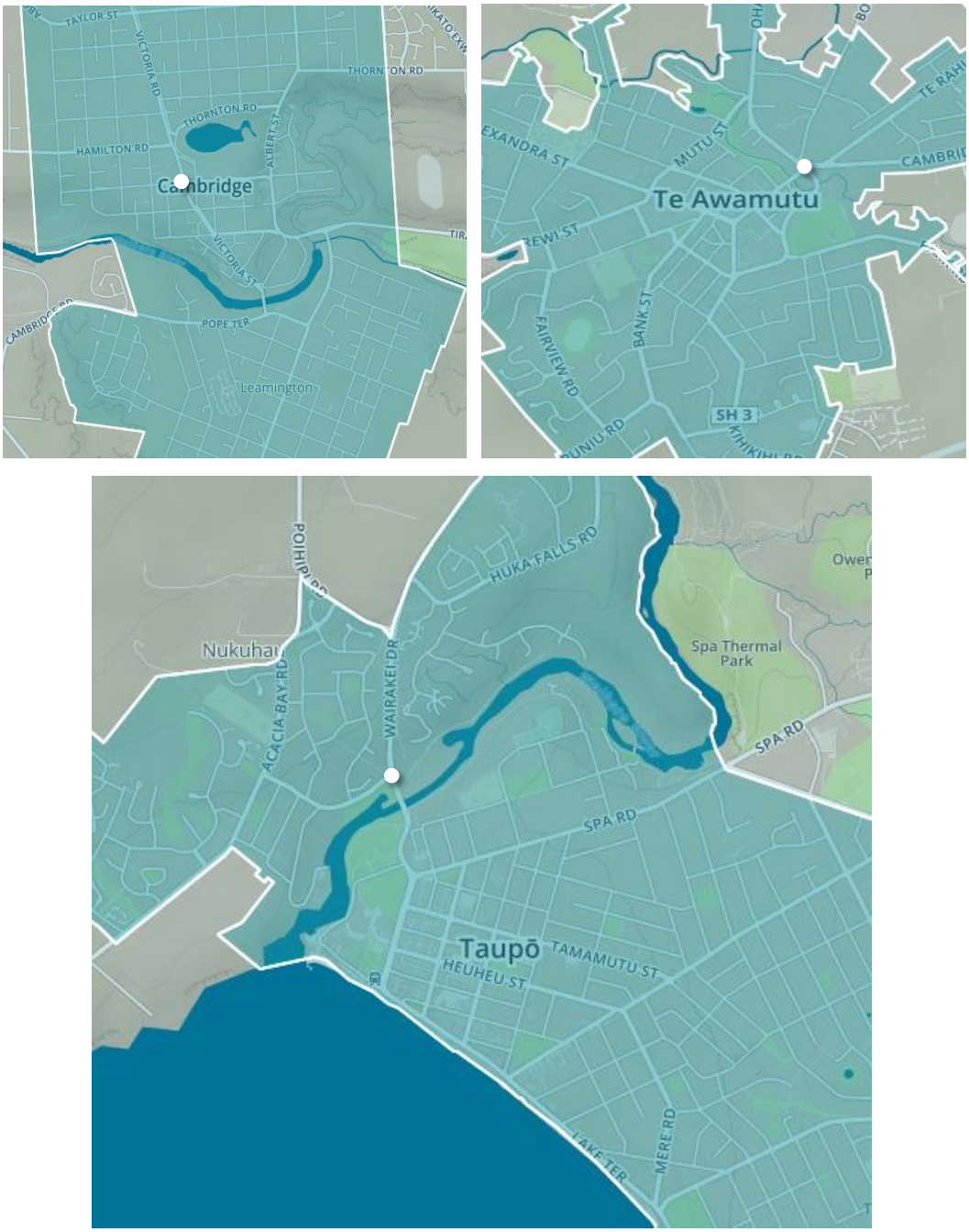


Figure 2.3: Map of passive NO_2 monitoring sites in Cambridge. Te Awamutu and Taupo.

2.4 Meteorological monitoring

Meteorological data, including ambient air temperature, wind speed and wind direction have been collected at Hamilton (Claudelands and Peachgrove Road), Tokoroa, Taupō, Matamata and Te Kuiti monitoring stations. Relative humidity data was also collected at Hamilton (Claudelands) and Taupo. All meteorological data is collected at a height of six metres above ground level except for Tokoroa where meteorological data is collected from the top of an existing water reservoir tower at a height of 10 metres. Details of the meteorological instrumentation used is provided in Table 2.4.

The meteorological data is recorded and logged by iQuest iRIS 320 dataloggers and telemetered hourly to Waikato Regional Council and stored in the hydrotel database. Subsequent data processing and archiving is undertaken in the WISKI (by Kisters) database.

Table 2.4 Meteorological monitoring instrument details.

Airshed	Windspeed	Wind direction	Air temperature	Relative humidity	Height above ground level (m)
Tokoroa	Vector A101M	Vector W200P	PT100	–	10
Taupō	Young Ultrasonic 85000	Young Ultrasonic 85000	Vaisala HMP45A	Vaisala HMP45A	6
Te Kuiti	Young Ultrasonic 81000	Young Ultrasonic 81000	Young Ultrasonic 81000	–	6
Hamilton	Young Ultrasonic 85000	Young Ultrasonic 85000	Vaisala HMP60	Vaisala HMP60	6
Matamata	Vaisla WMT52	Vaisla WMT52	Vaisla WMT52	Vaisla WMT52	6

2.5 Trend analysis

Analysis of trends in PM_{10} concentrations requires an assessment of the variability from year to year occurring because of the impact of meteorological conditions. For example, higher PM_{10} concentrations and more exceedances might be expected if a winter has a greater number of days when the wind speed is low and there is vertical stability in the lower atmosphere. Over the short term this inter-annual variability will mask any genuine underlying trend toward better or worse air quality. A reasonably long monitoring record is therefore needed to confirm or exclude the possibility of any underlying trend.

The method used for trend analysis in this report is consistent with the method used by Statistics NZ and MfE for Air Quality Domain and synthesis reporting. The method utilises the Theil-Sen function in the OpenAir R-Statistics package which is based on the Seasonal Mann-Kendall test for monotonic trends. It detects underlying trends in variable environmental time-series data sets and may suggest presence of an underlying trend which is not evident from visual inspection of the air quality record or summary statistics. This method generates probability (p) values from an analysis of monthly averages that are used to assess the likelihood that the apparent relationship is real or a result of chance. The conventional threshold for deciding whether a relationship is likely to be genuine is at a probability value of $p = 0.05$ or lower, which corresponds to a 95% confidence level and greater.

At least six years of data is required with an optimal requirement of the most recent 10-year period to be used where available. The Theil-Sen function with the deseason option is used.

3 Results

3.1 PM_{10} and $PM_{2.5}$ monitoring in Hamilton

The annual average PM_{10} concentrations for the Claudelands, Ohaupo Rd and Peachgrove Rd stations are provided in Figure 3.1 with comparison against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3.

PM_{10} concentrations in the Hamilton airshed have always met the 2005 WHO annual average guideline. However, PM_{10} concentrations in 2004 and 2006, as measured at the now decommissioned Peachgrove Rd station, would have exceeded the more recently introduced 2021 WHO guideline. The annual averages in 2019 for both the Ohaupo Rd and Claudelands stations were also close to exceeding the 2021 WHO annual guideline. A potential cause of this elevated annual average for 2019 was the elevated PM_{10} concentrations measured over the November to December period associated with the Australian bushfires. However, it is also acknowledged that while annual average PM_{10} concentrations at Claudelands increased in 2019 (and also in 2020), this increase has coincided with the replacement of the FH62 BAM monitor in May 2019 with the newer optical based Teledyne T640x monitor which has been observed to record higher PM_{10} concentrations.

A summary of the maximum and second highest 24-hour average PM_{10} concentrations and number of exceedances per year of the 24-hour average ambient PM_{10} standard of 50 µg/m^3 as measured at the Claudelands, Ohaupo Rd and Peachgrove Rd stations is provided in Figure 3.2.

Exceedances of the PM_{10} standard were recorded at the Peachgrove Rd station in 2001, 2003, 2004, 2006, 2009, 2011 and 2013. One of the exceedances in 2009 of 101 µg/m^3 was identified as being caused by a dust storm event in Australia. The eight exceedances in 2013 were identified as arising from dust emissions associated with significant upgrading of the Peachgrove Road, Te Aroha Street and Ruakura Road intersection at the time. The eight exceedances were exempted as exceptional circumstances under regulation 16A of the NESAQ. All other exceedances identified over the monitoring period are considered to be associated with normal airshed emission sources with domestic home heating identified as the main contributor. Also of note are the maximum PM_{10} concentrations of 49 and 45 µg/m^3 measured at both the Claudelands and Ohaupo Rd stations respectively in December 2019 which were identified as being linked to the Australian bushfires.

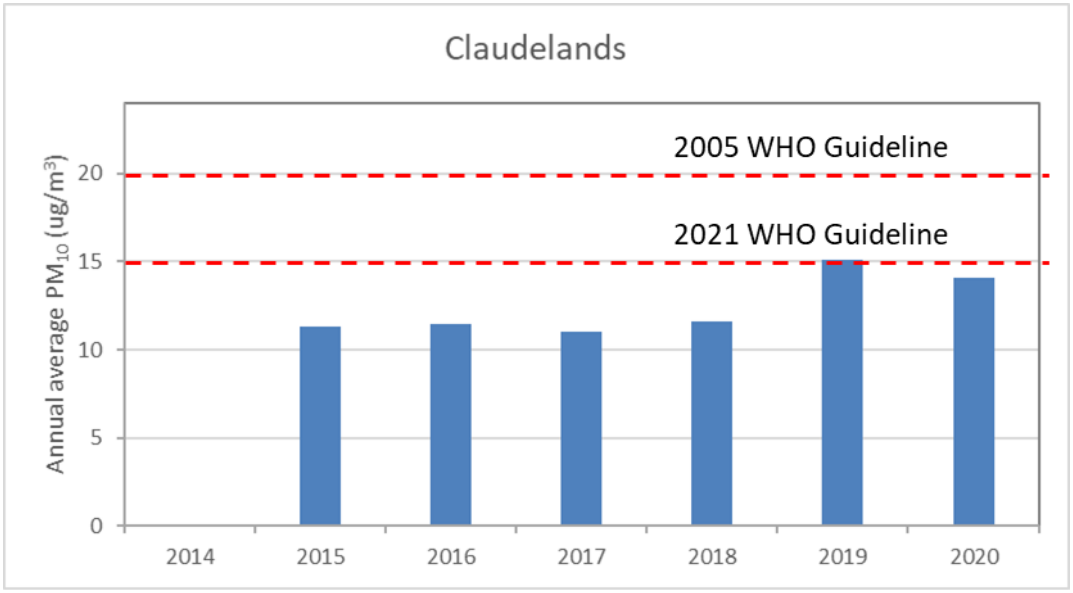
Figure 3.3 shows the year-to-year variability in 24-hour average PM_{10} concentrations relative to MfE air quality indicator categories for the Claudelands, Ohaupo Rd and Peachgrove Rd stations. The proportion of 24-hour average PM_{10} concentrations falling within the good air quality category (less than 33% of the guideline) for 2019 at Claudelands and Ohaupo Rd decreased to 66 and 73% respectively from a previous average of about 80% which is likely associated to an extent with the Australian bushfires. However, it is clear that the return to increased data falling within the good category in 2020 at the Ohaupo Rd site is not observed to the same extent at the Claudelands station which is also likely to be associated with the change in monitoring instrument at that station.

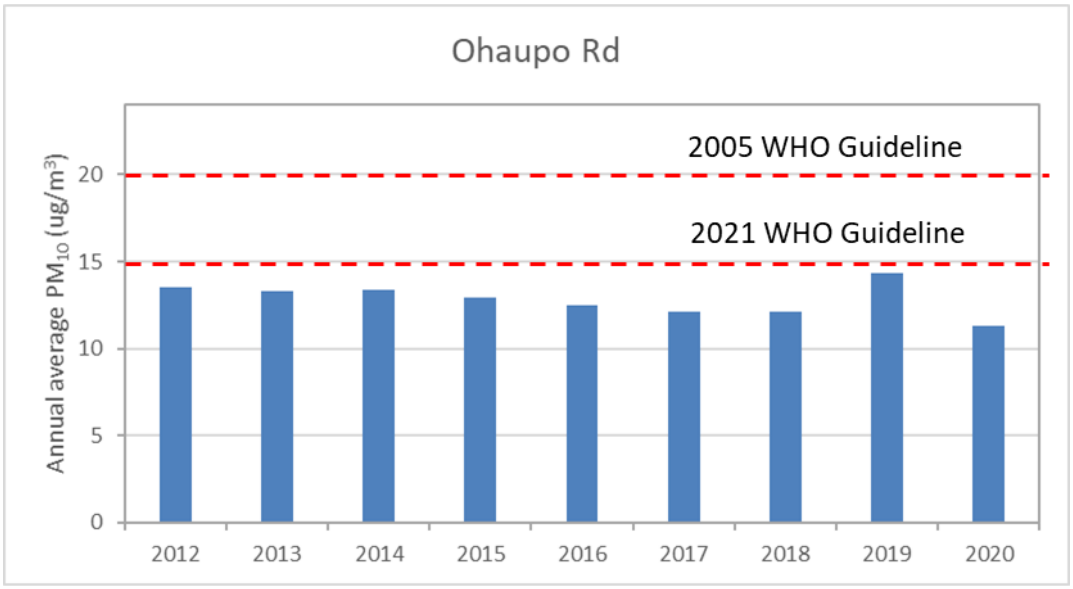
Permanent monitoring of $PM_{2.5}$ in Hamilton only began in 2019 at the Claudelands station. Comparison of annual $PM_{2.5}$ averages for the years 2019 and 2020 against the 2005 WHO annual average guideline of 10 µg/m^3 and the recently introduced 2021 WHO annual average guideline of 5 µg/m^3 indicates that the 2005 WHO guideline was complied with but not the 2021 WHO guideline for both of those years (refer to Table 3.1).

The number of days when the 2005 WHO 24-hour $PM_{2.5}$ guideline of 25 µg/m^3 was exceeded and the 2021 WHO 24-hour $PM_{2.5}$ guideline of 15 µg/m^3 was exceeded in 2019 and 2020 is provided in Table 3.1.

Table 3.1 Summary of $PM_{2.5}$ monitoring data in Hamilton (Claudelands).

	Annual average (ug/m^3)	Max 24-hr average (ug/m^3)	Exceedances WHO 24-hr average	
			2005 guideline	2021 guideline
2019	8.1	41	2	13
2020	6.9	30	1	21





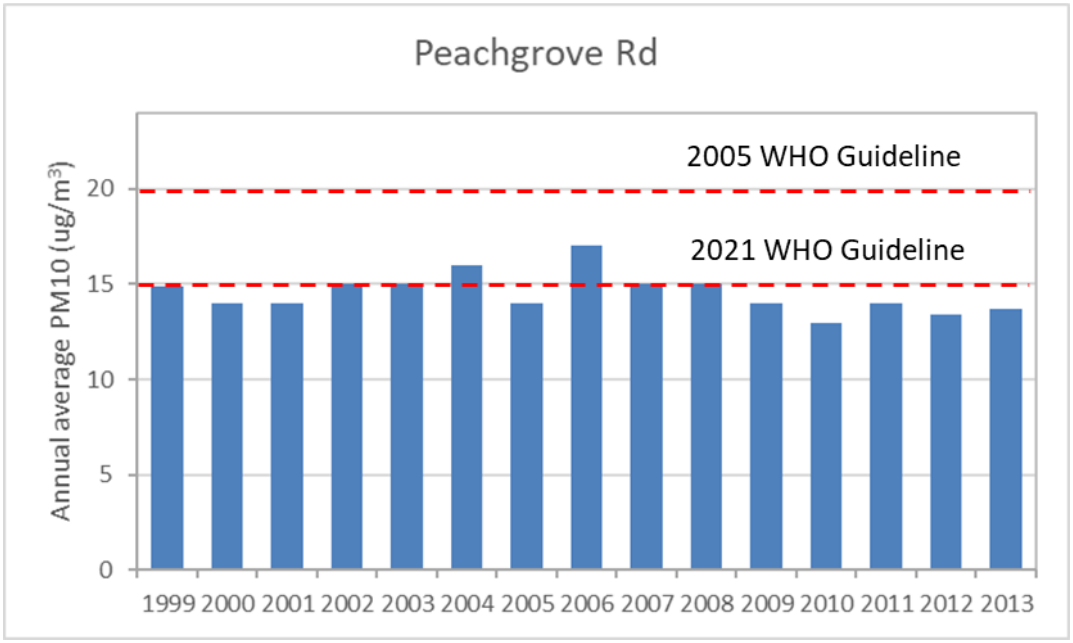
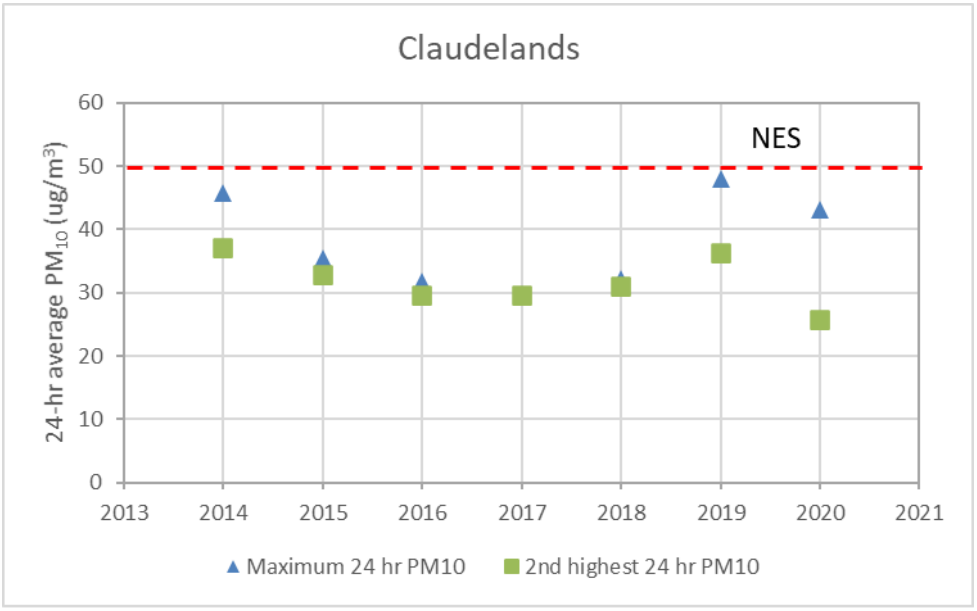
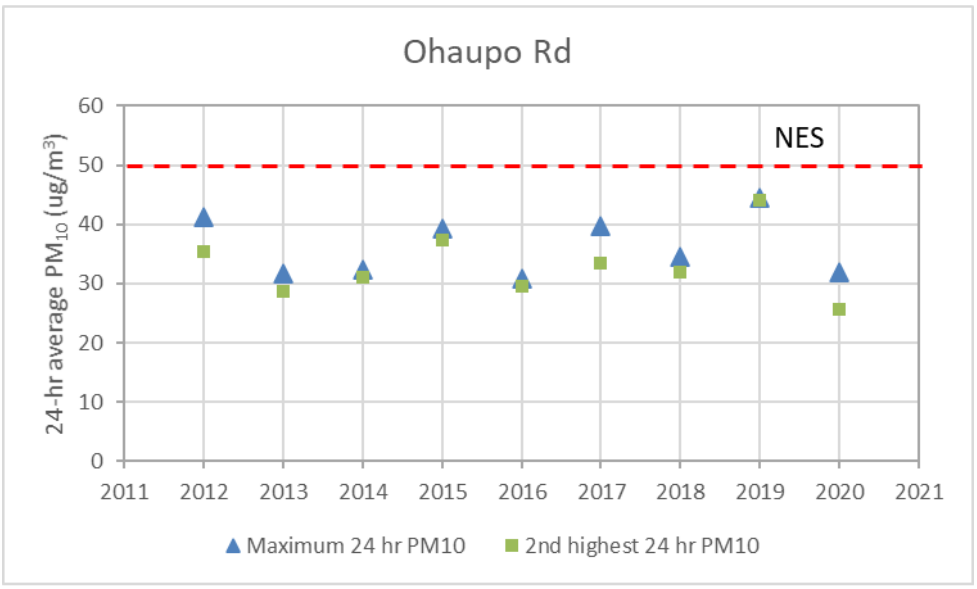


Figure 3.1 **Annual average PM_{10} concentrations measured at Claudelands, Ohaupo Rd and Peachgrove Rd stations.**





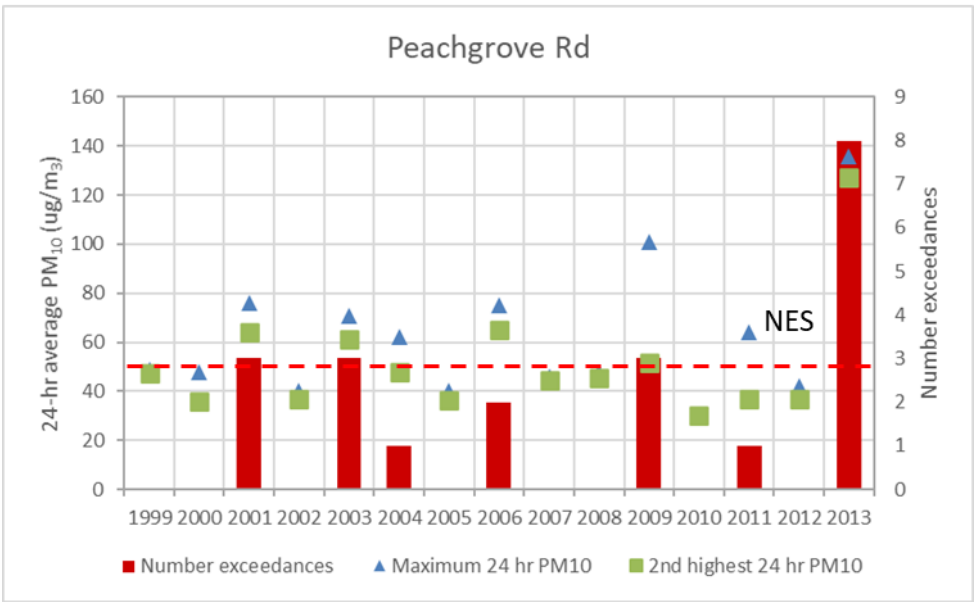


Figure 3.2 **Number of days (right axis) when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded compared with the maximum 24-hour average concentration and the 2nd highest 24-hour average concentration (left axis) measured at Claudelands, Ohaupo Rd and Peachgrove Rd stations.**

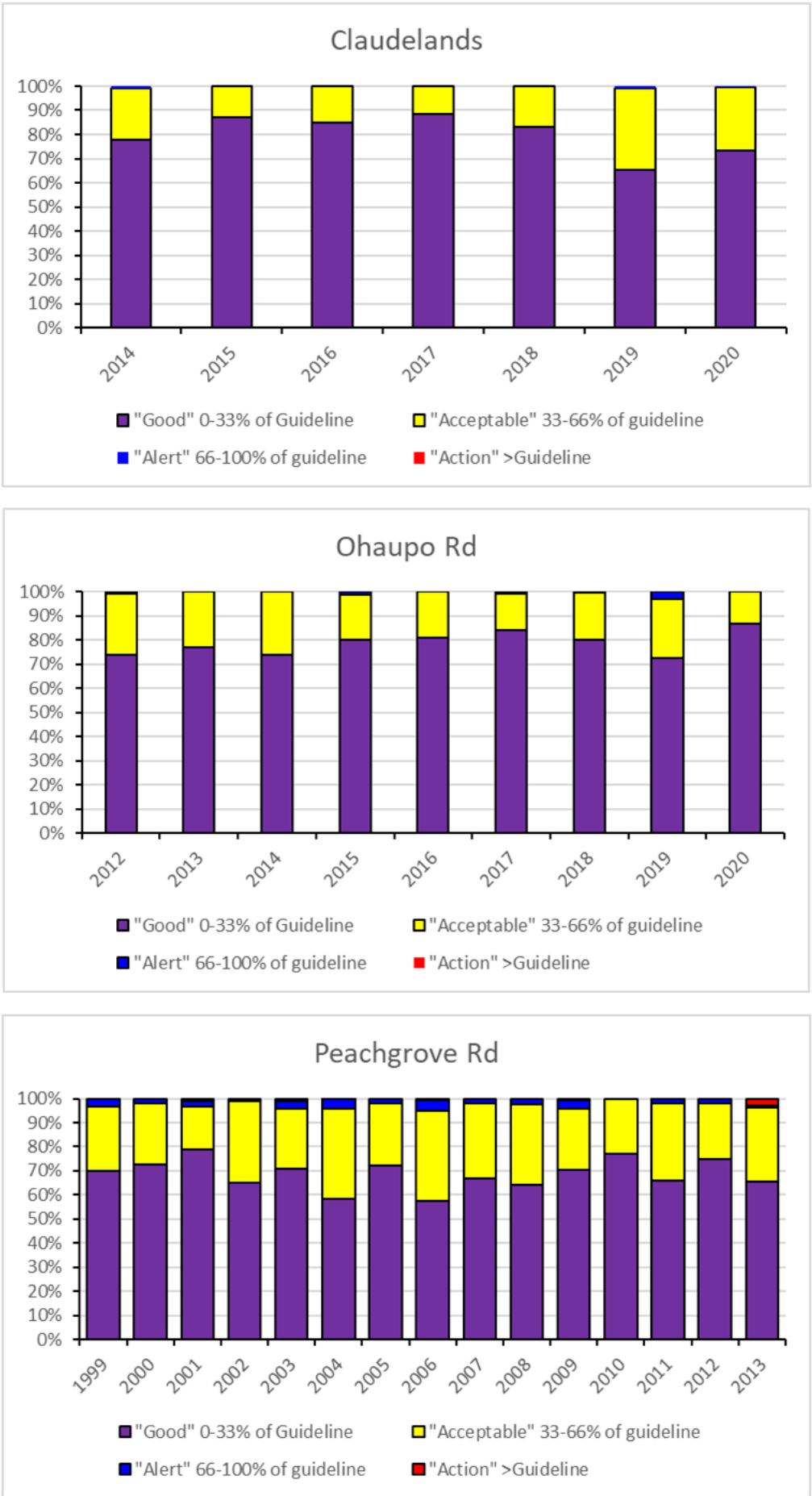


Figure 3.3 Comparison of 24-hour average PM_{10} concentrations measured at Claudelands, Ohaupo Rd and Peachgrove Rd stations relative to MfE air quality indicator categories.

A comparison of hourly, daily, weekly, and monthly average PM_{10} concentrations at Ohaupo Road and Claudelands over the period 2014 to 2020 is presented in Figure 3.4.

While the monthly averages and seasonal patterns throughout the year are very similar, there are some differences in the daily and weekly patterns with the Claudelands pattern indicating higher night-time concentrations and lower daytime concentrations compared to the Ohaupo Road site which has higher daytime concentrations but with concentrations falling off more in the weekend.

These differences are indicative of the higher home heating contribution to the PM_{10} concentrations at Claudelands compared to the higher traffic contributions at the Ohaupo Road site. This is supported by the typical daily concentration pattern of higher concentrations in the evening and a smaller peak in the morning due to solid fuel burning for domestic heating which has previously been identified in NZ urban areas (Trompetter *et al.*, 2010) although acknowledging that traffic emissions can also contribute to the morning peak.

Interestingly, the seasonal distribution pattern for both sites indicates an elevated peak of about 13 ug/m^3 over the months of November through to January compared with a peak of about 16 to 14 ug/m^3 in the May to July period which suggests a summertime/ non-home heating impact on PM_{10} concentrations that is not fully explained by the contribution from traffic emissions which needs further investigation. Possibly it relates to industry sources which will be more dominant in the summertime due to the absence of woodburners. This summer and winter seasonal pattern is also inconsistent with the more pronounced difference between wintertime and summertime observed for most of the other airsheds in the Waikato region. A separation of this seasonal pattern by year as presented in Figure 3.4(b) indicates that this seasonal pattern is consistently occurring although with some variation in magnitude. A larger separation in the pattern between the two sites becomes more evident from mid-2019 onwards after the Claudelands FH62 BAM was replaced with a Teledyne T640x.

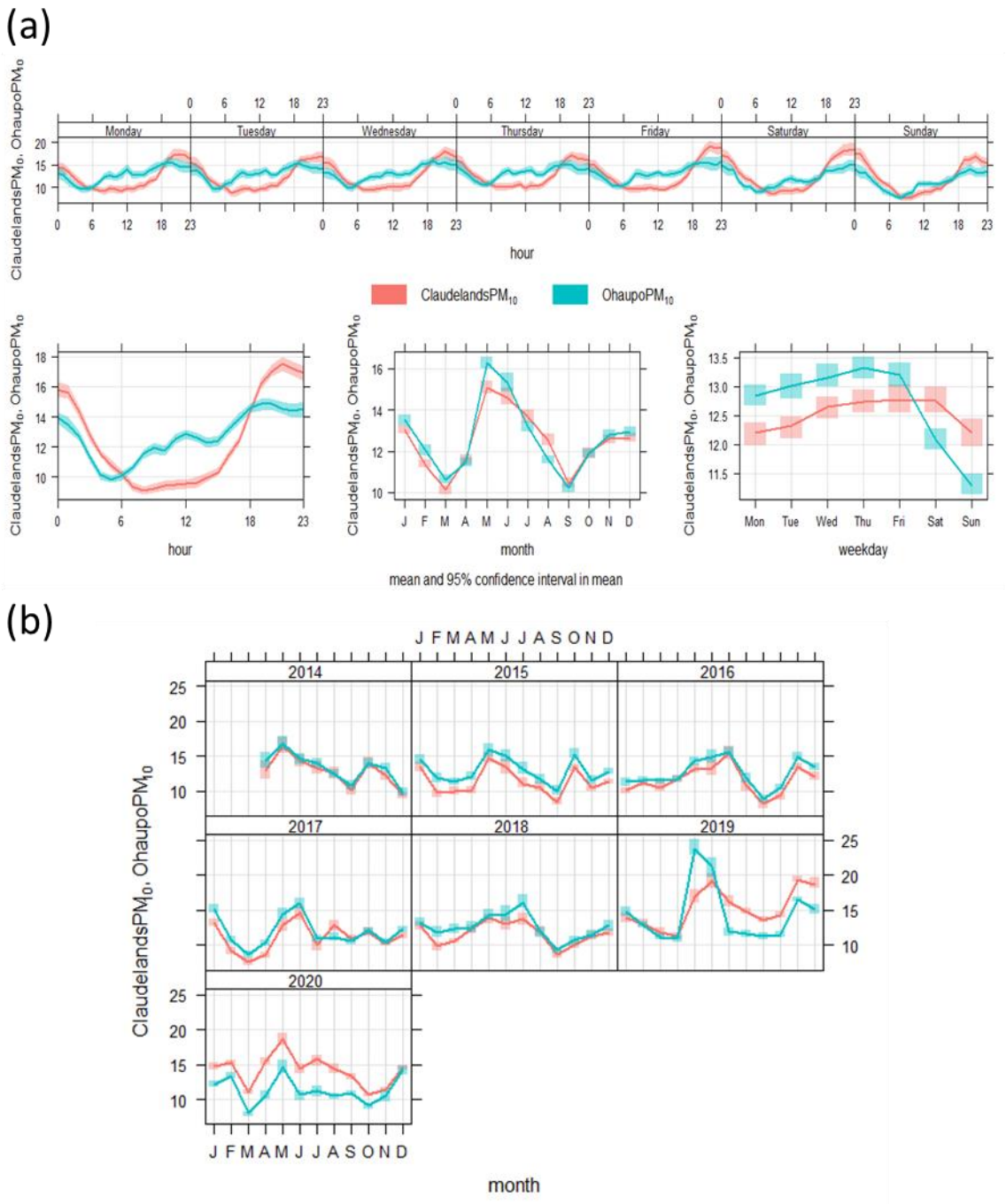


Figure 3.4 Comparison of hourly, daily, weekly and monthly average PM_{10} concentrations measured at Claudelands and Ohaupo Rd sites in Hamilton for the period 2014 to 2020.

A comparison of hourly, daily, weekly, and monthly average PM_{10} concentrations at Peachgrove Road station over the period 1998 to 2013 is presented in Figure 3.5.

There is a strong daily diurnal pattern with a strong daytime peak centred around 9 am likely reflective of traffic emission contributions to PM_{10} concentrations at that location. The seasonal distribution pattern with elevated wintertime concentrations compared to summertime concentrations is more consistent with a strong home heating contribution.

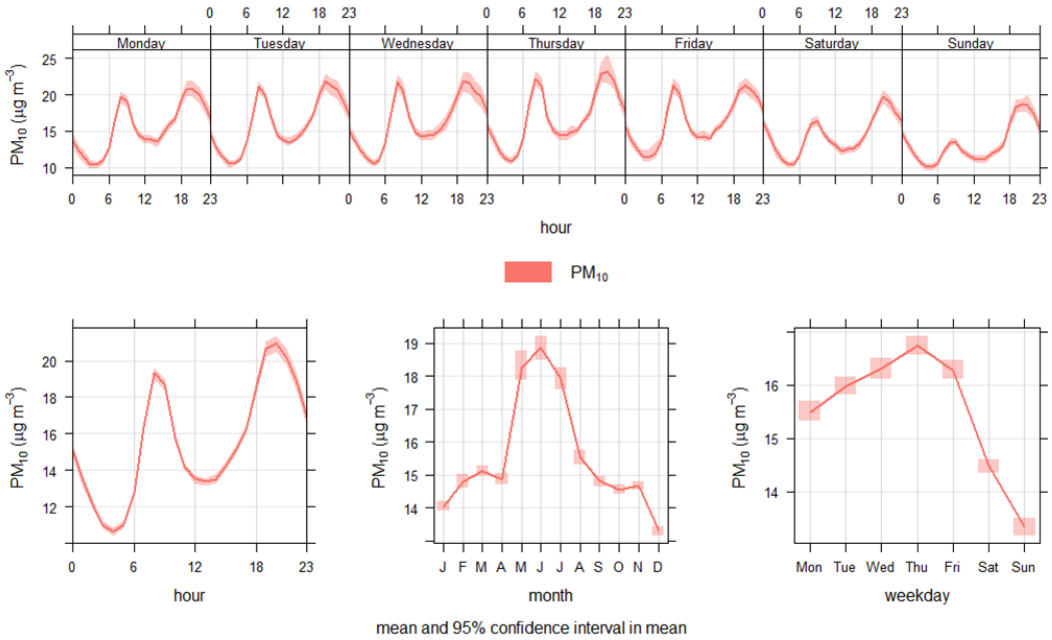


Figure 3.5 Comparison of hourly, daily, weekly and monthly average PM_{10} concentrations measured at Peachgrove Rd for the period 1998 to 2013.

A windrose showing the relative frequency and speed of winds from different directions for the period 2015 to 2020, as measured at the Claudelands station, is presented in Figure 3.6. The wind rose indicates a prevailing wind direction from the west-southwest and west with a high frequency of low to moderate windspeeds.

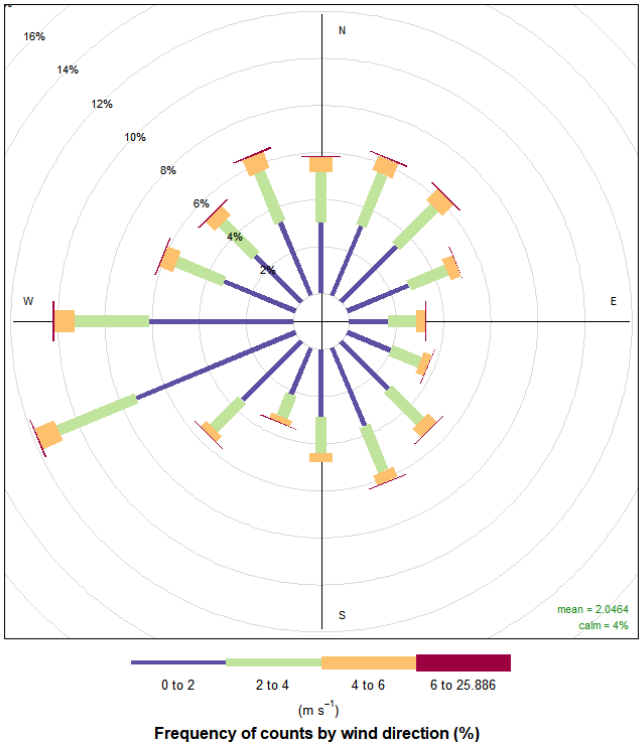


Figure 3.6 Windrose of wind direction and windspeed data as measured at Claudelands station over the period 2015 to 2020.

A trend analysis of PM_{10} data from the Claudelands site, using the Theil-Sen method in OpenAir (with deseason function) indicates no statistically significant trend over the period May 2014 to April 2019 (refer to Figure 3.7). Note that this period selected for the trend analysis excludes the data from late May 2019 onwards when a T640x was used for monitoring of PM_{10} and is arguably too short a period for identifying reliable trends over.

A trend analysis of PM_{10} data from the Ohaupo Road site, using the Theil-Sen method in OpenAir (with deseason function) indicates a statistically significant improving trend ($p< 0.001$) over the period 2012 to 2020 (refer to Figure 3.7).

Improvements in air quality at the Ohaupo Road site identified by this trend analysis may be a reflection of improving vehicle engine technology resulting in lower emissions.

Air emission inventories have been carried out for Hamilton in 1997, 2001, 2005 and 2012 and 2018 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. Domestic heating was the main source of winter PM_{10} emissions in Hamilton in 2018 accounting for 77% of the daily winter PM_{10}. This is lower than for the 2012 estimate (88%) because of the additional industrial sources which were outside of the 2012 inventory area. Industrial sources contributed 15% of the daily winter PM_{10} with other sources including transport (5%), and outdoor burning (3%). On an average winter's day, around 1154 kilograms of PM_{10} are discharged in Hamilton. Direct comparison of 2018 estimated total winter PM_{10} emissions to those for 2012 are inappropriate because of the larger study area for 2018 which includes significant additional industrial emissions. If the additional sources associated with the larger study area are excluded results would suggest a 20% reduction in PM_{10} emissions from 2012 to 2018 for Hamilton (Wilton, 2018).

While the 2018 air emission inventory for Hamilton estimates industry to be the next main PM_{10} source of PM_{10} emissions after domestic heating, a 2020 airshed modelling assessment (which combines the emission assessment with source dispersion characteristics and meteorological conditions) predicts that domestic home heating is the dominant source of ambient PM_{10} concentrations in Hamilton City followed by transport (Golder Associates, 2020).

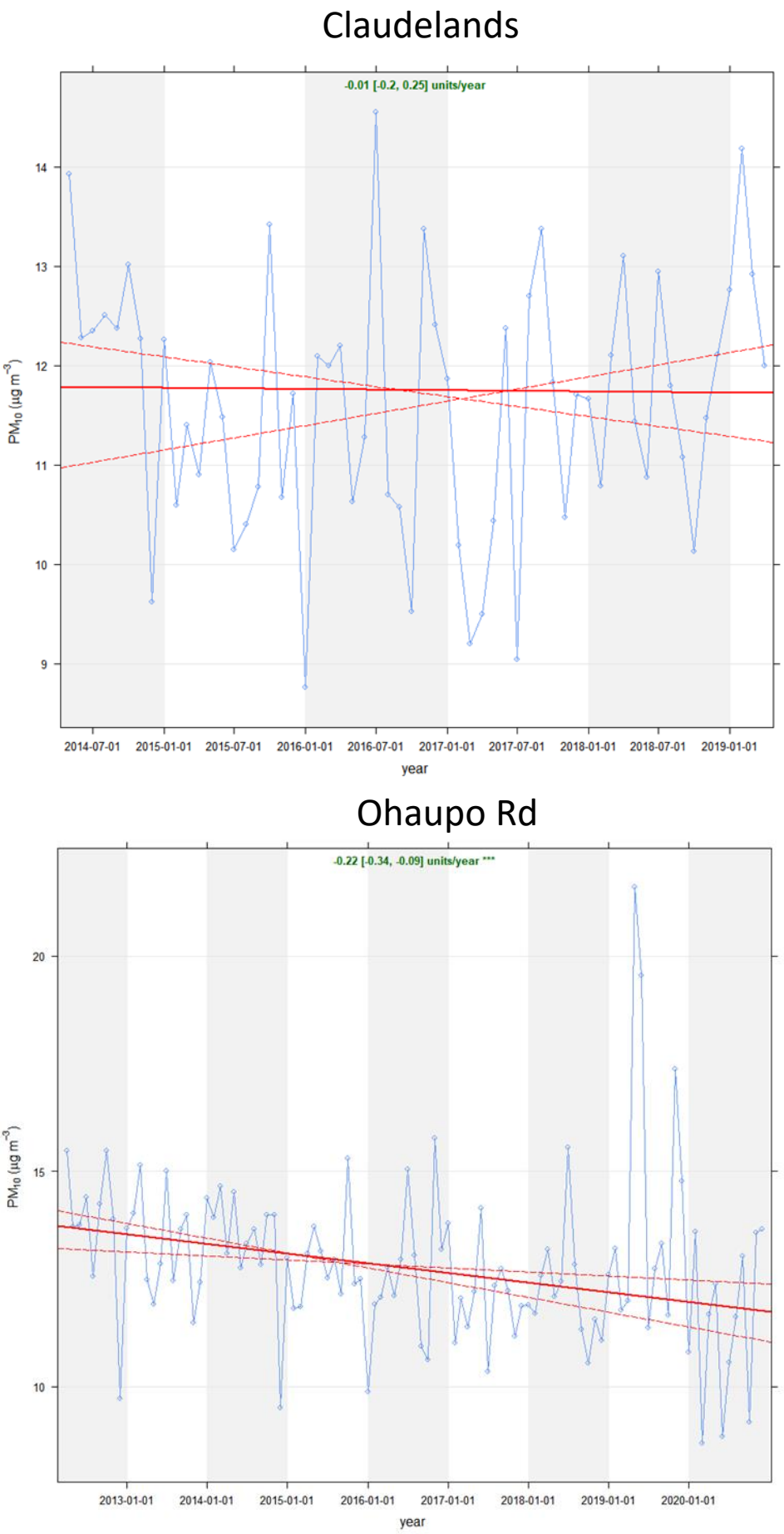


Figure 3.7 Claudelands and Ohaupo Road PM_{10} trend analysis.

3.2 BTEX monitoring in Hamilton

Benzene concentrations measured at all locations in Hamilton are all well below the Ministry for the Environment's annual average guideline of 3.6 µg/m^3 (refer to Figure 3.8). The annual average guideline prior to 2010 was 10 µg/m^3. An improving trend or "levelling-out" of concentrations is evident for annual average concentrations of benzene at all sites over the monitoring period 2003 to 2020. Large decreases in benzene concentrations were observed over the period 2003 to 2007. These earlier decreases were attributed to changes in fuel specifications and improved vehicle technology (Smith, 2007).

Concentrations of toluene, total xylenes and ethylbenzene measured in Hamilton at all sites over the monitoring period 2003 to 2020 have also been well below the relevant MfE thresholds and USEPA Reference Concentration values.

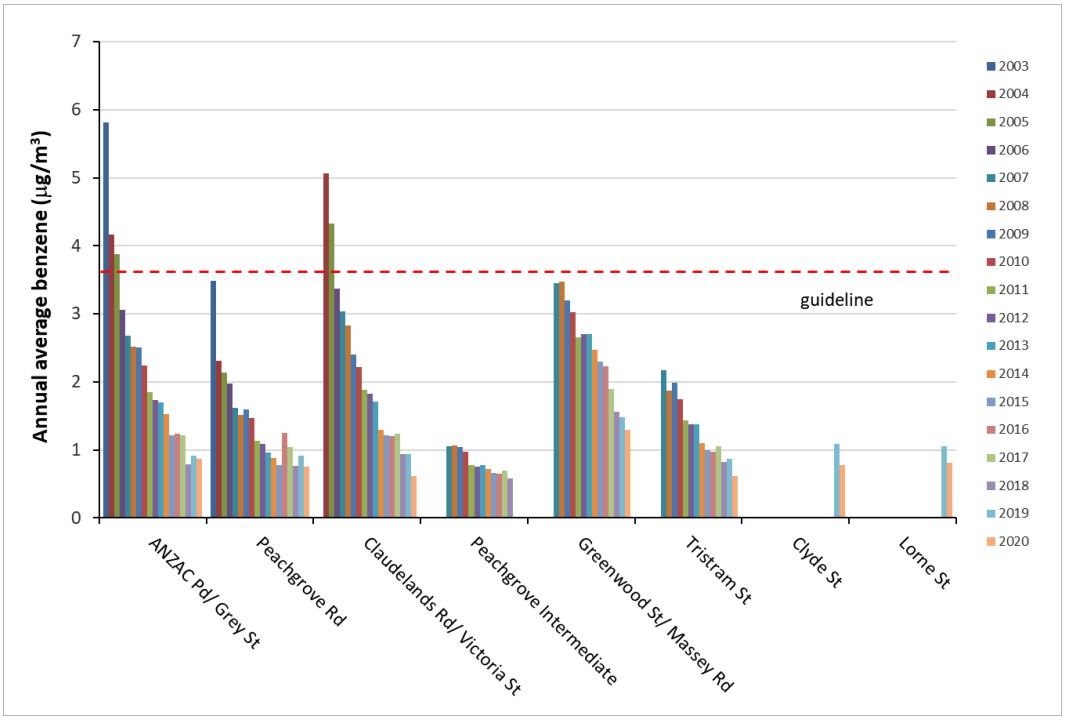


Figure 3.8 Annual average benzene measured at Hamilton sites (2003 to 2020).

3.3 NO_2 monitoring in Hamilton

No exceedances of the NES one-hour average standard for NO_2 of 200 ug/m^3 have been identified at the Peachgrove Road or Ohaupo Road stations using a continuous analyser. However, 52 exceedances of this standard were identified in 2011 at a short-term station (carvaran) set up at the intersection of Te Rapa Road and Wairere Drive using a continuous analyser. These exceedances were identified as being caused by a large number of truck movements through the intersection over a two-month period during the construction of the Te Rapa Bypass. Subsequent monitoring for a year after this did not identify further breaches. Figure 3.9 shows the variability in 24-hour average PM_{10} concentrations relative to MfE air quality indicator categories for the Ohaupo Rd, Peachgrove Rd and Te Rapa stations. The Ohaupo Rd station results for 2020 indicate that there is a larger proportion of data falling within the "Excellent" (<10% of the 1-hour average NO_2 standard) category compared to 2013 and 2014.

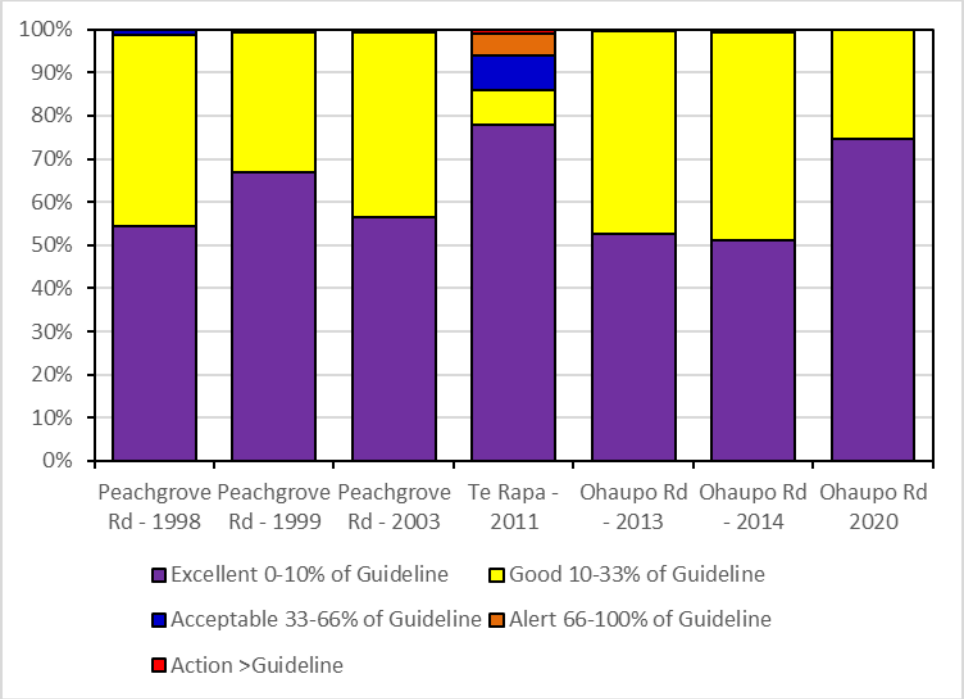


Figure 3.9 Percentage of hourly average nitrogen dioxide concentrations in the excellent, good, acceptable, alert or action categories (1998 to 2020).

The annual average NO_2 concentration for 2011 at Te Rapa was 11.4 ug/m^3 which exceeds the 2021 WHO guideline. All other NO_2 monitoring periods using a continuous analyser where shorter than 12 months (typically 3 to 6 months) and therefore annual averages cannot be calculated. However, the indication from averaging NO_2 over those shorter periods is that the annual averages would likely be well in excess of the 2021 WHO guideline of 10 ug/m^3 at the Peachgrove Rd and Ohaupo Rd sites.

The results from NZTA's passive NO_2 monitoring programme from 2007 to 2020 (Figure 3.10) show that the Lorne Street/Ohaupo Road site and Greenwood Road/Killarney Road site in Hamilton have frequently exceeded the 2005 WHO annual average NO_2 guideline of 40 μg/m^3. If a comparison is made with the recently introduced 2021 WHO annual guideline of 10 μg/m^3 it is evident that all of the sites would be in exceedance.

It is important to note that the passive analyser monitoring method used should be considered a 'screening' method which is not necessarily suitable for direct comparison with WHO's annual average guideline. However, the extent of those exceedances when compared with the 2021 WHO guideline is sufficient to indicate that this updated WHO guideline will be exceeded at most of these sites.

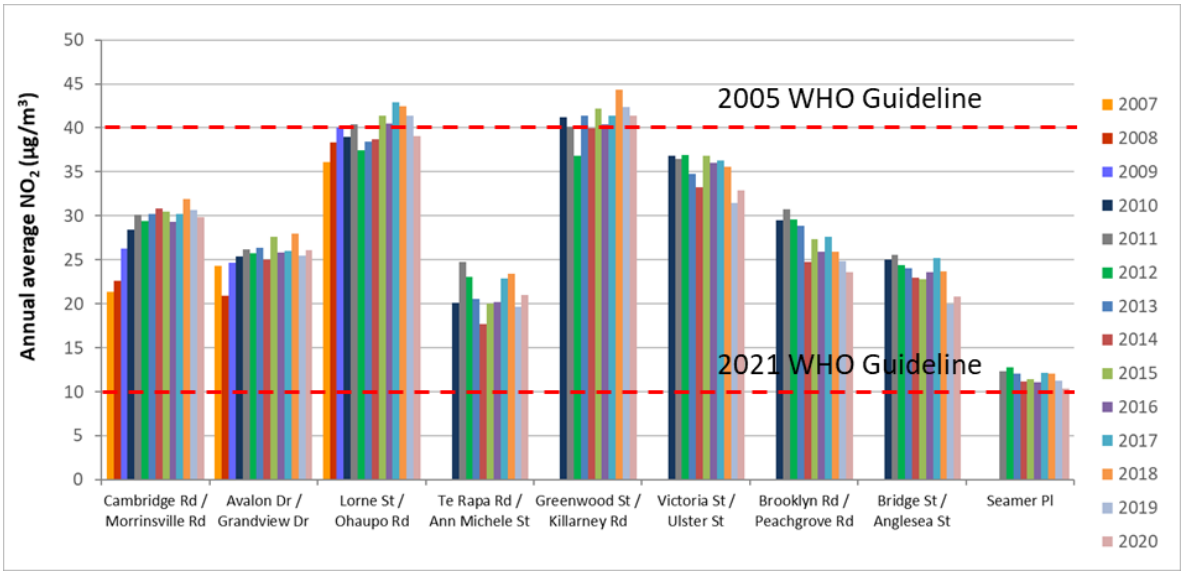


Figure 3.10 Annual average NO_2 measured at Hamilton sites (2007 to 2020).

A trend analysis of NO_2 data from the nine Hamilton passive NO_2 sites for the ten-year period 2011 to 2020 (refer to Figure 3.11), using the Theil-Sen method in OpenAir (with deseason function) identified four sites with statistically significant improving trends ($p< 0.001$, $p< 0.01$ & $p<0.05$) and one site with a statistically significant worsening trend ($p< 0.001$) which could be as a result of increasing vehicle counts (vehicle kilometres travelled) outweighing the engine technology improvements. The other four sites have indeterminant trends.

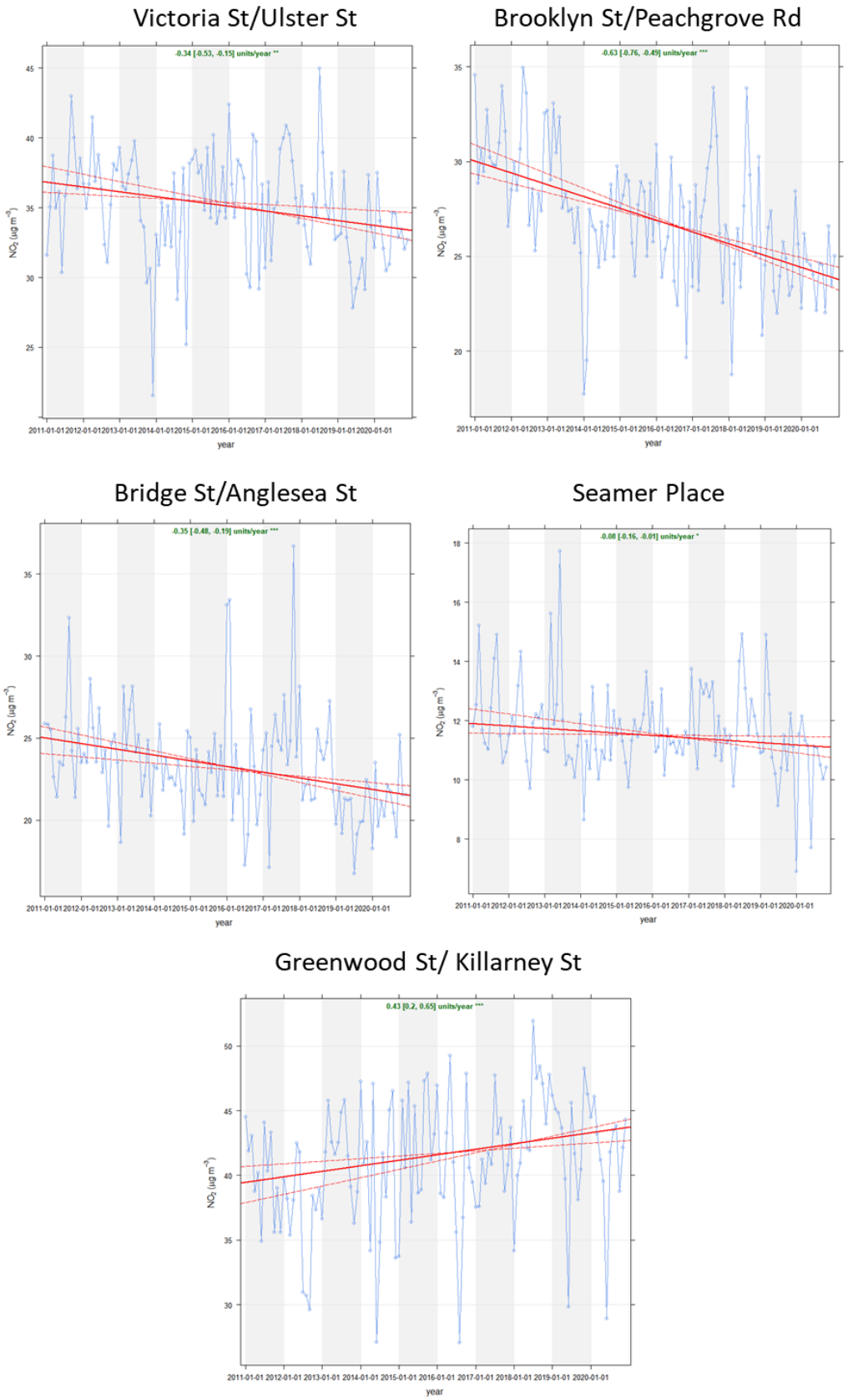


Figure 3.11 NO_2 trend analysis for 2011 to 2020 for Hamilton sites displaying a statistically significant change.

An intensive passive NO_2 monitoring campaign was undertaken in Hamilton for WRC by NIWA in 2017 (Longley & Somervell, 2020). The monitoring involved the exposure of Palmes Tubes (one-month exposure period) at 36 locations across the city for a 12-month period. Locations were selected to cover rural background, urban background, inner urban background and urban peak sites (i.e. CBD street canyons and intersections).

The highest concentrations were found in the urban peak (city centre) areas with annual averages up to 30 ug/m^3 and a mean annual average of just over 20 ug/m^3 which is approximately double the mean annual average determined for urban (residential) background sites of 10 ug/m^3 (refer to Figure 3.12). The results also suggest that concentrations in the central business district (CBD) are very likely to be lower than at intersection sites on NZTA's State Highway network.

In conclusion, this work indicates that annual average concentrations of NO_2 may be just meeting or slightly exceeding the 2021 WHO annual average guideline in urban (residential) background areas, although noting that as the method used is a screening method, there is likely to be some uncertainty around results close to the guideline. Nevertheless, elevated concentrations that are likely to be exceeding the 2021 WHO guidelines may be occurring at CBD locations, especially if emissions were to increase (due to increased heavy-duty diesel traffic for instance), or there is reduced dispersion of existing emissions (due to an increase in building density) in the future. The 2018 air emission inventory for Hamilton (Wilton, 2018) identified that transport was estimated to have contributed to only 5% of PM_{10} & $PM_{2.5}$ emissions but 85% of NO_x emissions (NO + NO_2). An increase in use of electric vehicles within the CBD could therefore help mitigate this potential.

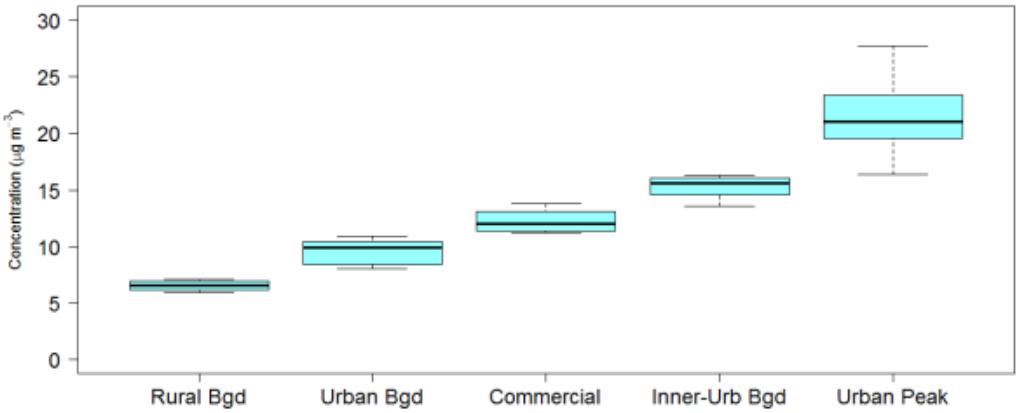


Figure 3.12 Box and whisker plot of annual mean NO_2 concentrations by site class for NIWA's 2017 passive NO_2 monitoring investigation in Hamilton.

3.4 PM_{10} and $PM_{2.5}$ monitoring in Tokoroa

The annual average PM_{10} and $PM_{2.5}$ concentrations for the Tokoroa station are provided in Figure 3.13 and 3.14 respectively. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3. $PM_{2.5}$ concentrations are compared against the 2005 WHO annual average guideline of 10 µg/m^3 and the recently introduced 2021 WHO annual average guideline of 5 µg/m^3.

Prior to 2006, PM_{10} concentrations in the Tokoroa airshed exceeded the 2005 WHO annual average guideline but have complied with the guideline since 2006. However, PM_{10} concentrations in Tokoroa have only complied with the 2021 WHO guideline in 2016 and 2018. It is also important to note that while annual average PM_{10} concentrations in Tokoroa increased in 2019 and 2020 compared to a steady decrease in annual averages prior to that, this increase has coincided with the replacement of the FH62 BAM monitor in August 2019 with the newer optical based Teledyne T640x monitor which has been observed to record higher PM_{10} concentrations. Future trend analysis for data post 2019 will require a collocation investigation to be undertaken to assist with establishing the relationship between the two monitoring methods.

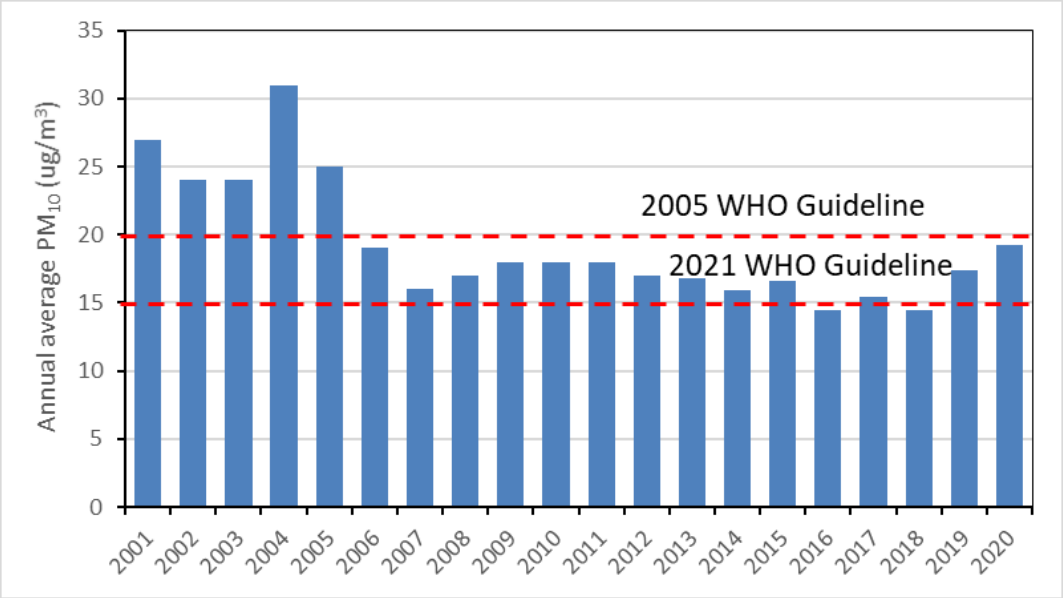


Figure 3.13 Annual average PM_{10} concentrations measured in Tokoroa from 2001 to 2020.

$PM_{2.5}$ concentrations in Tokoroa have exceeded both the 2005 and 2021 WHO annual average guideline since monitoring began in 2015, but with an indication that concentrations have been decreasing although again noting that monitoring with the Teledyne T640x began in August 2019.

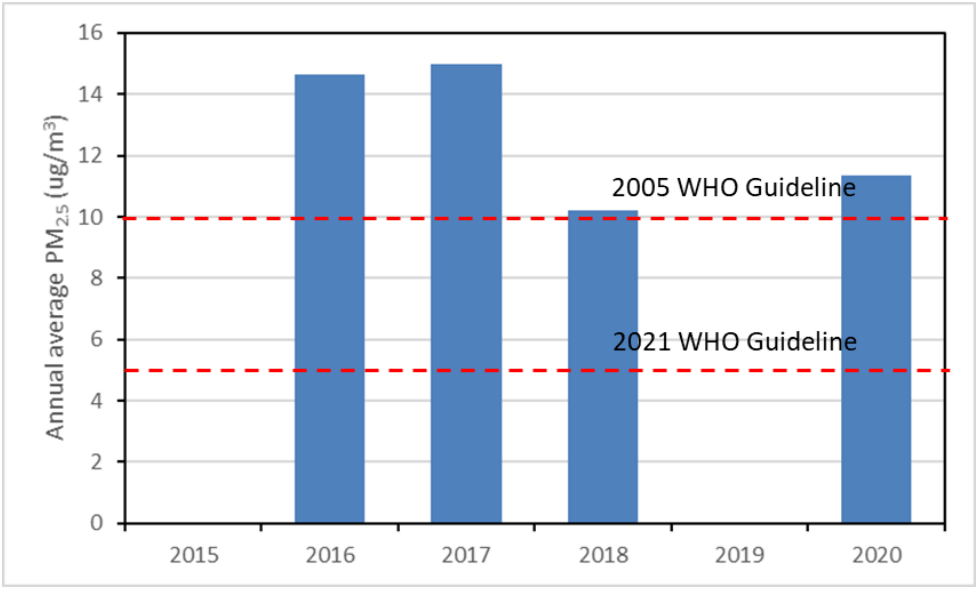


Figure 3.14 Annual average $PM_{2.5}$ concentrations measured in Tokoroa from 2015 to 2020 (note 2015 and 2019 data excluded due to only 40% data capture).

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2001 to 2020 is shown in Figure 3.15. The NES 24-hour PM_{10} standard has been exceeded multiple days per year since monitoring began in 2001 but with a general decrease in both exceedance number and magnitude of that exceedance since 2004. The lower numbers prior to 2004 are likely reflective of both poor data capture and instrumental problems that were identified prior to 2006. The increase in exceedance numbers and maximum concentration in 2020 coincides with the change to the Teledyne T640x monitor in August 2019.

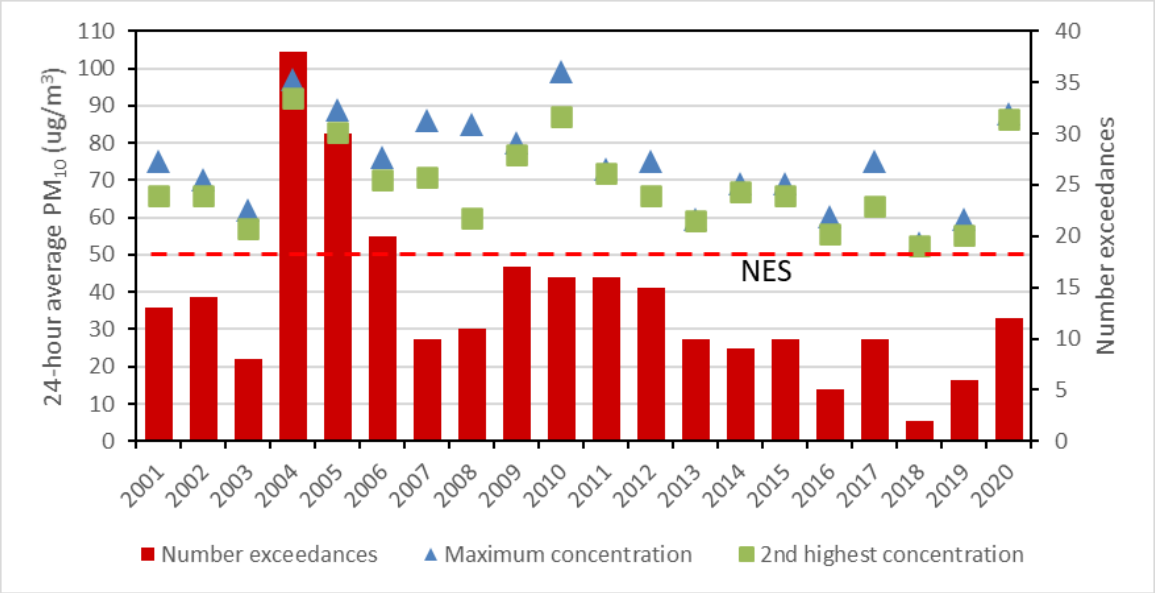


Figure 3.15 Number of days (right axis) when the PM_{10} standard of 50 µg/m³ as a 24-hour average was exceeded compared with the maximum 24-hour average concentration and the 2nd highest 24-hour average concentration (left axis) measured from 2001 to 2020 in Tokoroa.

The number of days when the 2005 WHO 24-hour $PM_{2.5}$ guideline of 25 µg/m³ was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2015 to 2020 is shown in Figure 3.16. The 2005 WHO $PM_{2.5}$ guideline, with exclusion of the years 2015 and 2019 (only 40% data), has been exceeded 31 to 53 times per year over this period. This number of exceedances increases significantly (62 to 94 times per year) if comparison is made to the 2021 WHO guideline.

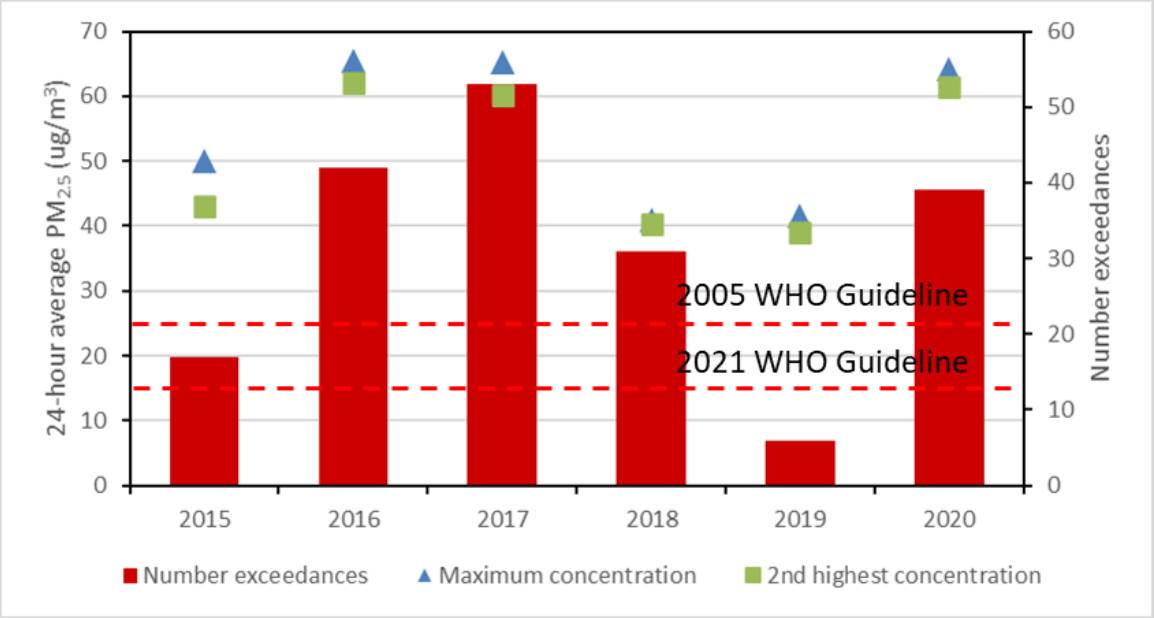


Figure 3.16 Number of days (right axis) when the $PM_{2.5}$ standard of 25 µg/m³ as a 24-hour average was exceeded compared with the maximum 24-hour average concentration and the 2nd highest 24-hour average concentration (left axis) measured from 2015 to 2020 in Tokoroa.

Figure 3.17 shows the relationship between PM_{10} and $PM_{2.5}$ concentrations for Tokoroa for wintertime (June to August) for the four years that full datasets are available. The positive correlation between $PM_{2.5}$ and PM_{10} is strong with r^2 ranging from 0.85 to 0.94 for the years 2016 to 2018 when two separate BAM instruments were being used to measure PM_{10} and $PM_{2.5}$. The correlation is even stronger at $r^2 = 0.996$ for 2020 when PM_{10} and $PM_{2.5}$ data were measured using the same T640x instrument. The high positive slope values of 0.75 to 0.86 for 2017, 2018 and 2020 is consistent with the expectation that the majority of particulate being measured over

the winter months is less than 2.5 microns in size and is being generated from combustion sources like woodburners. A high slope value of less than one is also consistent with the expectation that as $PM_{2.5}$ is a subset of PM_{10} the $PM_{2.5}$ concentration should be lower. However, the slope value of 1.09 for 2016 indicates that $PM_{2.5}$ was generally higher than PM_{10} which in theory is not possible and is indicative of the problems that can arise from monitoring both particulate fractions using a different instrument.

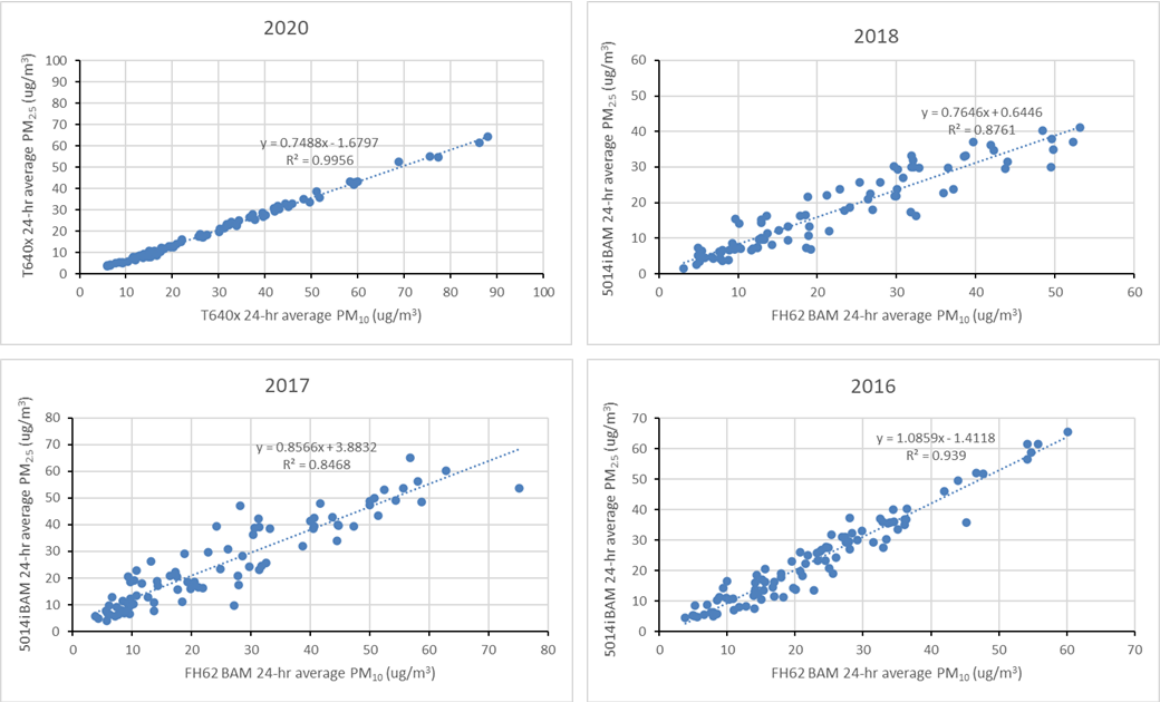


Figure 3.17 Relationship between 24-hour average PM_{10} and $PM_{2.5}$ concentrations measured in winter (June to August) in Tokoroa.

The 24-hour average PM_{10} concentrations from 2001 to 2020 are presented relative to air quality indicator categories in Figure 3.18. The proportion of data within the "action" category has decreased below about 5% since 2007 with a significant increase in the proportion of data falling within the good category since 2006 which indicates that while there are still exceedances occurring, for the majority of the year, air quality is less than a third of the guideline (categorised as good). However, some increase in concentrations have been observed in 2019 and 2020 when the new T640x instrument was introduced.

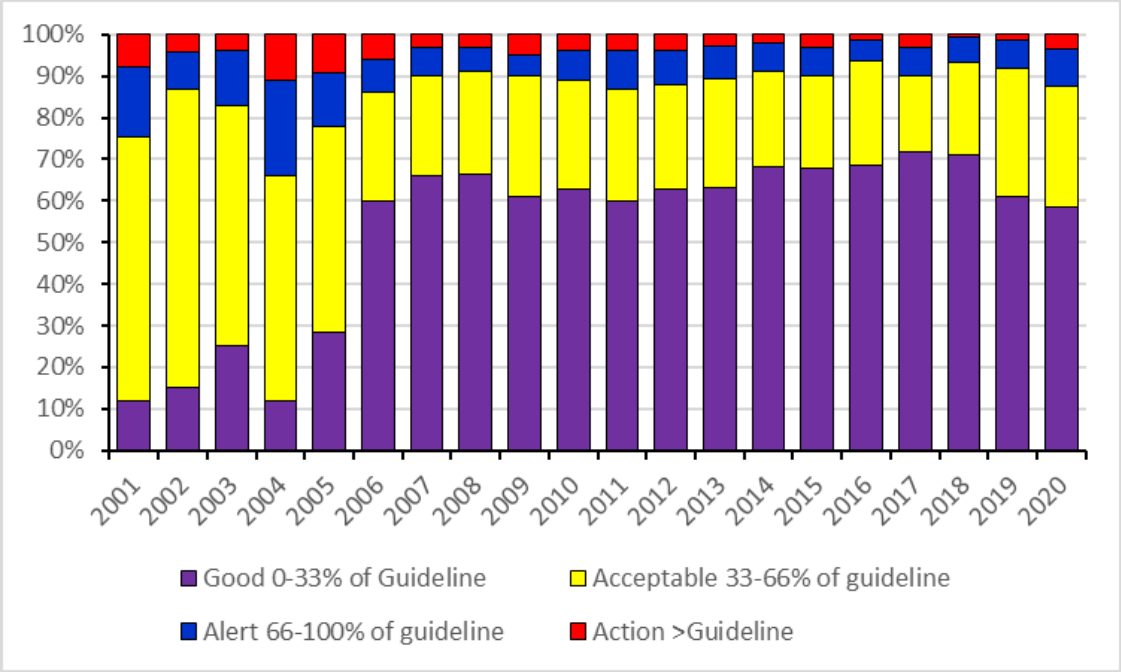


Figure 3.18 Comparison of 24-hour average PM_{10} concentrations measured in Tokoroa from 2001 to 2020 to air quality indicator categories.

The 24-hour average $PM_{2.5}$ concentrations from 2016 to 2020 are presented relative to air quality indicator categories in Figure 3.19. Note that $PM_{2.5}$ data from 2015 and 2019 was excluded due to the small datasets recorded in those two years. The proportion of data within the "action" category has decreased in 2018 and 2020 compared to the previous two years with a corresponding increase in the proportion of data falling within the good category. As for PM_{10}, it is important to note that the new T640x instrument was introduced in mid-2019 but there is less indication that trends in $PM_{2.5}$ data have been impacted by changing to a different instrument.

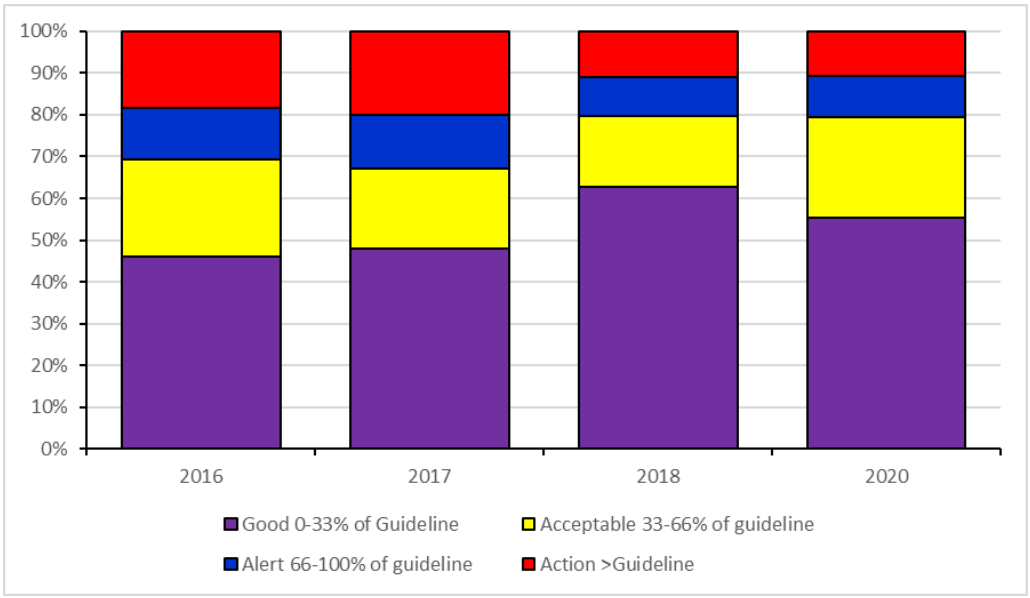


Figure 3.19 Comparison of 24-hour average $PM_{2.5}$ concentrations measured in Tokoroa from 2016 to 2020 to air quality indicator categories.

A comparison of hourly, daily, weekly, and monthly average PM_{10} concentrations in Tokoroa over the period 2006 to 2020 is presented in Figure 3.20. The hourly pattern of elevated concentrations overnight and low concentrations throughout the day for Monday through to Sunday is typical of the pattern observed where home heating is the major source of PM_{10}. Interestingly, the smaller peak often seen in the morning time is almost absent on the weekend compared with the weekdays indicating possibly some different woodburner behaviours

occurring on weekends compared with weekdays. While the morning peak is typically expected to be generated by woodburning in airsheds dominated by woodburner emissions, motor vehicle emissions may also be contributing to this peak and may also help to explain the lower morning peak observed during the weekend when there is lighter traffic.

Another interesting observation is that Tuesdays and Fridays seem to be the worst days for elevated PM_{10} with a larger morning peak which is more difficult to interpret although possibly it could be caused by a very regular industrial emission source on those two days of the week.

The seasonal distribution pattern throughout the year is consistent with seasonal patterns observed for most of the other airsheds in the Waikato region, where home heating is the major source of PM_{10}, with the most elevated months being May through to August.

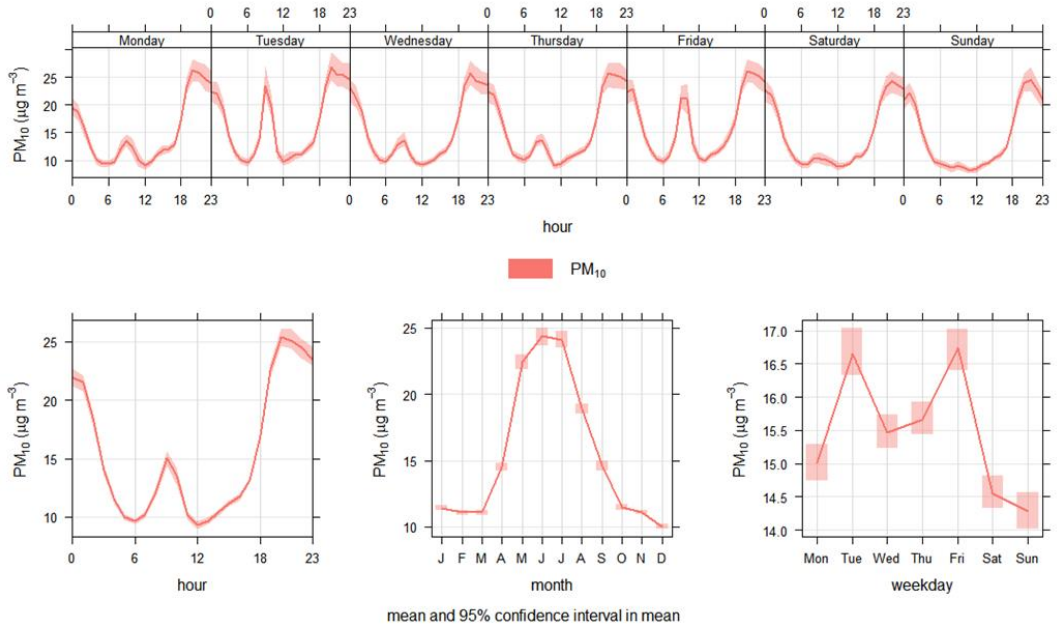


Figure 3.20 Comparison of hourly, daily, weekly and monthly average PM_{10} concentrations measured in Tokoroa for the period 2006 to 2020.

A windrose showing the relative frequency and speed of winds from different directions for the period 2015 to 2020 as measured at the Tokoroa station, is presented in Figure 3.21. The wind rose indicates two distinct prevailing wind directions, one from the west-northwest and another from the southeast with a high frequency of low to moderate windspeeds.

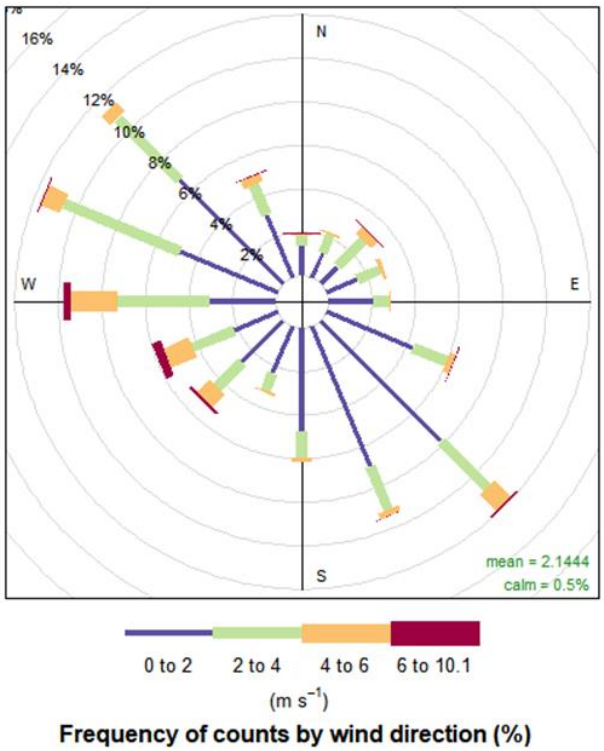


Figure 3.21 Windrose of wind direction and windspeed data as measured in Tokoroa over the period 2015 to 2020.

A trend analysis of PM_{10} data from the Tokoroa station, using the Theil-Sen method in OpenAir (with deseason function) indicates a statistically significant improving trend ($p < 0.001$) over the period 2010 to 2019 (refer to Figure 3.22). Note that this period selected for the trend analysis excludes data from 2020 when a T640x was used for monitoring of PM_{10}. If the data from 2020 is included in the analysis then no statistically significant change is identified.

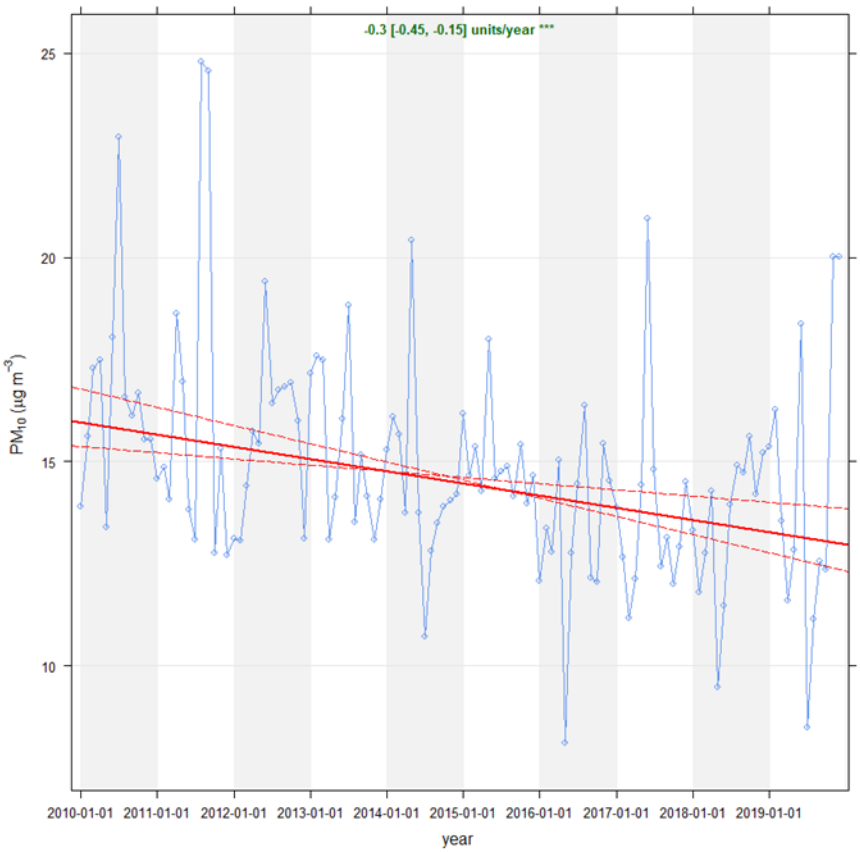


Figure 3.22 Tokoroa PM_{10} trend analysis for the period 2010 to 2019.

Air emission inventories have been carried out for Tokoroa in 2001, 2004, 2012, 2016 and 2019 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. Domestic heating was the main source of winter PM_{10} emissions in Tokoroa in 2019 accounting for 92% of the daily winter PM_{10} and 83% of the annual PM_{10} emissions. Outdoor burning contributed 4% of the daily winter PM_{10} with industry and motor vehicles only contributing 2% each to daily winter PM_{10}. Total daily winter PM_{10} emissions were estimated at 351 kilograms per day for 2019. This is around 8% less than the 2016 emission estimate of 383 kg/day suggesting minimal reduction in PM_{10} emissions in Tokoroa from 2016 to 2019. Between 2012 and 2016 emissions were estimated to have decreased by around 32% (Wilton, 2019).

The results of a source apportionment study in Tokoroa in 2015 to 2016 (Davy and Trompetter, 2017a) determined that emissions from biomass combustion, attributed to solid fuel fires for home heating during the winter, were the primary source of PM_{10} in the Tokoroa airshed. Solid fuel fires were responsible for an average of 80% of PM_{10} mass on high pollution days (i.e. days when PM_{10} was over two thirds of the standard). On the five days that the standard was exceeded in Tokoroa in 2016, solid fuel fires for home heating were responsible for over 90% of PM_{10} concentrations. This study has also identified arsenic and lead contamination associated with the PM_{10} from home heating indicating that treated and painted wood is being burnt.

3.5 PM_{10} monitoring in Taupō

The annual average PM_{10} concentrations for the Taupō station are provided in Figure 3.23. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3. Apart from 2006, PM_{10} concentrations in the Taupō airshed have complied with the 2005 WHO annual average guideline. Since 2009, PM_{10} concentrations have also complied with the 2021 WHO annual average guideline and have steadily reduced since then.

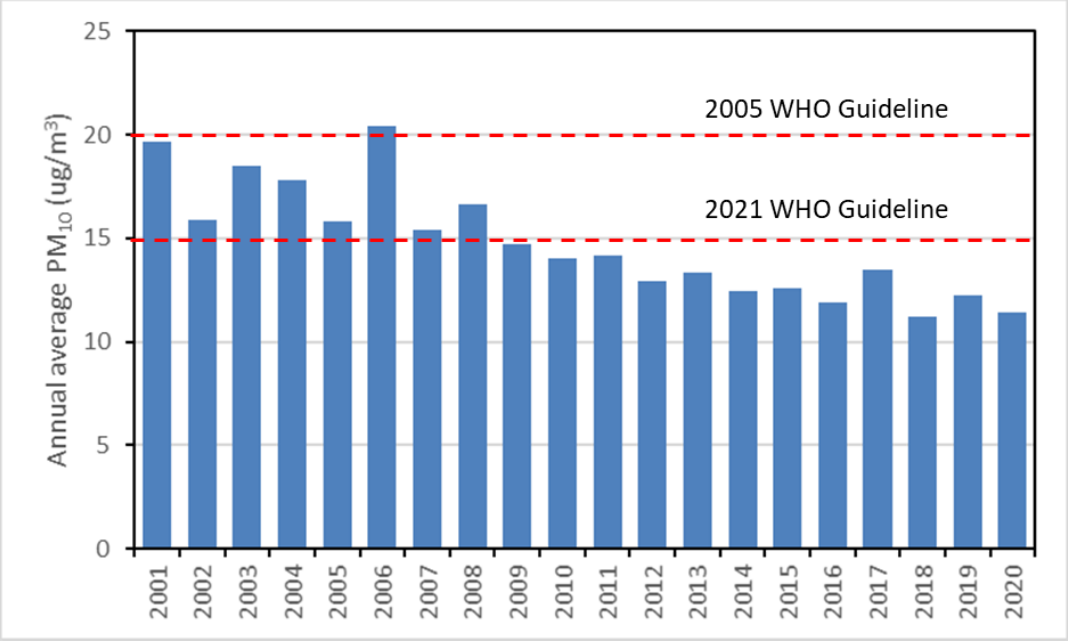


Figure 3.23 Annual average PM_{10} concentrations measured in Taupō from 2001 to 2020.

Figure 3.24 shows the changes in 24-hour average PM_{10} concentrations relative to air quality indicator categories at the Taupō site from 2001 to 2020. There has been a gradual increase in the proportion of PM_{10} concentrations in the 'good' category over the monitoring period.

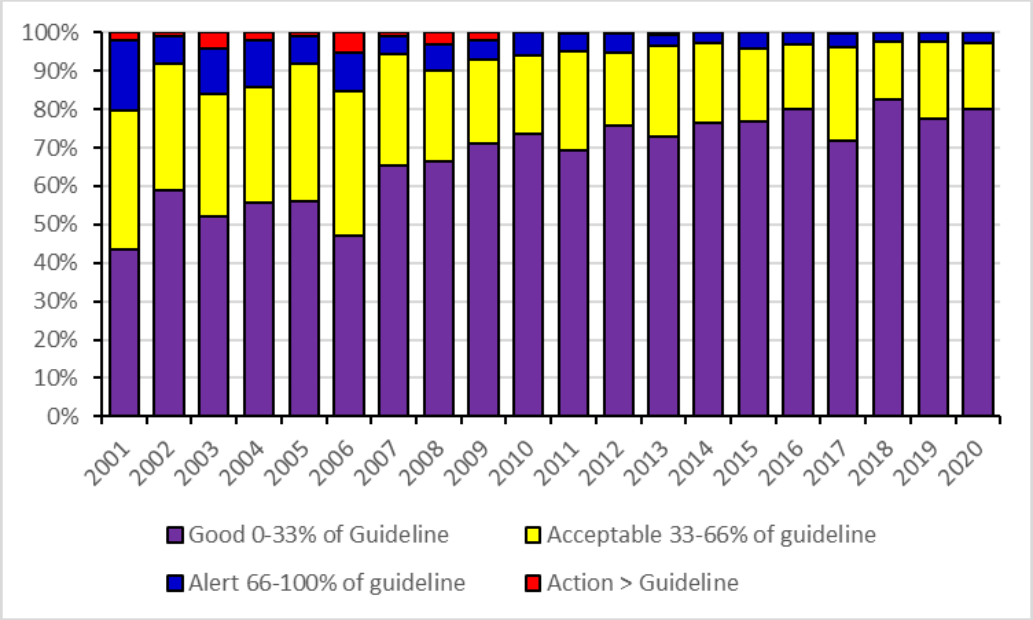


Figure 3.24 Comparison of 24-hour average PM_{10} concentrations measured at the Taupō site from 2001 to 2020 to air quality indicator categories.

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2001 to 2020 is shown in Figure 3.25. Both the number of exceedances and maximum concentrations reduced significantly from 2010 onwards and coincided with the re-routing of State Highway 1 away from the CBD and the conversion of the Hospital heating from coal to geothermal which could have potentially contributed to some of the air quality improvement. Taupō airshed was found to meet the criteria under Regulation 17(4) of the NES for being re-classified as non-polluted as of 27 June 2018 i.e. greater than 5 years of no more than one exceedance per 12 month period.

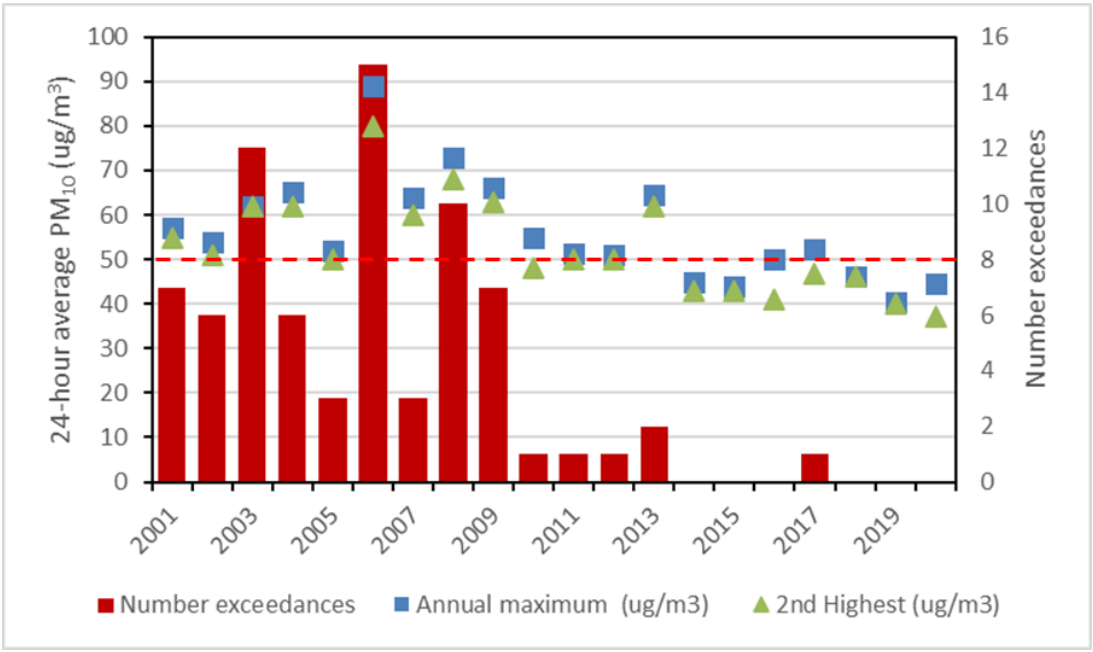


Figure 3.25 Number of days (right axis) when the 24-hour average standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd highest concentration (left axis) measured from 2001 to 2020 in Taupō.

A comparison of hourly, daily, weekly, and monthly average PM_{10} concentrations in Taupō over the period 2007 to 2020 is presented in Figure 3.26. The hourly pattern of elevated concentrations overnight and low concentrations throughout the day but with a smaller morning time peak for Monday through to Sunday is typical of the pattern observed where home

heating is the major source of PM_{10}. The morning time peak is smaller on the weekend compared with the weekdays indicating possibly some different woodburner behaviours occurring on weekends compared with weekdays which is also reflected in the lower daily averages observed for the weekend, although acknowledging also the reduced impact from traffic emissions on the weekend. The seasonal distribution pattern throughout the year is consistent with seasonal patterns observed for most of the other airsheds in the Waikato region, where home heating is the major source of PM_{10}, with the most elevated months being May through to August.

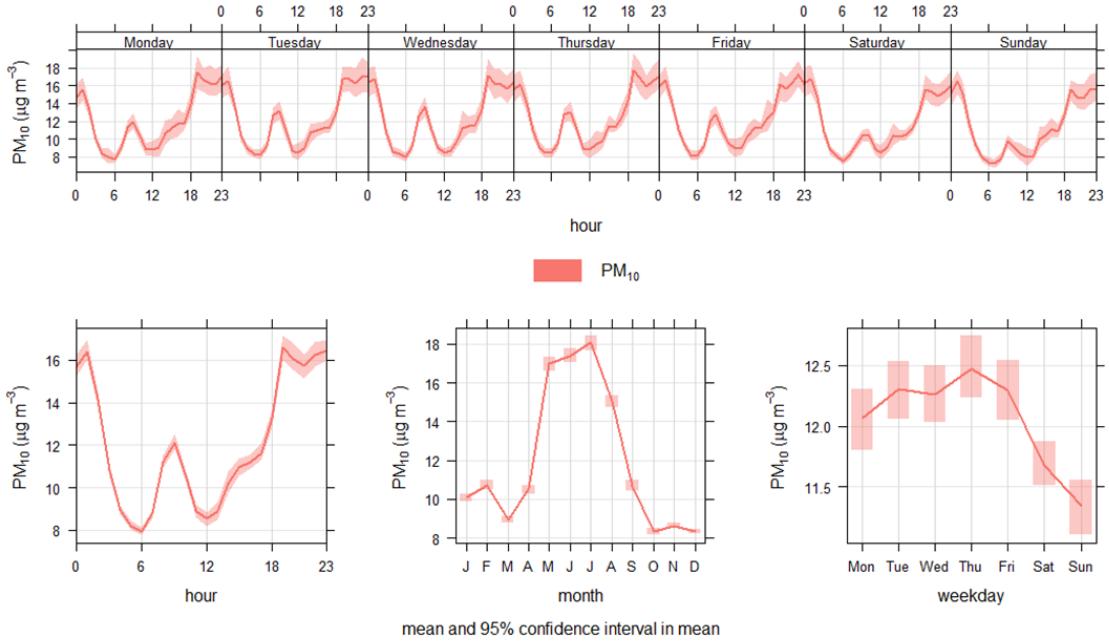


Figure 3.26 Comparison of hourly, daily, weekly and monthly average PM_{10} concentrations measured in Taupō for the period 2007 to 2020.

A windrose showing the relative frequency and speed of winds from different directions for the period 2015 to 2020 as measured at the Taupō station, is presented in Figure 3.27. The wind rose indicates one distinct prevailing wind direction from the northeast and a second from the west-southwest wind direction. The mean windspeed of 1.3 m/s is also somewhat lower than the mean windspeeds of 2.0 and 2.1 m/s calculated for Hamilton and Tokoroa respectively.

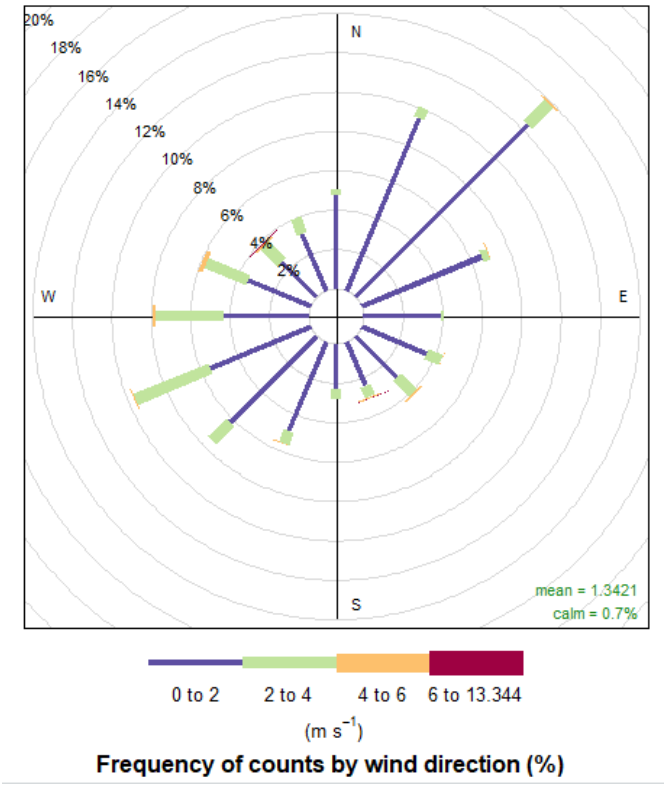


Figure 3.27 Windrose of wind direction and windspeed data as measured in Taupō over the period 2015 to 2020.

A trend analysis of PM_{10} data from the Taupō station, using the Theil-Sen method in OpenAir (with deseason function) indicates a statistically significant improving trend ($p< 0.05$) over the ten year period 2011 to 2020 (refer to Figure 3.27).

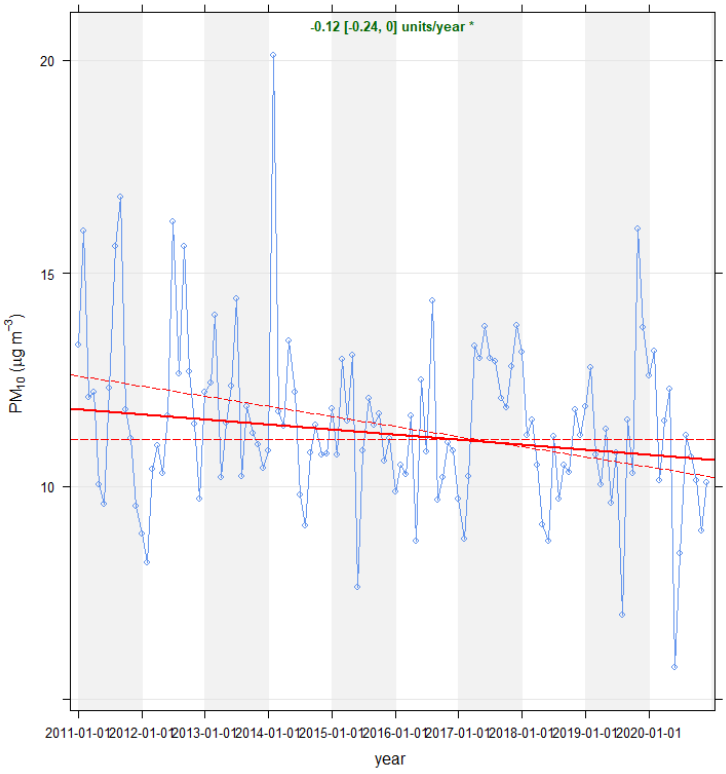


Figure 3.28 Taupō PM_{10} trend analysis for the period 2011 to 2020.

Air emission inventories have been carried out for Taupō in 2001, 2004, 2009 and 2014 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the

year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. Domestic heating was the main source of winter PM_{10} emissions in Taupō in 2015 accounting for 97% of the daily winter PM_{10} emissions. Other sources included transport (2%) and outdoor burning (1%). On an average winter's day, around 561 kilograms of PM_{10} are discharged from these sources. The industrial contribution to PM_{10} emissions in Taupō was negligible as the industrial area to the northeast of the urban area is excluded from the Taupo urban area inventory. The reason for excluding the industrial area is due to its geographical separation by approximately 2 km of rural and undeveloped land.

The previous 2009 emission inventory for Taupō estimated around 727 kilograms of PM_{10} were discharged on an average winters day of which 683 kilograms was from domestic home heating and 29 kilograms was from motor vehicles. This assessment indicates a reduction in total PM_{10} emissions in Taupō of around 23% from 2009 to 2014. The majority of this occurs as a result of a decrease in PM_{10} emissions from domestic heating. The estimated reduction in PM_{10} emissions over this time is consistent with an evaluation of trends in PM_{10} concentrations in Taupō which suggests a reduction in PM_{10} concentrations of around 24% occurring mostly between 2009 and 2010 (Wilton, 2015a).

3.6 NO_2 monitoring in Taupō

The results from NZTA's passive NO_2 monitoring programme from 2007 to 2020 (Figure 3.29) show that the Tongariro St / Norman Smith St site in Taupō has always complied with the 2005 WHO annual average NO_2 guideline of 40 ug/m^3. However, if a comparison is made with the recently introduced 2021 WHO annual guideline of 10 ug/m^3 it is evident that the site has always been in exceedance.

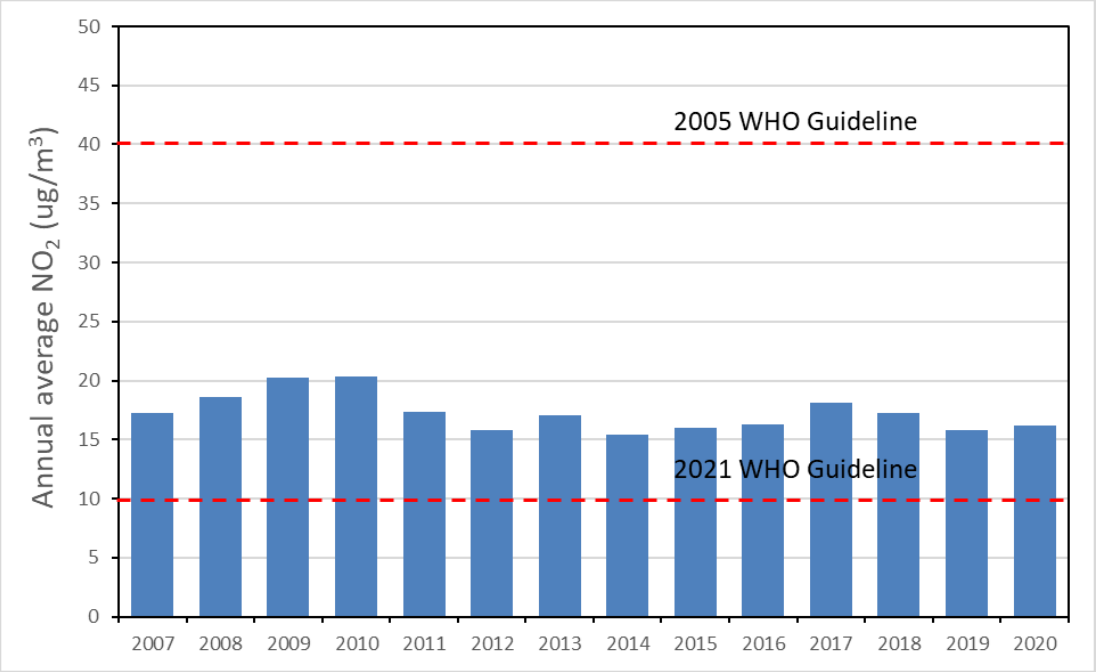


Figure 3.29 Annual average NO_2 concentrations measured in Taupo (2007 to 2020).

A trend analysis of NO_2 data from the Taupō site for the ten-year period 2011 to 2020, using the Theil-Sen method in OpenAir (with deseason function) indicates no statistically significant trend over this period (refer to Figure 3.30).

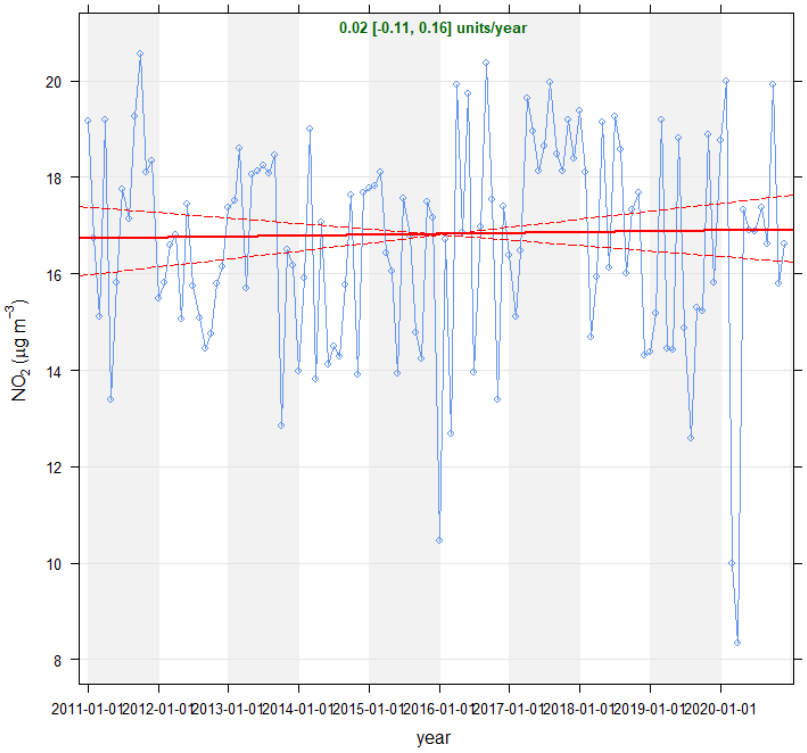


Figure 3.30 NO_2 trend analysis for 2011 to 2020 for Taupo displaying no statistically significant change.

3.7 PM_{10} and $PM_{2.5}$ monitoring in Te Kuiti

The annual average PM_{10} concentrations for the Te Kuiti station are provided in Figure 3.31. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3. PM_{10} concentrations in the Te Kuiti airshed have complied with the 2005 WHO annual average guideline for the full monitoring period. Since 2017, PM_{10} concentrations have also just complied with the 2021 WHO annual average guideline except in 2020 when the annual average was 15.1 ug/m^3. However, noting that the introduction of the T640x in 2019 has likely been the cause of the increased PM_{10} averages for 2019 and 2020.

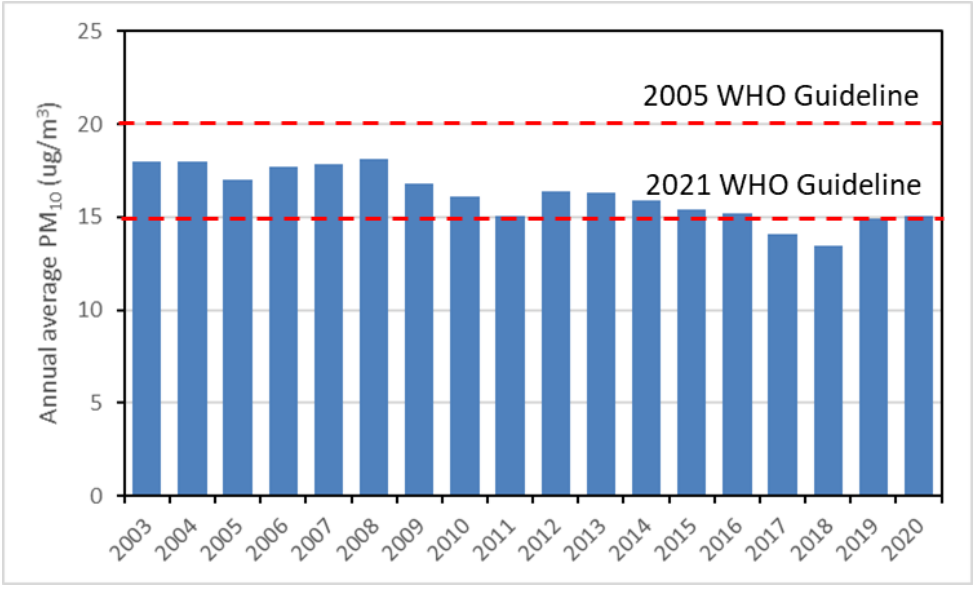


Figure 3.31 Annual average PM_{10} concentrations measured in Te Kuiti from 2003 to 2020.

Figure 3.32 shows variations in the 24-hour average PM_{10} concentrations relative to air quality indicator categories in Te Kuiti from 2003 to 2020. A gradual increase in the proportion of PM_{10}

concentrations in the 'good' category and decreases in the proportion of concentrations in the "acceptable", "action" and "alert" categories are an illustration of improvements in air quality in Te Kuiti.

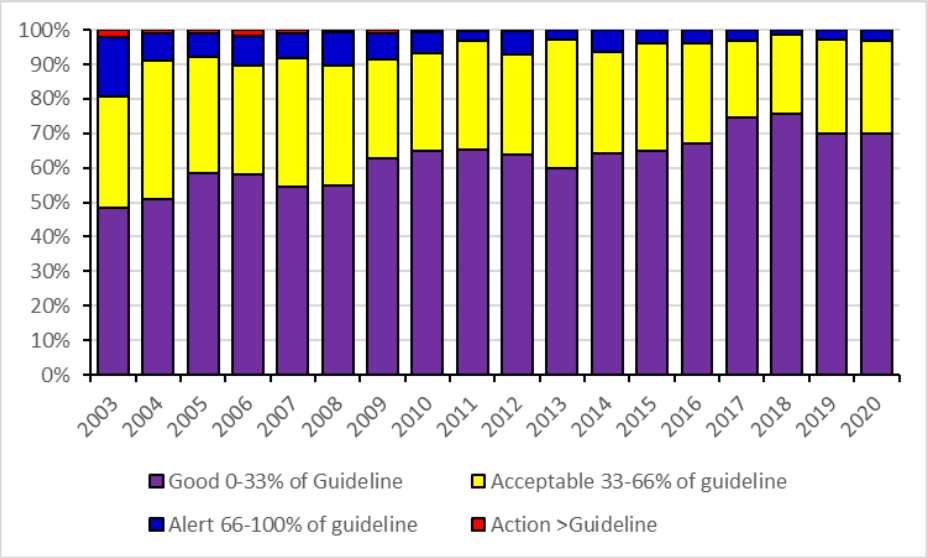


Figure 3.32 Comparison of 24-hour average PM_{10} concentrations measured at the Te Kuiti site from 2003to 2020 relative to air quality indicator categories.

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2003 to 2020 is shown in Figure 3.33. Both the number of exceedances and maximum concentrations reduced significantly from 2011 onwards. Te Kuiti airshed was found to meet the criteria under Regulation 17(4) of the NES for being re-classified as non-polluted as of 10 December 2016 i.e. greater than 5 years of no more than one exceedance per 12 month period.

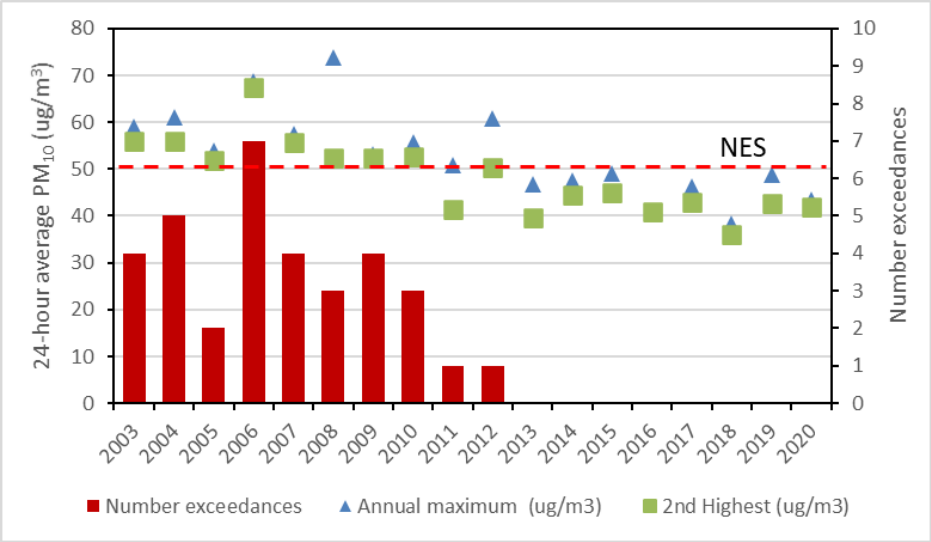


Figure 3.33 Number of days (right axis) when the 24-hour average standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd highest concentration (left axis) measured from 2003 to 2020 in Te Kuiti.

Permanent monitoring of $PM_{2.5}$ in Te Kuiti only began in May 2019. Comparison of the annual $PM_{2.5}$ average for the year 2020 against the 2005 WHO annual average guideline of 10 µg/m^3 and the recently introduced 2021 WHO annual average guideline of 5 µg/m^3 indicates that the 2005 WHO guideline was complied with but not the 2021 WHO guideline (refer to Table 3.2).

The number of days when the 2005 WHO 24-hour $PM_{2.5}$ guideline of 25 µg/m^3 was exceeded and the 2021 WHO 24-hour $PM_{2.5}$ guideline of 15 µg/m^3 was exceeded in 2019 and 2020 is provided in Table 3.2.

Table 3.2 Summary of $PM_{2.5}$ monitoring data in Te Kuiti.

	Annual average (ug/m^3)	Max 24-hr average (ug/m^3)	Exceedances WHO 24-hr average	
			2005 guideline	2021 guideline
2019	-	52	17	54
2020	7.8	43	6	41

A comparison of hourly, daily, weekly, and monthly average PM_{10} concentrations in Te Kuiti over the period 2003 to 2020 is presented in Figure 3.34. The hourly pattern of elevated concentrations overnight and low concentrations throughout the day but with a smaller morning time peak for Monday through to Friday is typical of the pattern observed where home heating is the major source of PM_{10}. However, there appears to be little evidence of a morning time peak on the weekend compared with the weekdays indicating possibly some different woodburner behaviours occurring on weekends which is also reflected in the lower daily averages observed for the weekend, although acknowledging also the reduced impact from traffic emissions on the weekend. The seasonal distribution pattern throughout the year is consistent with seasonal patterns observed for most of the other airsheds in the Waikato region, where home heating is the major source of PM_{10}, with the most elevated months being May through to August.

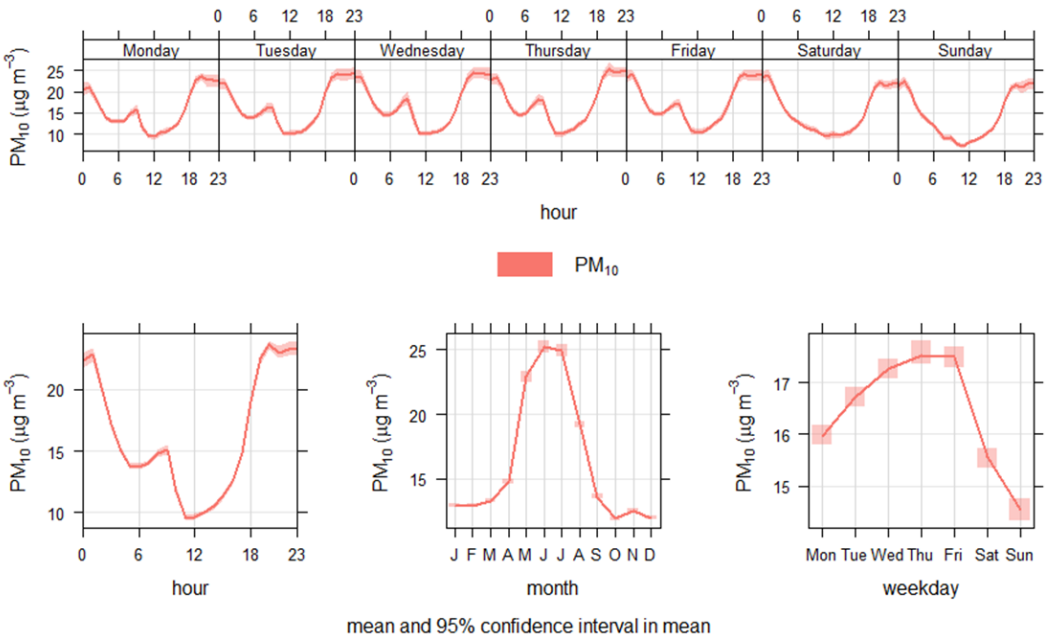


Figure 3.34 Comparison of hourly, daily, weekly and monthly average PM_{10} concentrations measured in Te Kuiti for the period 2003 to 2020.

A windrose showing the relative frequency and speed of winds from different directions for the period 2015 to 2020 as measured at the Te Kuiti station, is presented in Figure 3.35. While the prevailing wind direction is less distinct compared to other sites, the wind rose indicates a slightly more distinct prevailing wind direction from the northeast and a second from the west-southwest wind direction. The mean windspeed of 1.3 m/s is similar to that determined for Taupō but is somewhat lower than the mean windspeeds of 2.0 and 2.1 m/s calculated for Hamilton and Tokoroa respectively.

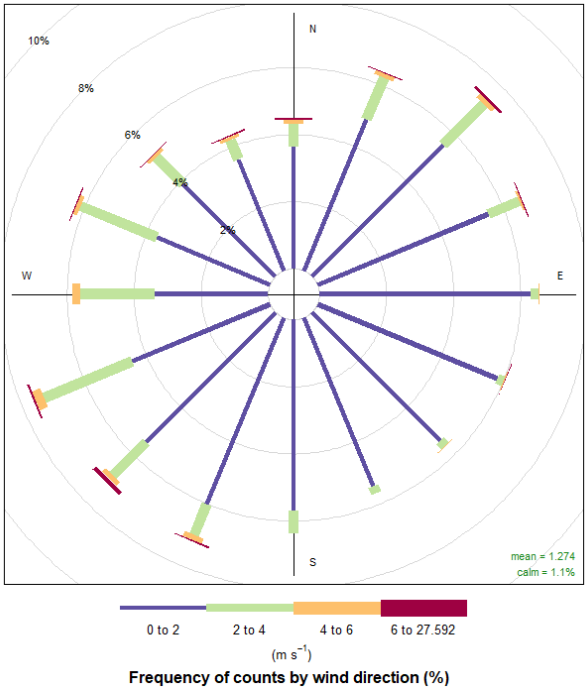


Figure 3.35 Windrose of wind direction and windspeed data as measured at the Te Kuiti station over the period 2015 to 2020.

A trend analysis of PM_{10} data from the Te Kuiti station, using the Theil-Sen method in OpenAir (with deseason function) indicates a statistically significant improving trend ($p< 0.01$) over the ten year period 2011 to 2020 (refer to Figure 3.36).

Air emission inventories have been carried out for Te Kuiti in 2001, 2007 and 2015 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. Domestic heating was the main source of PM_{10} emissions in Te Kuiti in 2015, accounting for 78% of daily winter emissions. The other main source is industry which contributes 16%. On an average winter's day during 2015, around 212 kilograms of PM_{10} was discharged from these sources. This compares with around 231 kg/day in Te Kuiti in 2007 (after adjusting for differences in methodology) which represents a 14% reduction as a result of reductions in both domestic heating and industrial emissions (Wilton, 2015b).

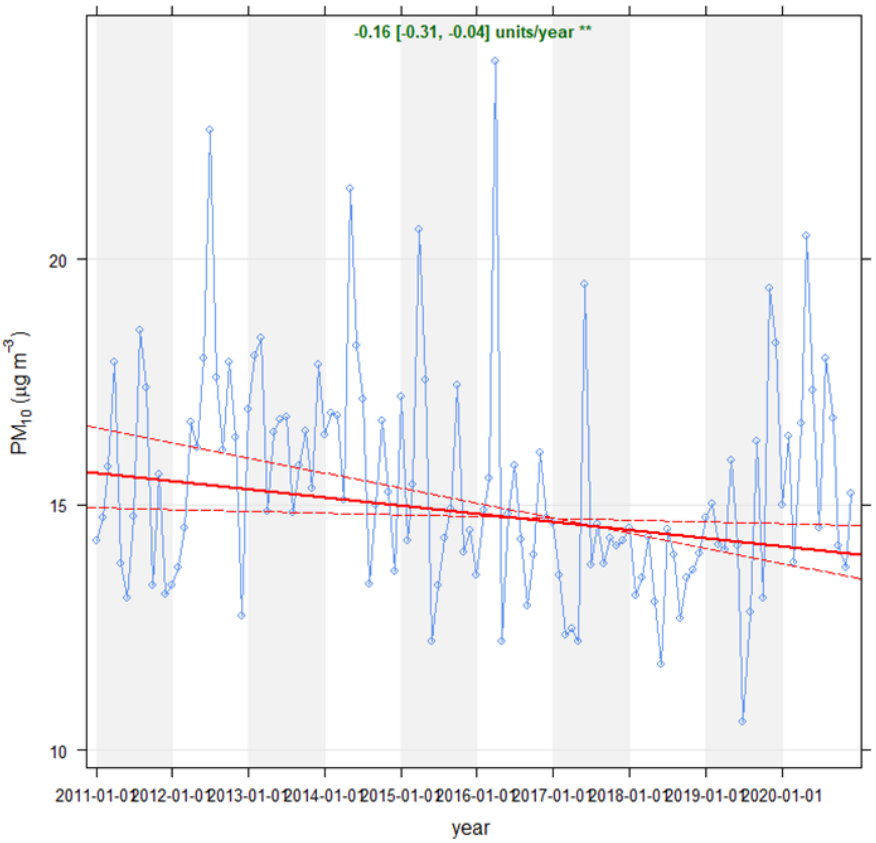


Figure 3.36 Te Kuiti PM_{10} trend analysis for the period 2011 to 2020.

3.8 PM_{10} monitoring in Putaruru

The annual average PM_{10} concentrations for the Putaruru station are provided in Figure 3.37. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3. PM_{10} concentrations in the Putaruru airshed have complied with the 2005 WHO annual average guideline for the full monitoring period of 2006 to 2020 and have been complying with the 2021 WHO annual average guideline since 2015. Note that data from 2006 has been excluded from the analysis because monitoring only began in July 2006.

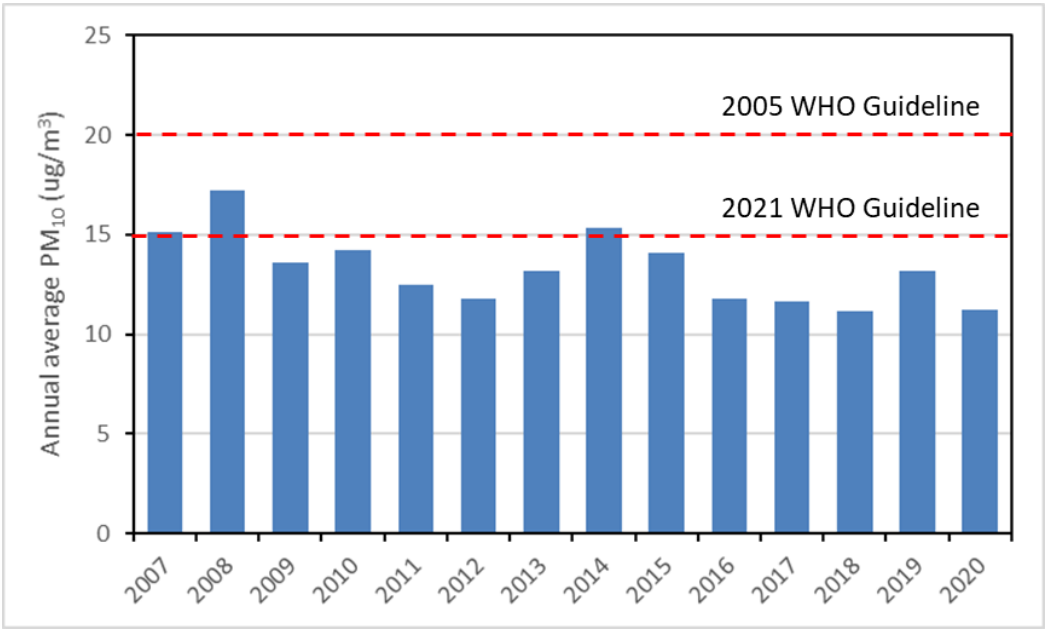


Figure 3.37 Annual average PM_{10} concentrations measured in Putaruru from 2006 to 2020.

Figure 3.38 shows variations in the 24-hour average PM_{10} concentrations relative to air quality indicator categories in Putaruru from 2007 to 2020. While there has been an improvement in the proportion of PM_{10} concentrations falling within the 'good' category, there was a similar level of improvement observed over the period 2011 to 2013 with a reversal of that improvement observed in 2014 and 2015.

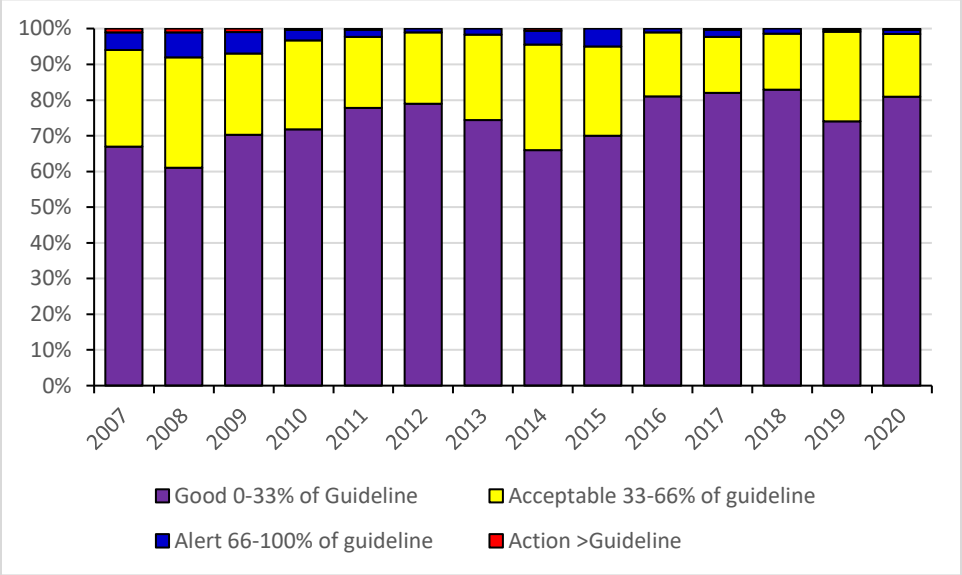


Figure 3.38 Comparison of 24-hour average PM_{10} concentrations measured at the Putaruru station from 2007 to 2020 relative to air quality indicator categories.

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2006 to 2020 is shown in Figure 3.39. The greatest number of exceedances 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. The two exceedances that occurred during 2014 are also atypical and occurred out of season. While both the number of exceedances and second highest concentrations have reduced over the full monitoring period, there continues to be an occasional exceedance from time to time. Despite this, the Putaruru airshed was found to meet the criteria under Regulation 17(4) of the NES for being re-classified as non-polluted as of 14 March 2019 i.e., greater than 5 years of no more than one exceedance per 12 month period.

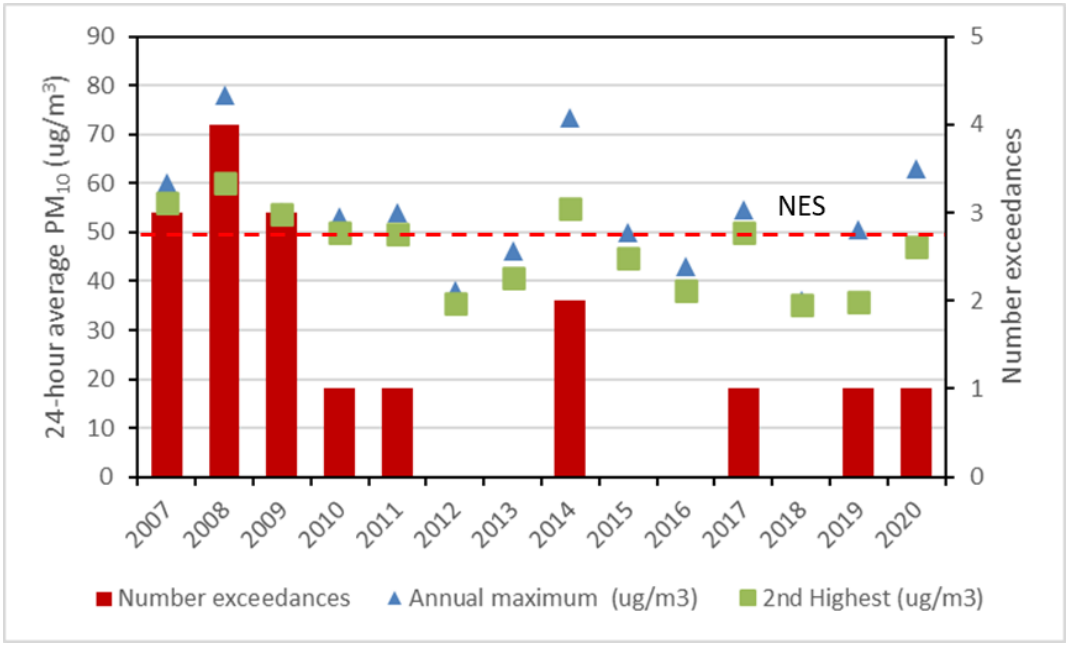


Figure 3.39 Number of days (right axis) when the 24-hour average standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd highest concentration (left axis) measured from 2007 to 2020 in Putaruru.

A comparison of hourly, daily, weekly, and monthly average PM_{10} concentrations in Putaruru over the period 2006 to 2020 is presented in Figure 3.40. The hourly pattern of elevated concentrations overnight and lower concentrations throughout the day is typical of the pattern observed where home heating is the major source of PM_{10}. However, unlike many of the other airsheds in the Waikato region that also have a smaller daytime peak typically centred around 9 am, the daytime peak in Putaruru seems to be broader and more centred around midday which may be influenced by differences in local meteorology resulting in a delayed peak compared to other airsheds. This pattern also seems to be similar on every day of the week, including weekends. Interestingly, the daily average seems to start off lower on Monday and gradually increase to a peak on Thursdays and Fridays before dropping back down on the weekend. The seasonal distribution pattern throughout the year is consistent with seasonal patterns observed for most of the other airsheds in the Waikato region, where home heating is the major source of PM_{10}, with the most elevated months being May through to August.

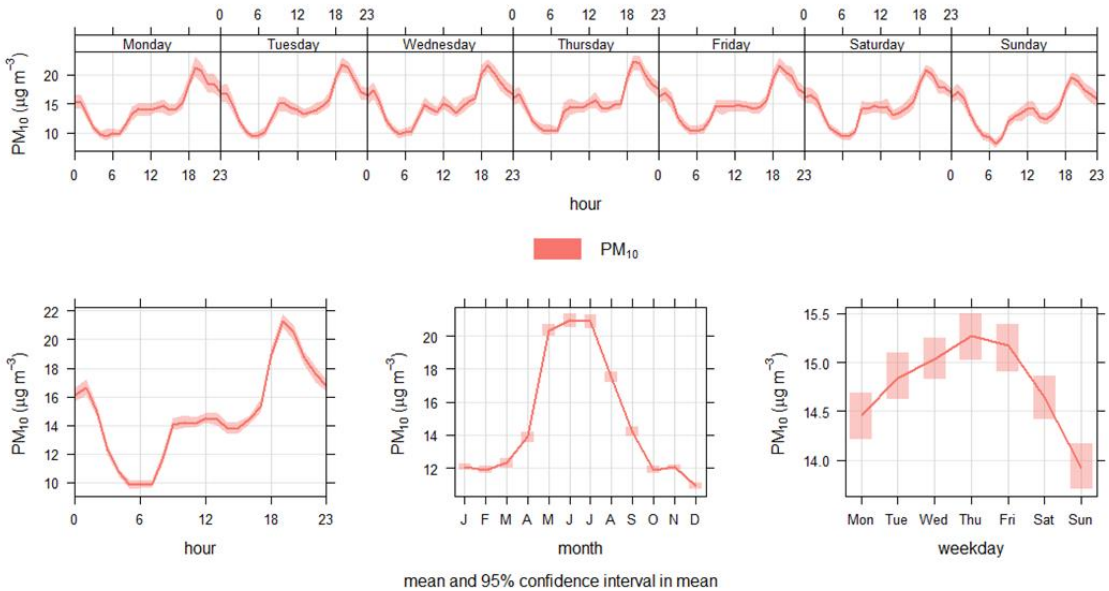


Figure 3.40 Comparison of hourly, daily, weekly and monthly average PM_{10} concentrations measured in Putaruru for the period 2006 to 2020.

A trend analysis of PM_{10} data from the Putaruru station, using the Theil-Sen method in OpenAir (with deseason function) indicates no statistically significant trend over the ten-year period 2011 to 2020 (refer to Figure 3.41).

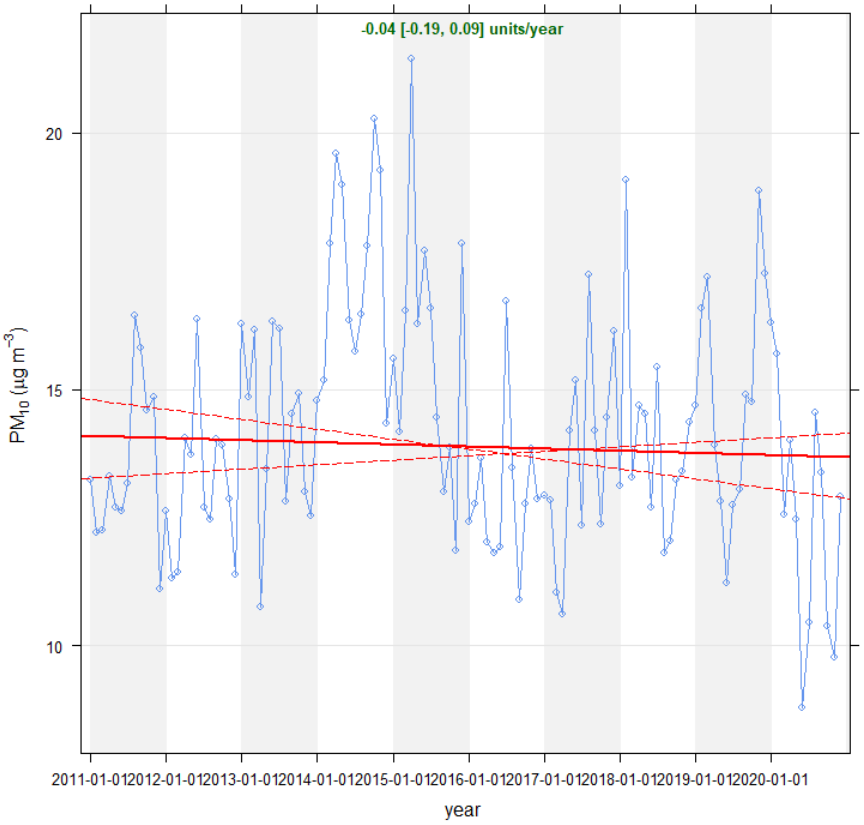


Figure 3.41 Putaruru PM_{10} trend analysis for the period 2011 to 2020.

Air emission inventories have been carried out for Putaruru in 2001, 2006 and 2015 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. In 2015 the domestic heating contribution to daily winter emissions of PM_{10} was 94% (127 kilograms per day) with minor contributions from outdoor burning (5%) and transport (1%). Around 135 kilograms per day of PM_{10} was discharged in Putaruru on an average winter's day during 2015. The previous 2006 air emission inventory for Putaruru found 354 kilograms per day during winter of which around 136 kg/day was from industry which was no longer operating by 2015. Around 205 kg/day of PM_{10} was discharged from domestic heating compared with 124 kg/day in 2015. A reduction in PM_{10} of around 62% in total emissions is estimated to have occurred from 2006 to 2015. The reduction in domestic heating emissions over this time is around 38% (Wilton, 2015b).

3.9 PM_{10} monitoring in Morrinsville

The annual average PM_{10} concentrations for the Morrinsville station are provided in Figure 3.42. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3. PM_{10} concentrations in the Morrinsville airshed have complied with both the 2005 and 2021 WHO annual average guideline for the full monitoring period of 2015 to 2020.

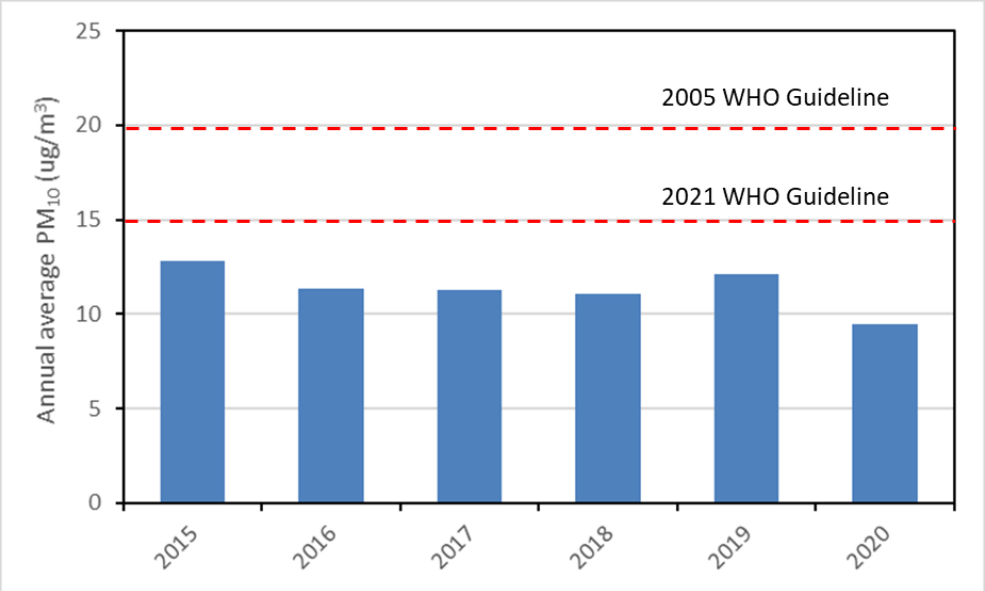


Figure 3.42 **Annual average PM_{10} concentrations measured at the Morrinsville station for the period 2015 to 2020.**

Figure 3.43 shows variations in the 24-hour average PM_{10} concentrations relative to air quality indicator categories in Morrinsville from 2015 to 2020. Approximately 85% of days per year experienced 24-hour average PM_{10} concentrations within the "good" category but with up to 95% of days falling within this category in 2020.

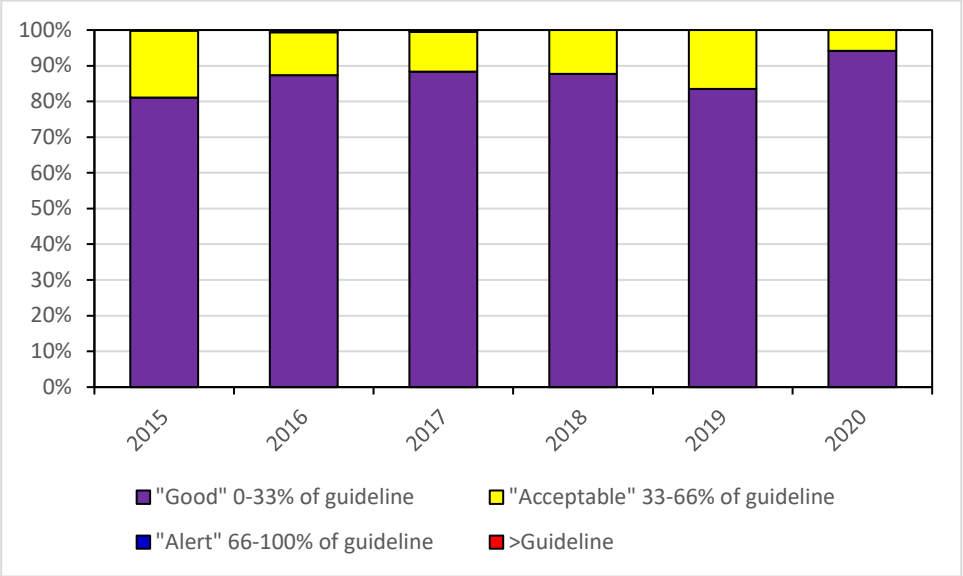


Figure 3.43 **Comparison of 24-hour average PM_{10} concentrations measured at the Morrinsville site from 2015 to 2020 relative to air quality indicator categories.**

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2015 to 2020 is shown in Figure 3.44. There have been no exceedances recorded over this monitoring period with the highest 24-hour average PM_{10} concentrations decreasing over this period.

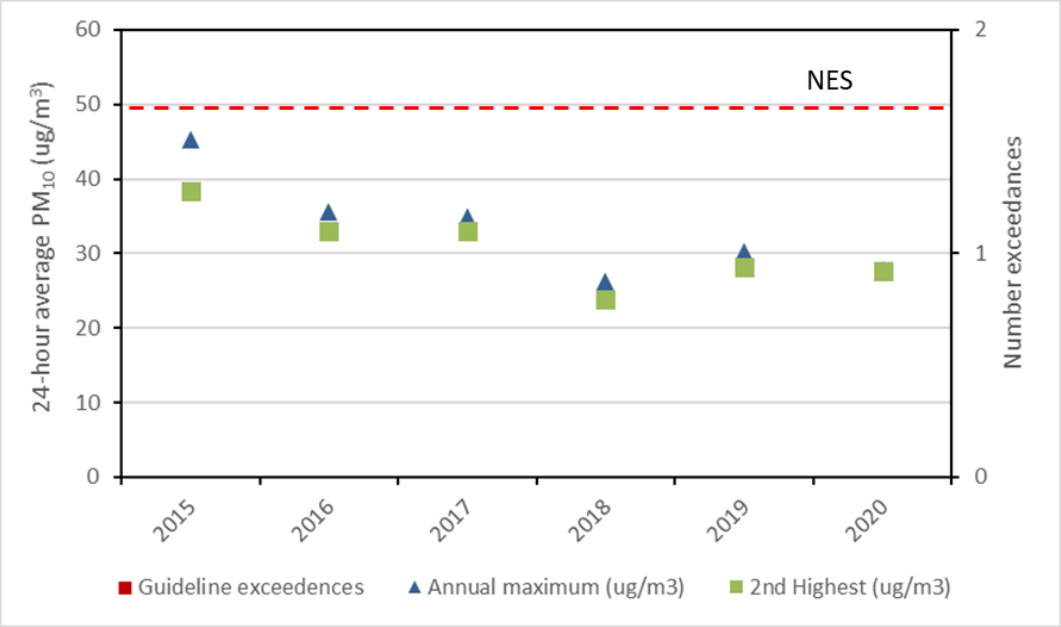


Figure 3.44 **Number of days (right axis) when the 24-hour average standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd highest concentration (left axis) measured from 2015 to 2020 in Morrinsville.**

A comparison of hourly, daily, weekly, and monthly average PM_{10} concentrations in Morrinsville over the period 2015 to 2020 is presented in Figure 3.45. The hourly pattern of elevated concentrations overnight and low concentrations throughout the day but with a smaller morning time peak for Monday through to Sunday is typical of the pattern observed where home heating is the major source of PM_{10}. The daily averages are lower on the weekend indicating some potentially different woodburner behaviours occurring on weekends compared with weekdays. Interestingly, as was the case for Hamilton, the seasonal distribution pattern for Morrinsville indicates a secondary peak of around 12 ug/m^3 for November through to February with a larger peak of 14 ug/m^3 in June and July with a low of 10 ug/m^3 in March and September which suggests a summertime/ non-home heating impact on PM_{10} concentrations. The Fonterra milk powder drying plant in Morrinsville could be contributing to elevations of PM_{10} in the summer months when wood burners are not operating.

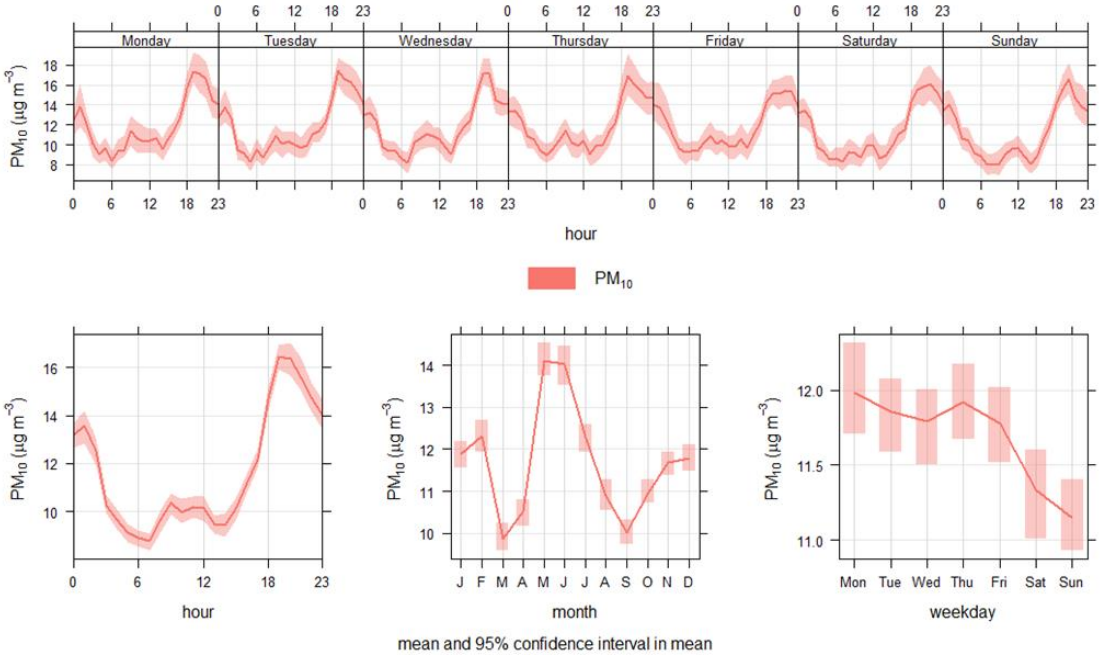


Figure 3.45 **Comparison of hourly, daily, weekly and monthly average PM_{10} concentrations measured in Morrinsville for the period 2015 to 2020.**

A trend analysis of PM_{10} data from the Morrinsville station, using the Theil-Sen method in OpenAir (with deseason function) indicates no statistically significant trend over the ten-year period 2009 to 2018 (refer to Figure 3.46).

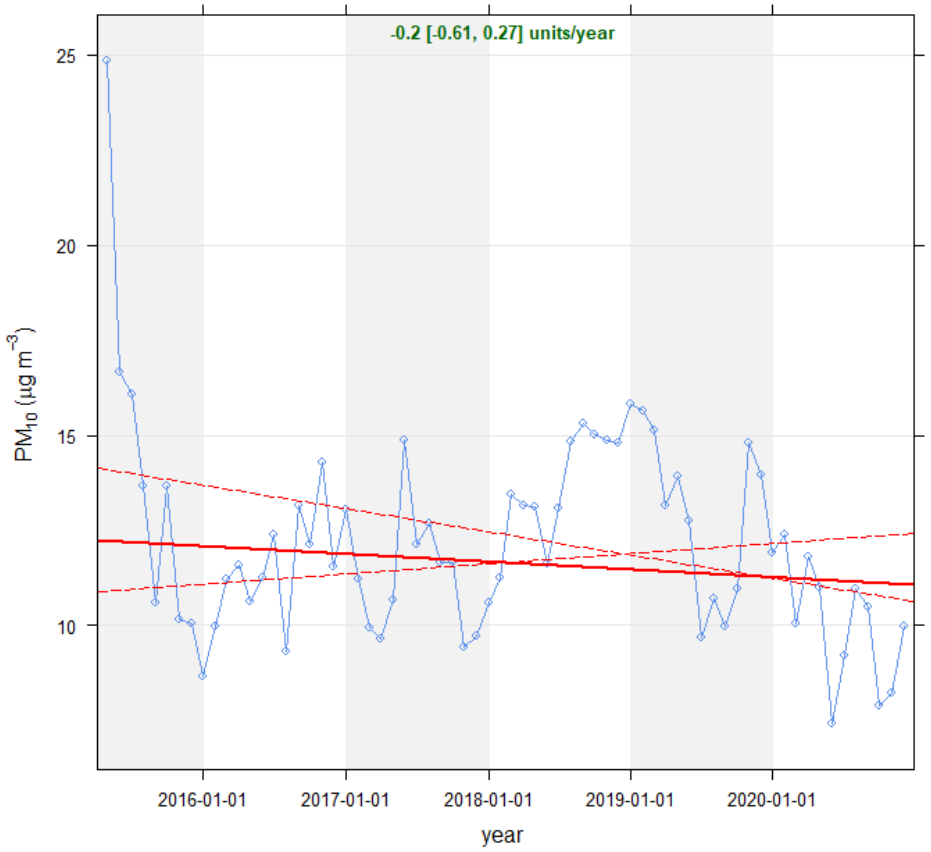


Figure 3.46 **Morrinsville PM_{10} trend analysis for the period 2015 to 2020.**

An air emission inventory was carried out for Morrinsville in 2016 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. The domestic heating contribution was 53% with industry being a major contributor to PM_{10} at 42% but not to $PM_{2.5}$ as the source was non combustion (the main source of industrial PM_{10} emissions in Te Awamutu is the milk powder emissions from Fonterra). Outdoor burning and transport contributes 4% and 1% respectively to wintertime PM_{10} emissions. Around 261 kilograms per day of PM_{10} is discharged in Morrinsville on an average winter's day (Wilton, 2016).

3.10 PM_{10} monitoring in Thames

The annual average PM_{10} concentrations for the Thames station are provided in Figure 3.47. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3. PM_{10} concentrations in the Thames airshed have complied with both the 2005 and 2021 WHO annual average guideline for the full monitoring period of 2016 to 2020.

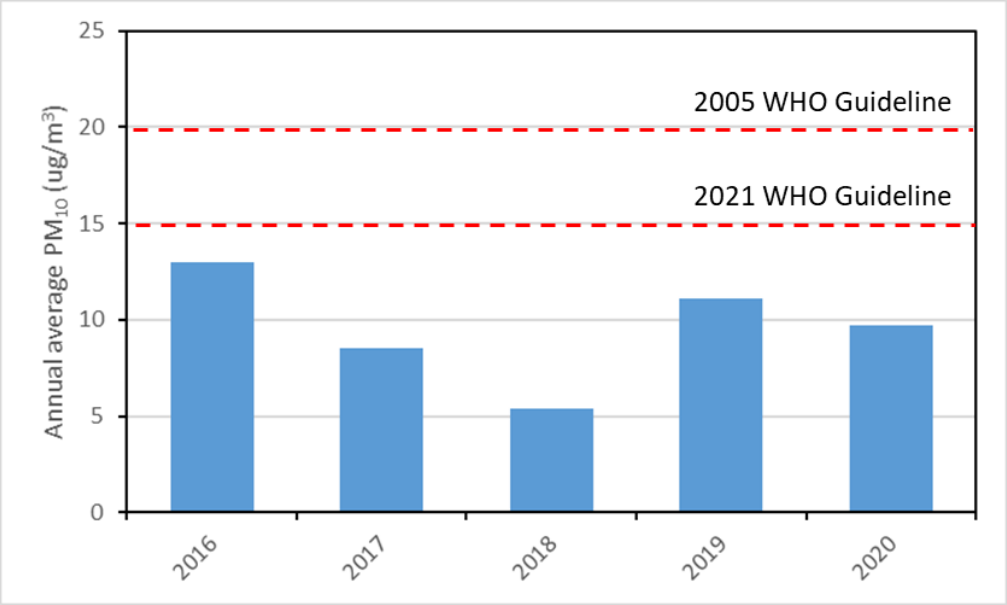


Figure 3.47 **Annual average PM_{10} concentrations measured at the Thames station for the period 2016 to 2020.**

Figure 3.48 shows variations in the 24-hour average PM_{10} concentrations relative to air quality indicator categories in Thames from 2016 to 2020. While nearly 100% of the data fell within the good category in 2018, the data for that year is cautioned due to some issues with the temperature and humidity control within the station enclosure at the time. However, if 2018, is excluded, the PM_{10} data has ranged from 77 to 93% of days where the PM_{10} concentrations were within the "good" category.

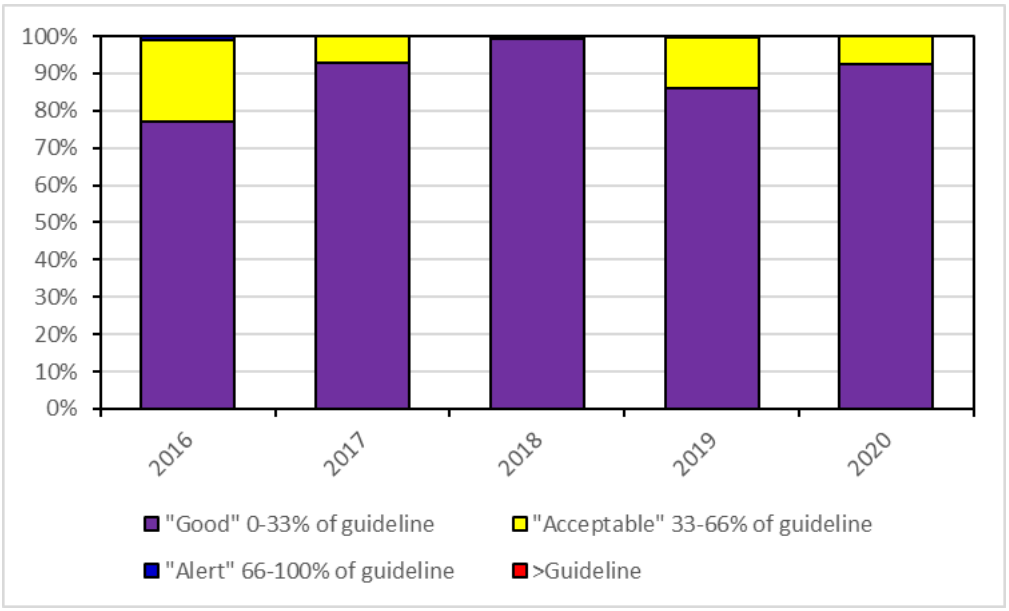


Figure 3.48 **Comparison of 24-hour average PM_{10} concentrations measured at the Thames site from 2016 to 2020 relative to air quality indicator categories.**

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2016 to 2020 is shown in Figure 3.49. There were no exceedances recorded over this monitoring period with typically low maximum PM_{10} concentrations.

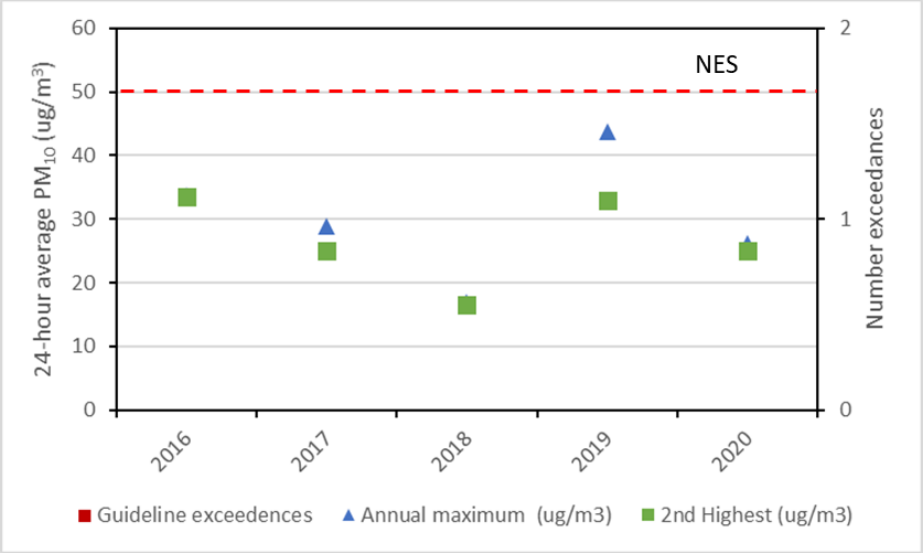


Figure 3.49 **Number of days (right axis) when the 24-hour average standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd highest concentration (left axis) measured from 2016 to 2020 in Thames.**

A comparison of hourly, daily, weekly, and monthly average PM_{10} concentrations in Thames over the period 2016 to 2020 is presented in Figure 3.50. The hourly pattern of elevated concentrations overnight and low concentrations throughout the day is typical of the pattern observed where home heating is the major source of PM_{10}. However, the smaller daytime peak around 9 am that is typically observed in other airsheds is not very apparent in Thames. Another difference of note is the higher daily average observed on Monday compared with the other days of the week. Interestingly, as was the case for Hamilton and Morrinsville, the seasonal distribution pattern for Thames indicates a secondary peak of around 11 ug/m^3 for November through to January with a larger peak of 13 ug/m^3 over May to July which suggests a summertime/ non-home heating impact on PM_{10} concentrations.

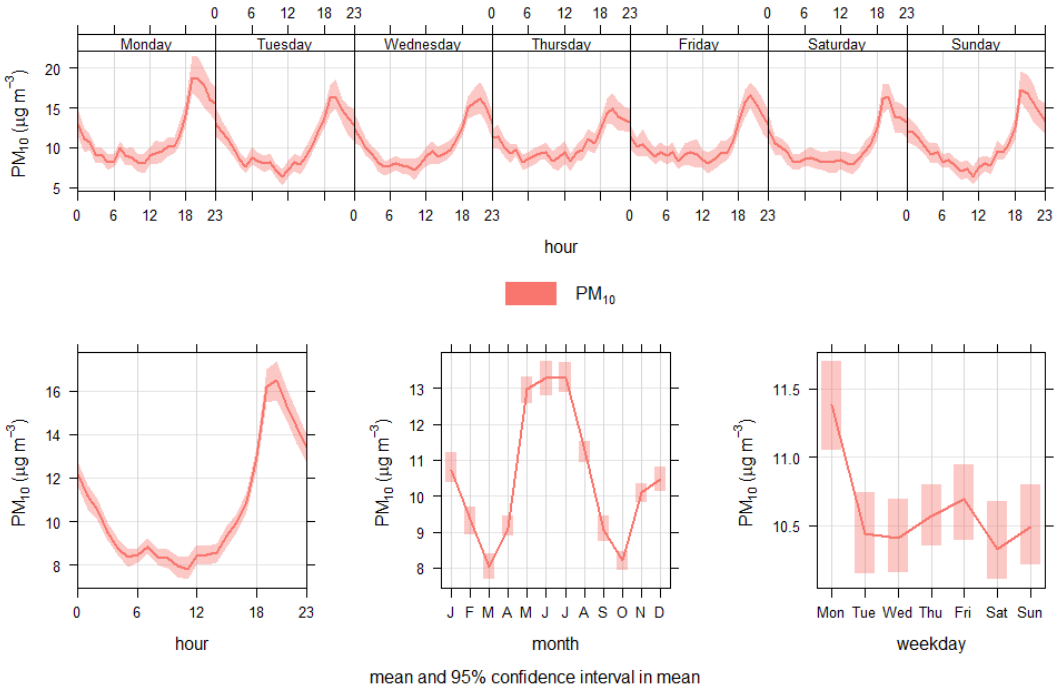


Figure 3.50 **Comparison of hourly, daily, weekly and monthly average PM_{10} concentrations measured in Thames for the period 2016 to 2020.**

No PM_{10} trend analysis was undertaken for Thames because of the limited data record.

An air emission inventory was carried out for Thames in 2009 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. The main source of PM_{10} emissions for Thames was domestic home heating, which accounted for 88% of total winter daily emissions in 2009. Outdoor burning contributed 6%, industry contributed 4% and transport contributed 2% to total emissions. Around 326 kilograms of PM_{10} are discharged on an average winter's day from these sources in Thames (Wilton & Baynes, 2010).

3.11 PM_{10} monitoring in Turangi

The annual average PM_{10} concentrations for the Turangi station are provided in Figure 3.51. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3. PM_{10} concentrations in the Turangi airshed have complied with both the 2005 and 2021 WHO annual average guideline for the full monitoring period of 2009 to 2018.

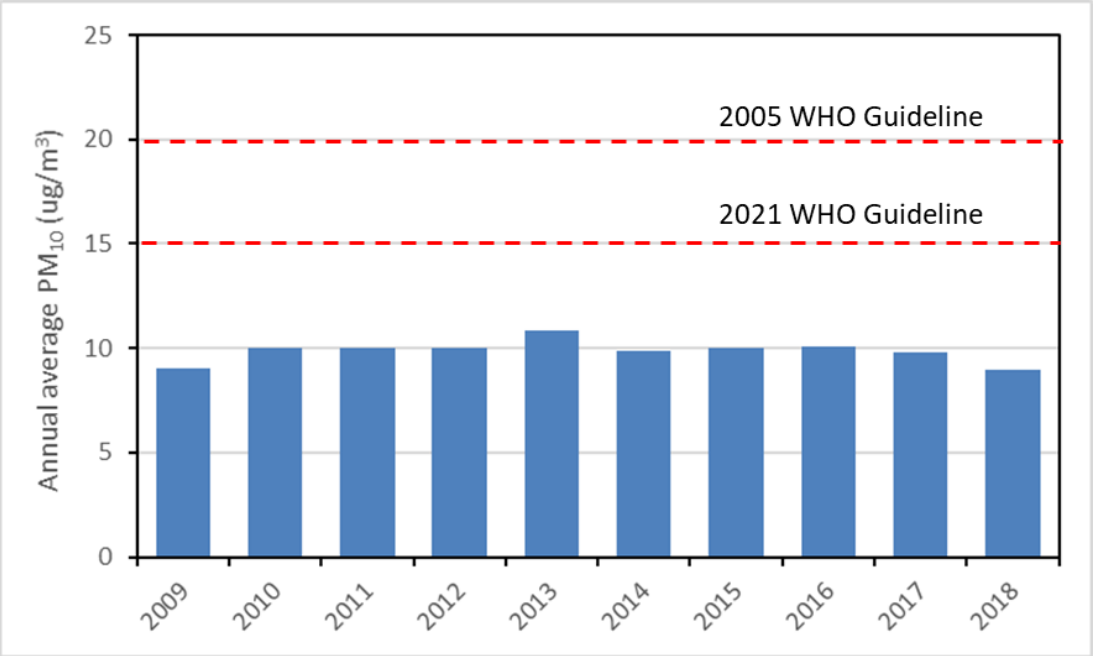


Figure 3.51 **Annual average PM_{10} concentrations measured at the Turangi station for the period 2009 to 2018.**

Figure 3.52 shows variations in the 24-hour average PM_{10} concentrations relative to air quality indicator categories in Turangi from 2009 to 2018. Approximately 90% of days per year experienced 24-hour average PM_{10} concentrations within the "good" category but with up to 95% of days falling within this category in 2018.

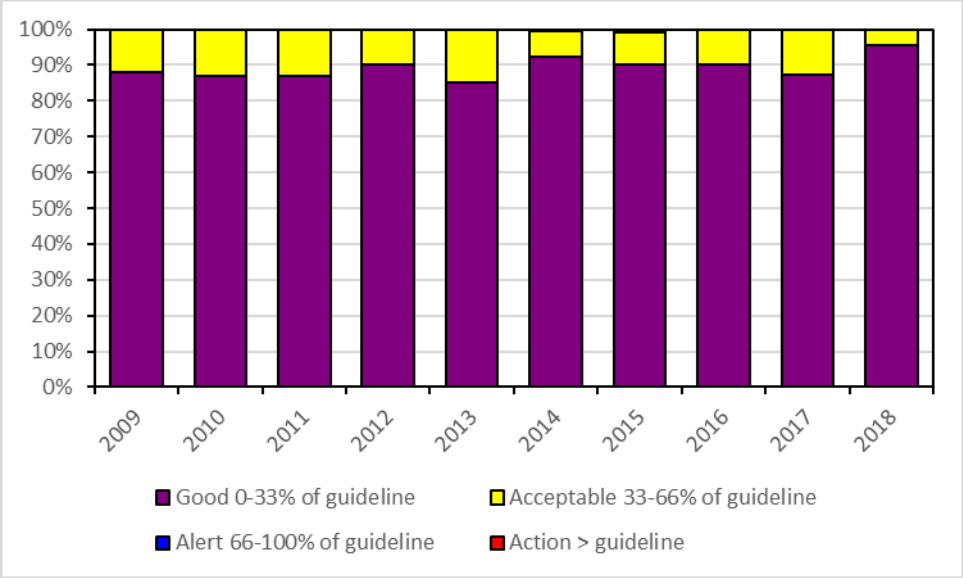


Figure 3.52 **Comparison of 24-hour average PM_{10} concentrations measured at the Turangi site from 2009 to 2018 relative to air quality indicator categories.**

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2009 to 2018 is shown in Figure 3.53. While there were no exceedances recorded over this monitoring period, the highest 24-hour average PM_{10} concentrations of 40 to 41 ug/m^3 were recorded in 2014 and 2015 respectively with lower maximum concentrations recorded prior to and subsequent to those two years.

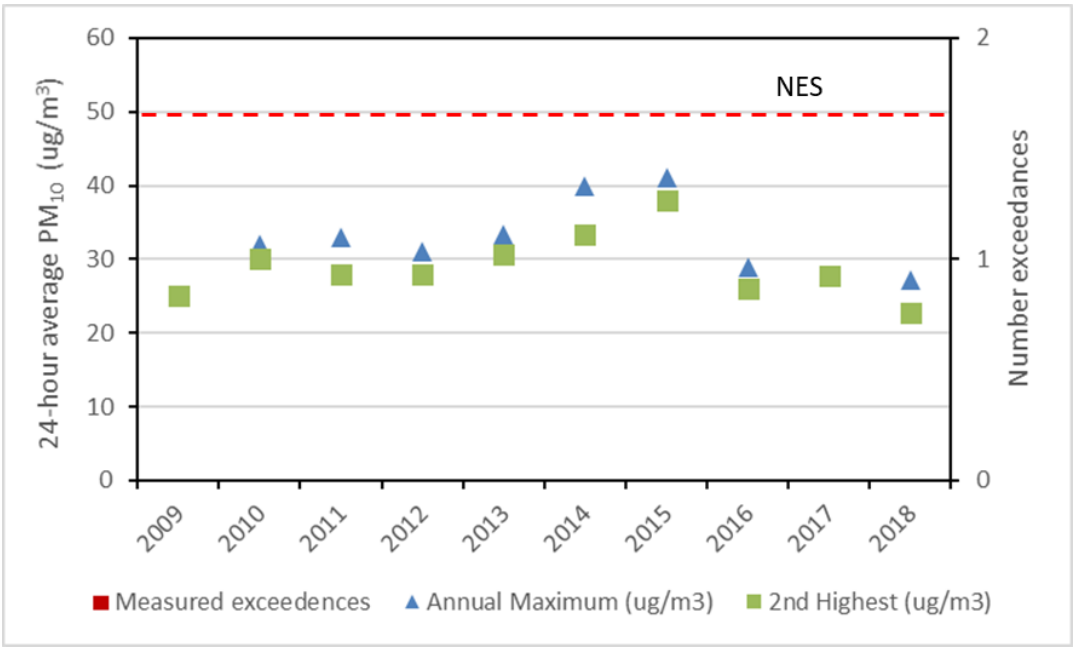


Figure 3.53 **Number of days (right axis) when the 24-hour average standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd highest concentration (left axis) measured from 2009 to 2018 in Turangi.**

A comparison of hourly, daily, weekly, and monthly average PM_{10} concentrations in Turangi over the period 2009 to 2018 is presented in Figure 3.54. The hourly pattern of elevated concentrations overnight and lower concentrations throughout the day is typical of the pattern observed where home heating is the major source of PM_{10}. However, unlike many of the other airsheds in the Waikato region that also have a smaller daytime peak typically centred around 9 am, the daytime peak in Turangi seems to be larger and more centred around midday, similar to that observed in Putaruru which may also be due to differences in local meteorology resulting

in a delayed peak compared to other airsheds. This pattern also seems to be similar on every day of the week, including weekends. As was also observed for Putaruru, the daily average seems to start off lower on Monday and gradually increase to a peak on Thursdays and Fridays before dropping back down on the weekend. The seasonal distribution pattern throughout the year is consistent with seasonal patterns observed for other airsheds in the Waikato region (apart from Hamilton, Morrisville and Thames), where home heating is the major source of PM_{10}, with the most elevated months being May through to August.

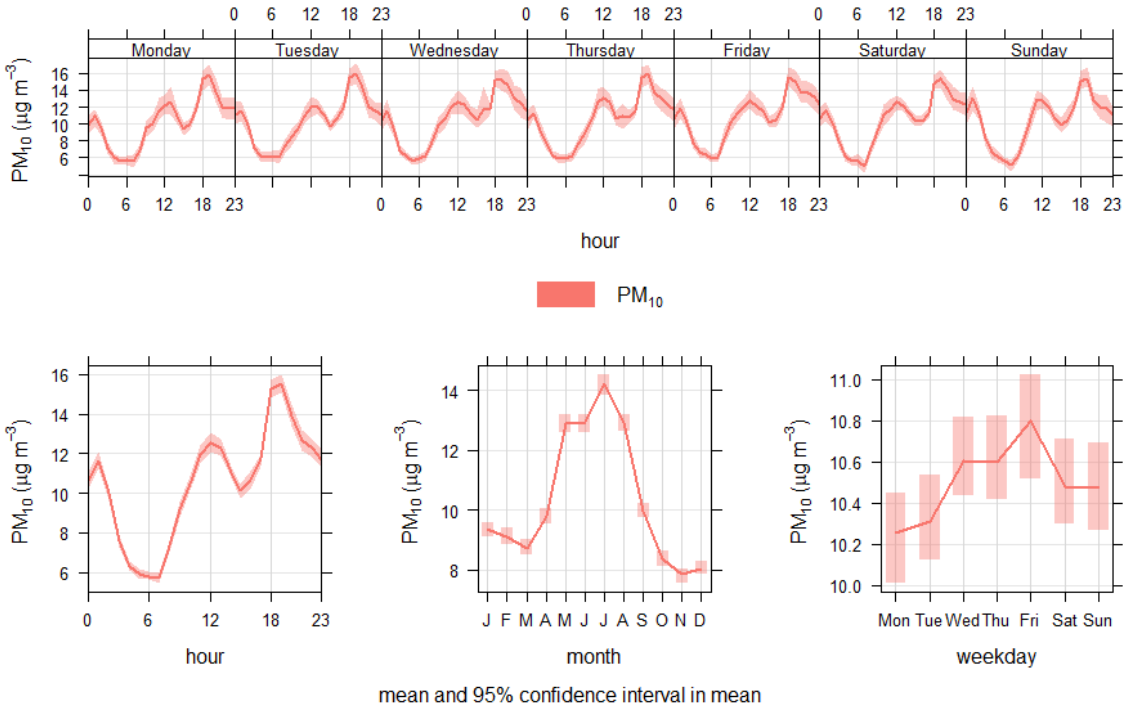


Figure 3.54 **Comparison of hourly, daily, weekly and monthly average PM_{10} concentrations measured in Turangi for the period 2009 to 2018.**

A trend analysis of PM_{10} data from the Turangi station, using the Theil-Sen method in OpenAir (with deseason function) indicates no statistically significant trend over the ten-year period 2009 to 2018 (refer to Figure 3.55).

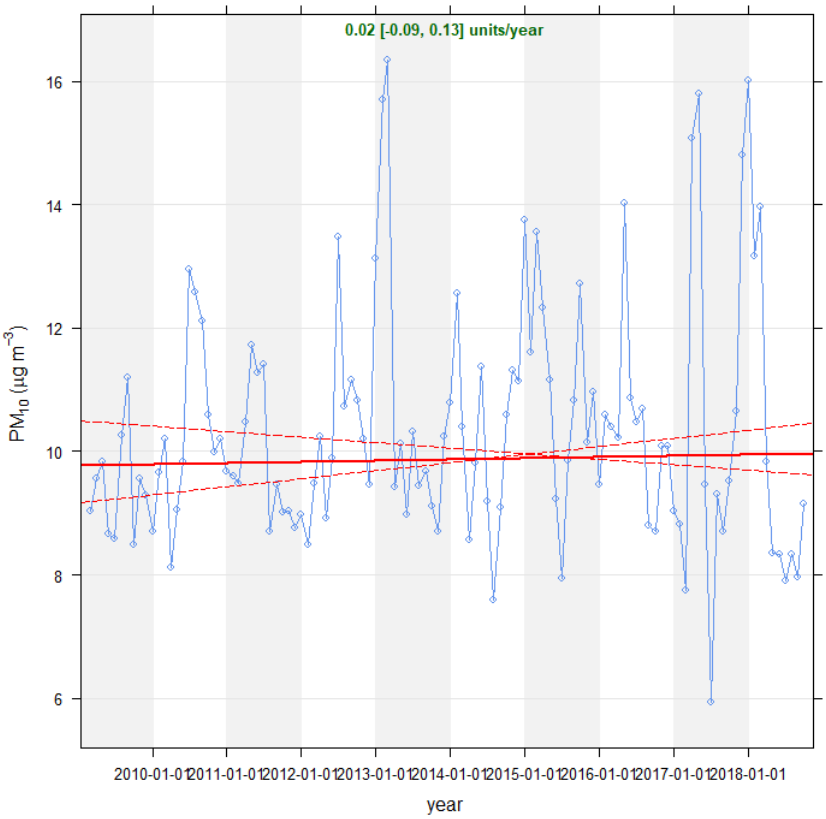


Figure 3.55 Turangi PM_{10} trend analysis for the period 2009 to 2018.

An air emission inventory was carried out for Turangi in 2006 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. The main source of PM_{10} emissions for Turangi was domestic home heating, which accounted for 89% of total winter daily emissions in 2006. Outdoor burning contributed 7% and transport contributed 4% to total emissions with a negligible contribution from industry. Around 188 kilograms of PM_{10} are discharged on an average winter's day from these sources in Turangi (Wilton, 2006).

3.12 PM_{10} monitoring in Cambridge

The annual average PM_{10} concentrations for the Cambridge station are provided in Figure 3.56. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3. PM_{10} concentrations in the Cambridge airshed have complied with both the 2005 and 2021 WHO annual average guideline for the full monitoring period of 2013 to 2016.

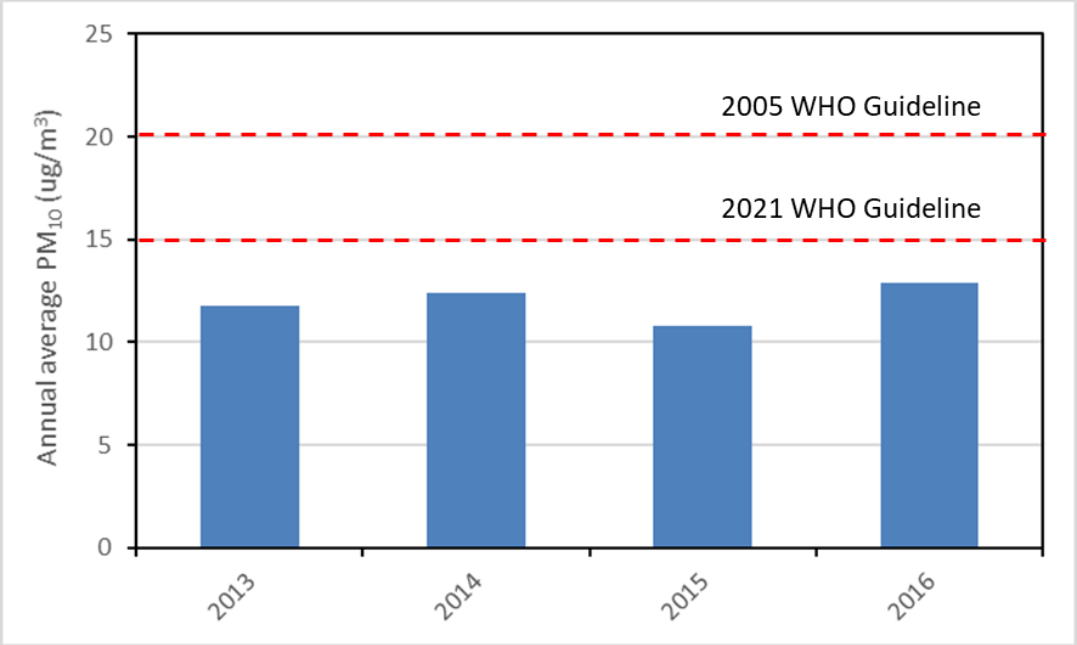


Figure 3.56 **Annual average PM_{10} concentrations measured at the Cambridge station for the period 2013 to 2016.**

Figure 3.57 shows variations in the 24-hour average PM_{10} concentrations relative to air quality indicator categories in Cambridge from 2013 to 2016. Approximately 80% of days per year experienced 24-hour average PM_{10} concentrations within the "good" category but with up to 90% of days falling within this category in 2015.

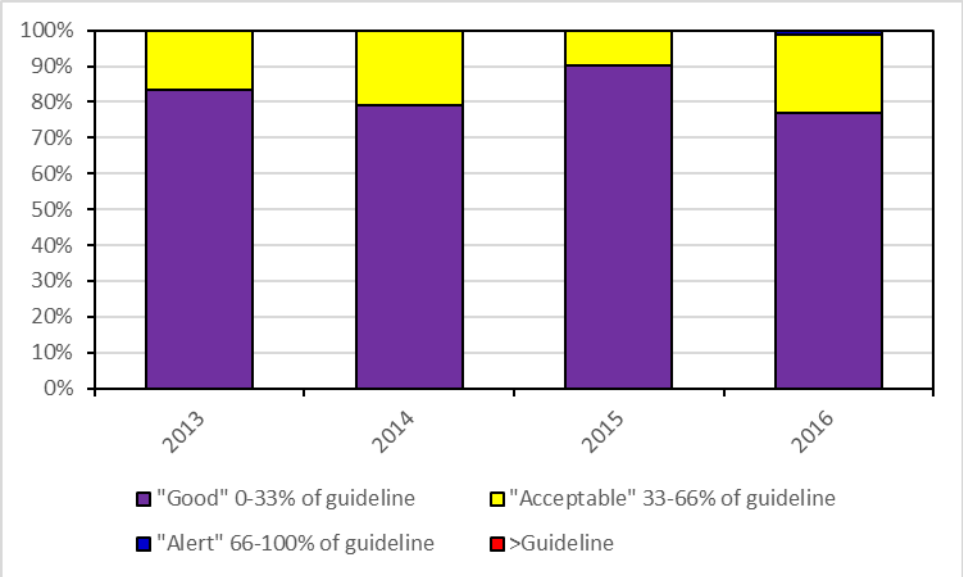


Figure 3.57 **Comparison of 24-hour average PM_{10} concentrations measured at the Cambridge site from 2013 to 2016 relative to air quality indicator categories.**

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2013 to 2016 is shown in Figure 3.58. There were no exceedances recorded over this monitoring period with the maximum 24-hour average PM_{10} concentrations ranging from 28 to 42 ug/m^3.

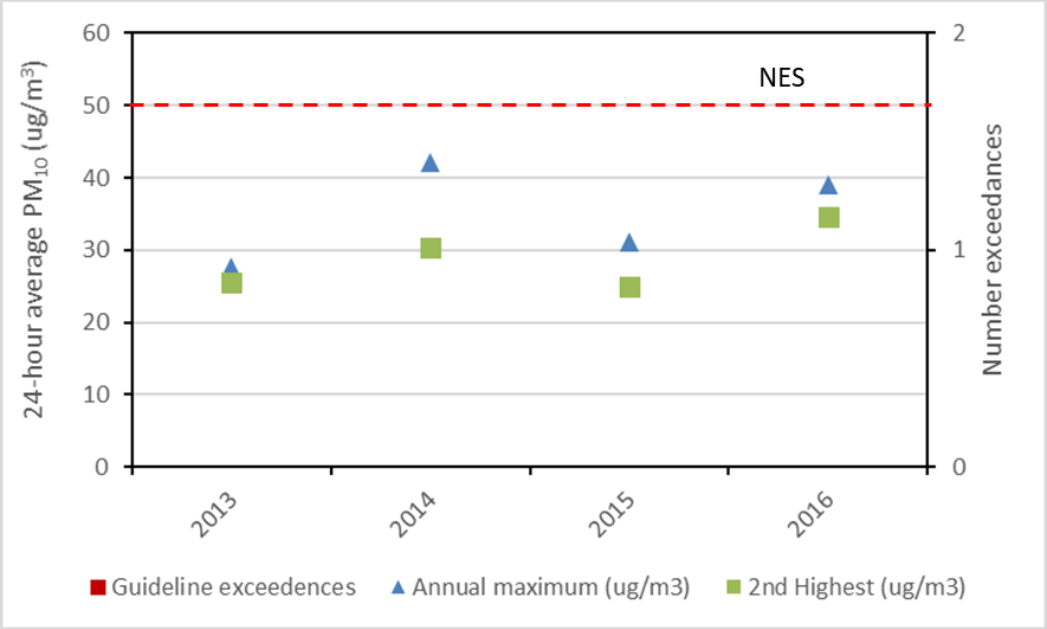


Figure 3.58 Number of days (right axis) when the 24-hour average standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd highest concentration (left axis) measured from 2013 to 2016 in Cambridge.

3.13 NO_2 monitoring in Cambridge

The results from NZTA's passive NO_2 monitoring programme from 2007 to 2020 (Figure 3.59) show that the Victoria St/ Queen St passive NO_2 site in Cambridge remained below the 2005 WHO annual average NO_2 guideline of 40 µg/m^3. However, if a comparison is made with the recently introduced 2021 WHO annual guideline of 10 µg/m^3 it is evident that this site would be in exceedance over the full monitoring period.

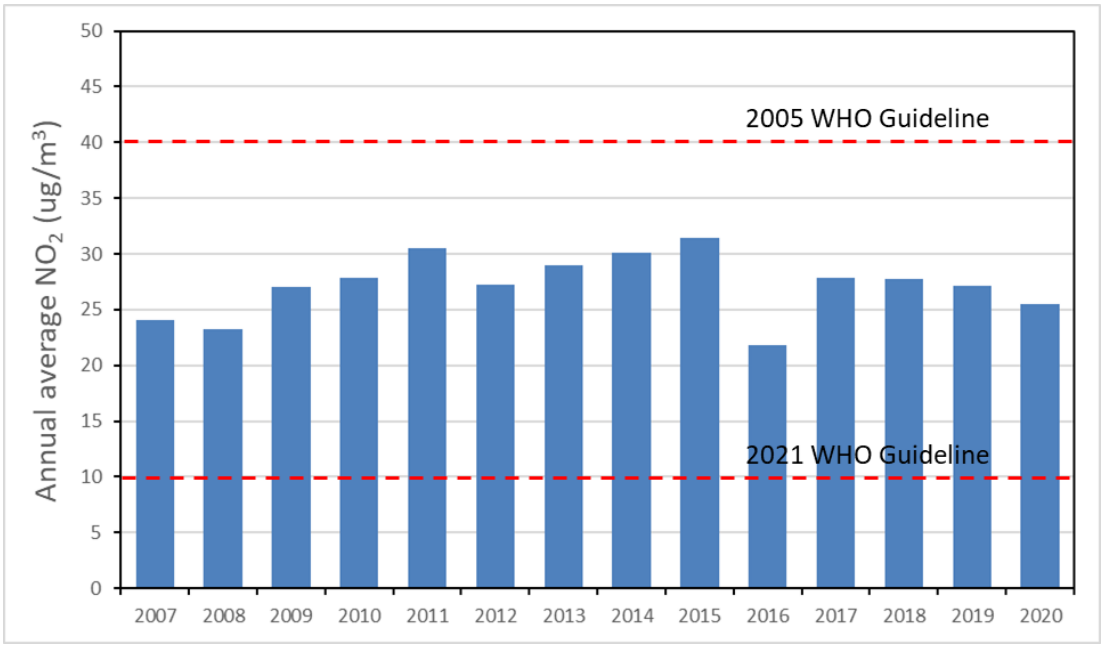


Figure 3.59 Annual average NO_2 measured in Cambridge (2007 to 2020).

A trend analysis of NO_2 data from the Victoria St/ Queen St site in Cambridge, using the Theil-Sen method in OpenAir (with deseason function) indicates a statistically significant improving trend ($p < 0.001$) over the ten year period 2011 to 2020 (refer to Figure 3.60).

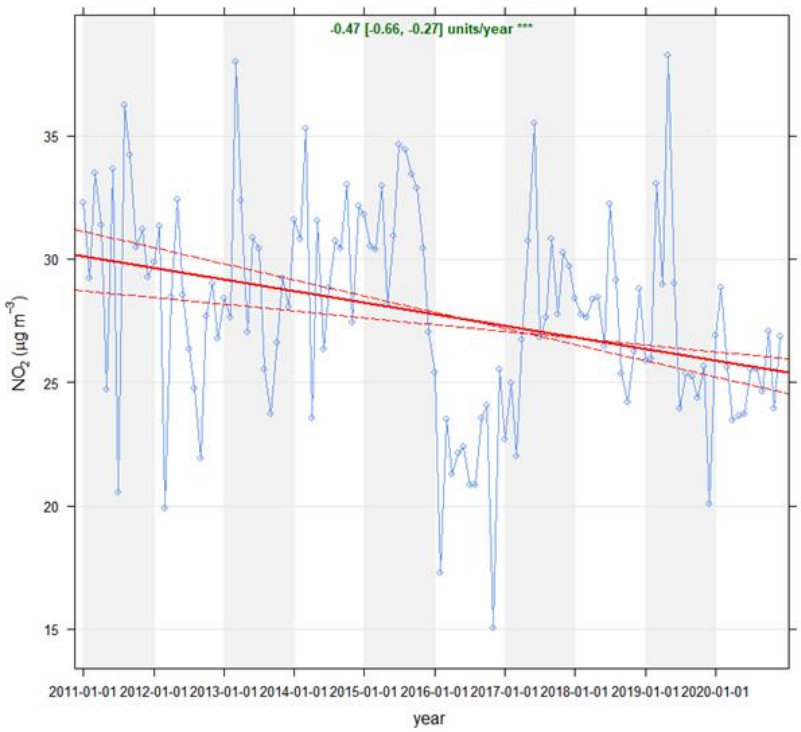


Figure 3.60 Cambridge NO_2 trend analysis for the period 2011 to 2020.

3.14 PM_{10} monitoring in Te Awamutu

The annual average PM_{10} concentrations for the Te Awamutu station are provided in Figure 3.61. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3. PM_{10} concentrations in the Te Awamutu airshed complied with both the 2005 and 2021 WHO annual average guideline for the full monitoring period of 2013 to 2016.

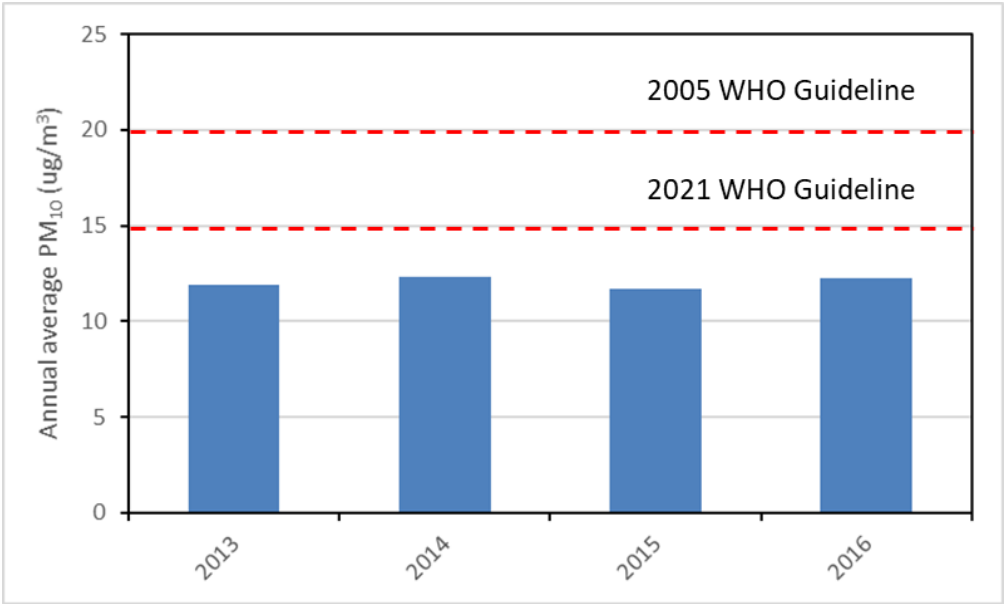


Figure 3.61 Annual average PM_{10} concentrations measured at the Te Awamutu station for the period 2013 to 2016.

Figure 3.62 shows variations in the 24-hour average PM_{10} concentrations relative to air quality indicator categories in Te Awamutu from 2013 to 2016. Approximately 85% of days per year experienced 24-hour average PM_{10} concentrations within the "good" category over the full monitoring period.

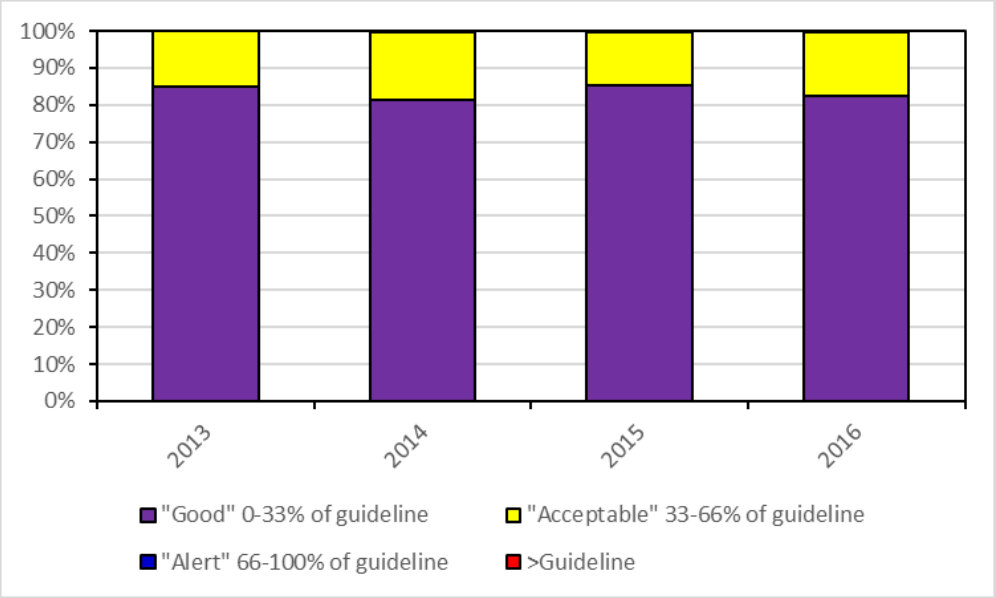


Figure 3.62 Comparison of 24-hour average PM_{10} concentrations measured at the Te Awamutu site from 2013 to 2016 relative to air quality indicator categories.

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2013 to 2016 is shown in Figure 3.63. There were no exceedances recorded over this monitoring period with the maximum 24-hour average PM_{10} concentrations ranging from 32 to 45 ug/m^3.

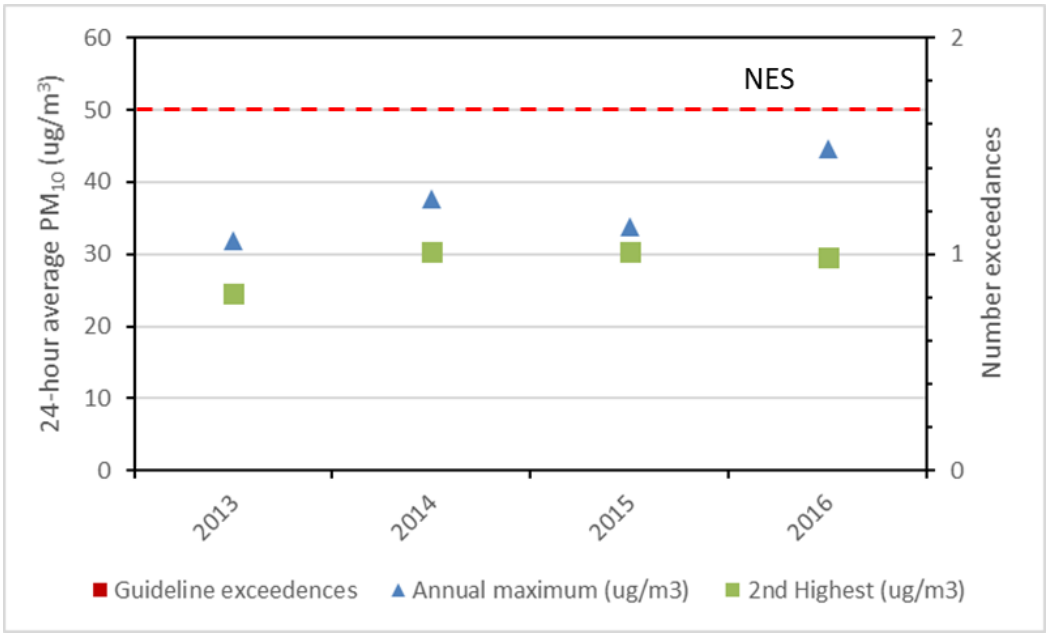


Figure 3.63 Number of days (right axis) when the 24-hour average standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd highest concentration (left axis) measured from 2013 to 2016 in Te Awamutu.

An air emission inventory was carried out for Te Awamutu in 2006 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. The main source of PM_{10} emissions for Te Awamutu was domestic home heating, which accounted for 58% of total winter daily emissions in 2006. Outdoor burning contributed 23%, industry contributed 15% and transport contributed 4% to total emissions. The main source of industrial PM_{10} emissions in Te Awamutu was the burning of gas (25%) and coal (75%) and milk powder

emissions from Fonterra. Around 416 kilograms of PM_{10} are discharged on an average winter's day from these sources in Te Awamutu (Wilton, 2006).

3.15 NO_2 monitoring in Te Awamutu

The results from NZTA's passive NO_2 monitoring programme from 2010 to 2020 (Figure 3.64) show that the Ohaupo Rd/ Albert Drive passive NO_2 site in Te Awamutu remained below the 2005 WHO annual average NO_2 guideline of 40 µg/m^3. However, if a comparison is made with the recently introduced 2021 WHO annual guideline of 10 µg/m^3 it is evident that this site would be in exceedance over the full monitoring period.

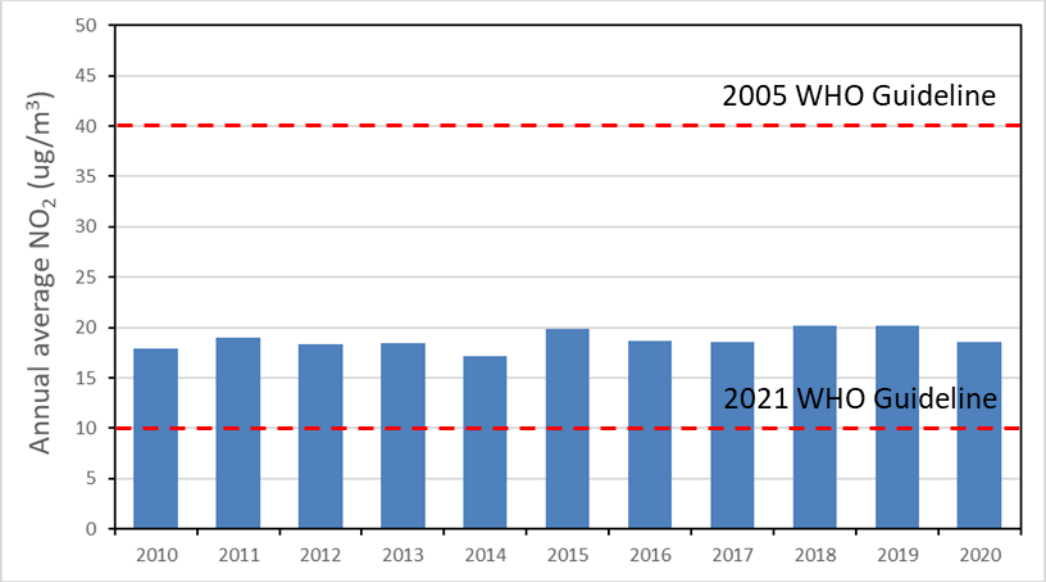


Figure 3.64 Annual average NO_2 measured in Te Awamutu (2010 to 2020).

A trend analysis of NO_2 data from the Ohaupo Rd/ Albert Drive site in Te Awamutu, using the Theil-Sen method in OpenAir (with deseason function) indicates no statistically significant trend over the ten-year period 2011 to 2020 (refer to Figure 3.65).

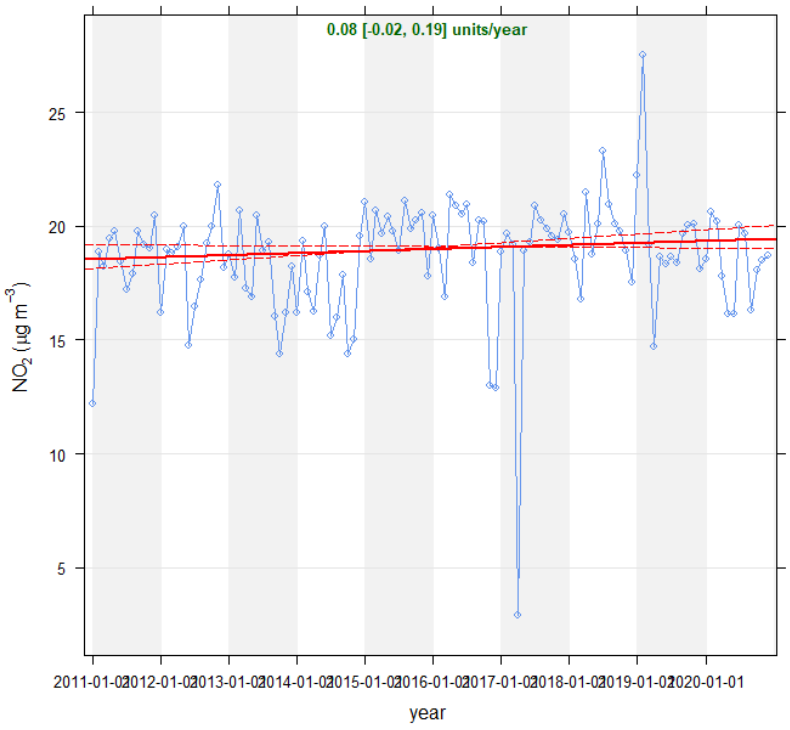


Figure 3.65 Te Awamutu NO_2 trend analysis for the period 2011 to 2020.

3.16 PM_{10} monitoring in Ngaruawahia

The annual average PM_{10} concentrations for the Ngaruawahia station are provided in Figure 3.66. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3. PM_{10} concentrations in the Ngaruawahia airshed complied with both the 2005 and 2021 WHO annual average guideline for the full monitoring period of 2008 to 2012.

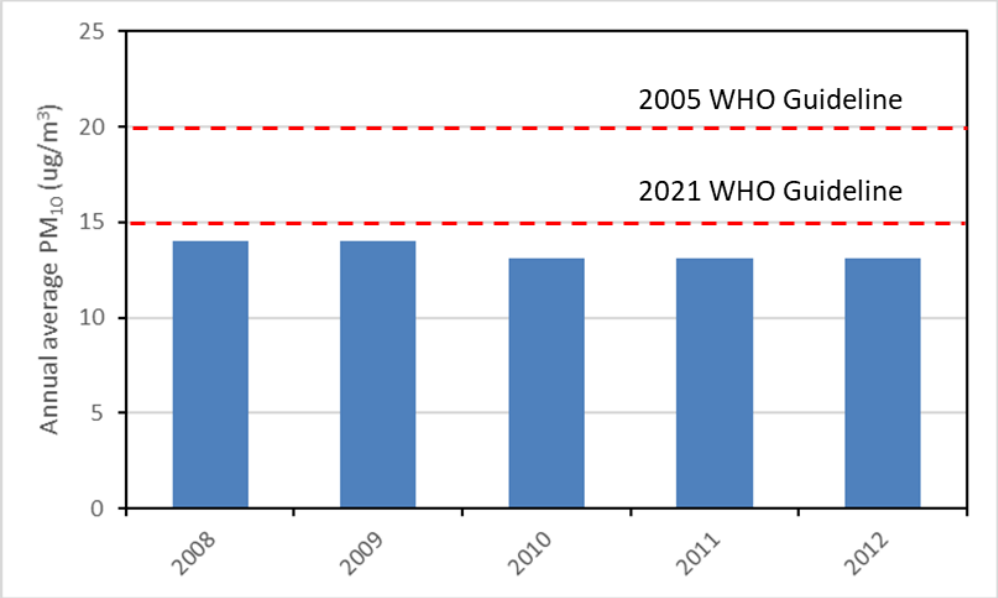


Figure 3.66 Annual average PM_{10} concentrations measured at the Ngaruawahia station for the period 2008 to 2012.

Figure 3.67 shows variations in the 24-hour average PM_{10} concentrations relative to air quality indicator categories in Ngaruawahia from 2008 to 2012. Approximately 75% of days per year experienced 24-hour average PM_{10} concentrations within the "good" category over the full monitoring period.

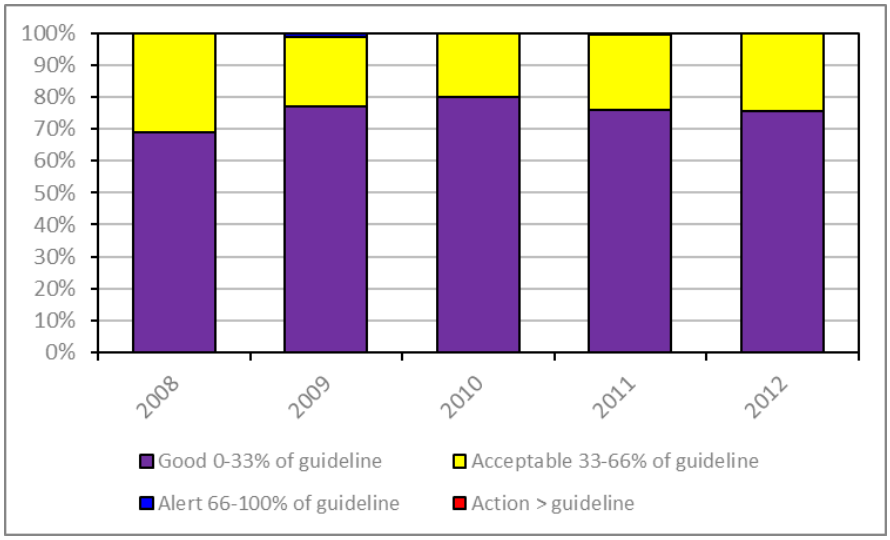


Figure 3.67 Comparison of 24-hour average PM_{10} concentrations measured at the Ngaruawahia site from 2008 to 2012 relative to air quality indicator categories.

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2016 to 2020 is shown in Figure 3.68. Only one exceedance (24-hour average of 113 ug/m^3) was recorded over this monitoring period in September 2009. This

exceedance identified at the time as being caused by the Australian dust storm which also caused an exceedance in Hamilton and Matamata on the same day. The maximum 24-hour average PM_{10} concentrations over the monitoring period, excluding the one exceedance in 2009, ranged from 29 to 44 ug/m^3.

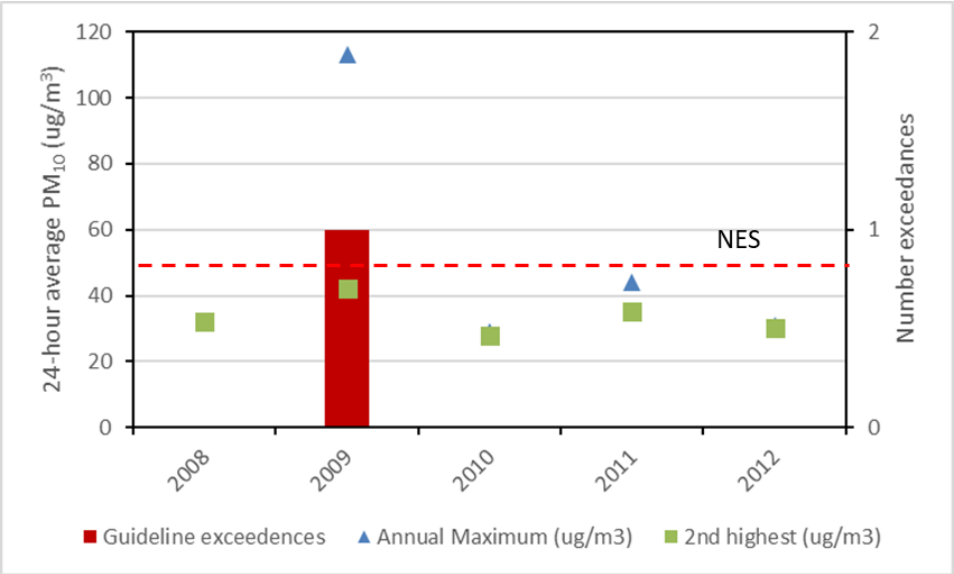


Figure 3.68 Number of days (right axis) when the 24-hour average standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd highest concentration (left axis) measured from 2008 to 2012 in Ngaruawahia.

An air emission inventory was carried out for Ngaruawahia in 2006 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. The main source of PM_{10} emissions for Ngaruawahia was domestic home heating, which accounted for 86% of total winter daily emissions in 2006. Outdoor burning contributed 12% and transport contributed 2% to total emissions with a negligible contribution from industry. Around 386 kilograms of PM_{10} are discharged on an average winter's day from these sources in Ngaruawahia (Wilton, 2006).

3.17 PM_{10} monitoring in Matamata

The annual average PM_{10} concentrations for the Matamata station are provided in Figure 3.69. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3. PM_{10} concentrations in the Matamata airshed complied with both the 2005 and 2021 WHO annual average guideline for the full monitoring period of 2005 to 2012.

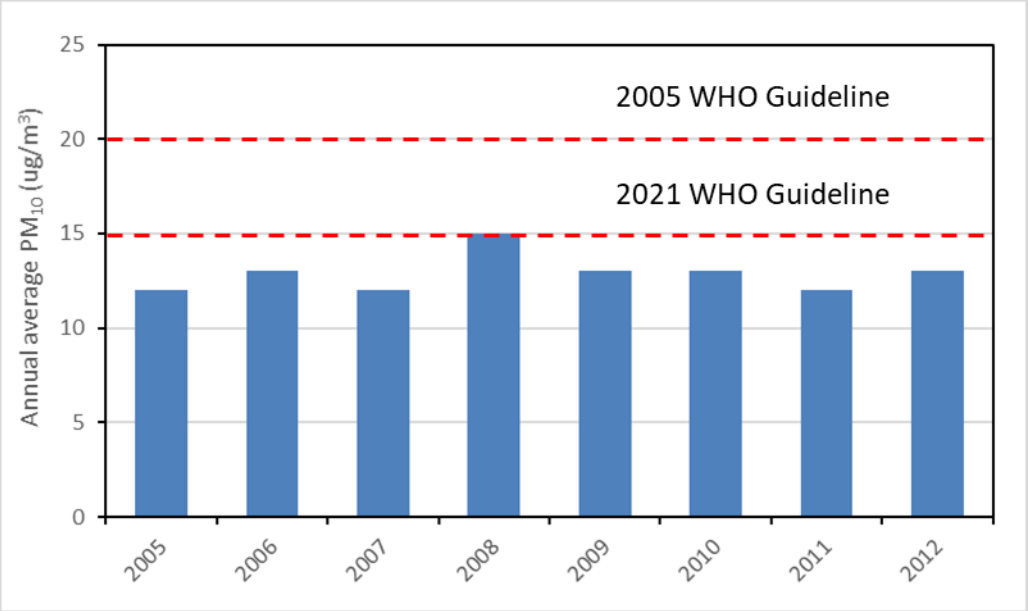


Figure 3.69 Annual average PM_{10} concentrations measured at the Matamata station for the period 2005 to 2012.

Figure 3.70 shows variations in the 24-hour average PM_{10} concentrations relative to air quality indicator categories in Matamata from 2005 to 2012. Approximately 80% of days per year experienced 24-hour average PM_{10} concentrations within the "good" category over the full monitoring period apart from 2008 where the proportion of days was lower at 69%.

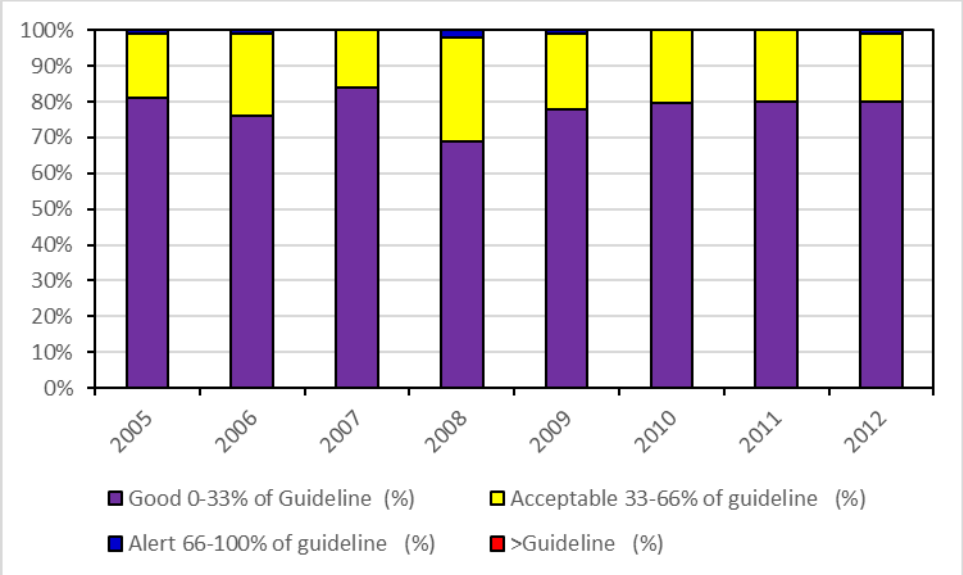


Figure 3.70 Comparison of 24-hour average PM_{10} concentrations measured at the Matamata site from 2005 to 2012 relative to air quality indicator categories.

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2016 to 2020 is shown in Figure 3.71. Only one exceedance (24-hour average of 93 ug/m^3) was recorded over this monitoring period in September 2009. This exceedance was identified at the time as being caused by the Australian dust storm which also caused an exceedance in Hamilton and Ngaruawahia on the same day. The maximum 24-hour average PM_{10} concentrations over the monitoring period, excluding the one exceedance in 2009, ranged from 31 to 45 ug/m^3.

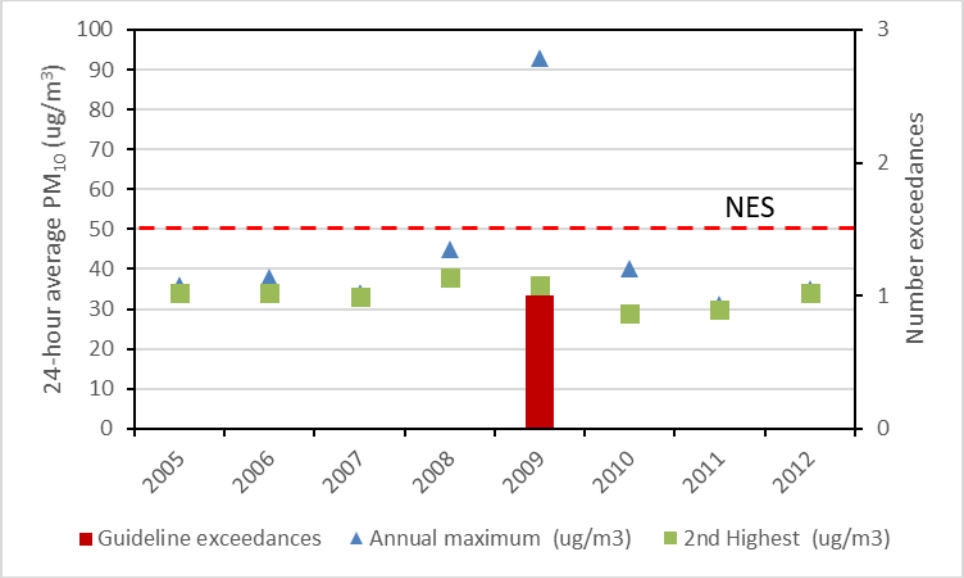


Figure 3.71 Number of days (right axis) when the 24-hour average standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd highest concentration (left axis) measured from 2005 to 2012 in Matamata.

An air emission inventory was carried out for Matamata in 2001 and 2006 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. The main source of PM_{10} emissions for Matamata was domestic home heating, which accounted for 92% of total winter daily emissions in 2006. Outdoor burning contributed 4%, industry contributed 0.6% and transport contributed 3.6% to total emissions. Around 229 kilograms of PM_{10} are discharged on an average winter's day from these sources in Matamata (Smith & Wilton, 2007).

3.18 PM_{10} monitoring in Waihi

The annual average PM_{10} concentrations for the Waihi station are provided in Figure 3.72. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 µg/m^3 (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 µg/m^3. PM_{10} concentrations in the Waihi airshed complied with both the 2005 and 2021 WHO annual average guideline for the full monitoring period of 2008 to 2011.

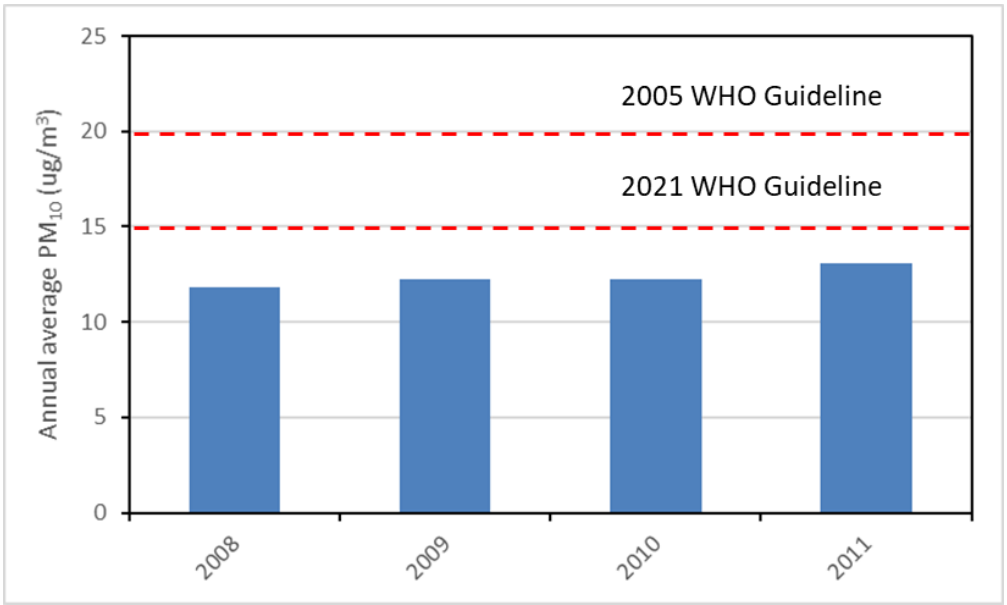


Figure 3.72 Annual average PM_{10} concentrations measured at the Waihi station for the period 2008 to 2011.

Figure 3.73 shows variations in the 24-hour average PM_{10} concentrations relative to air quality indicator categories in Waihi from 2008 to 2011. Approximately 80% of days per year experienced 24-hour average PM_{10} concentrations within the "good" category over the full monitoring period apart from 2008 where the proportion of days was higher at 87%.

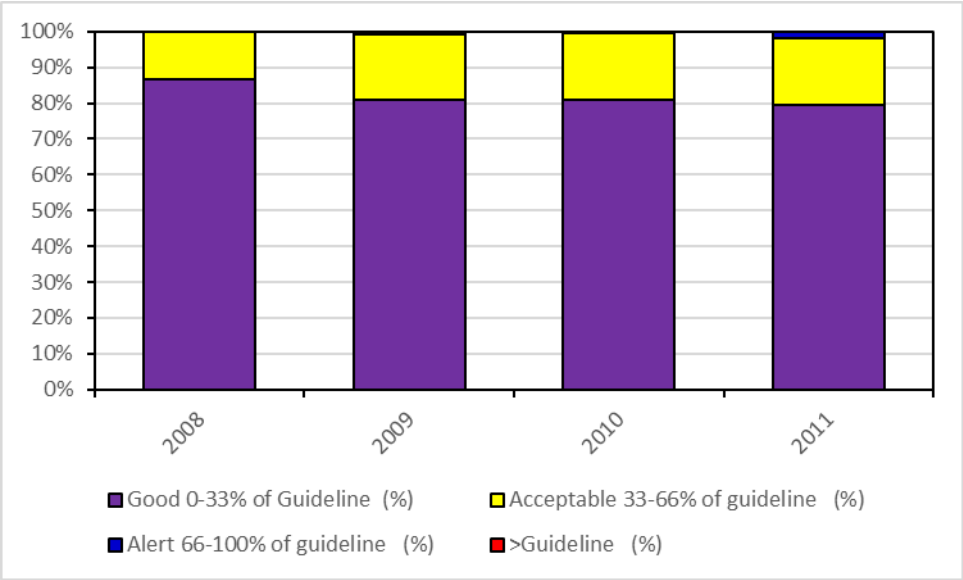


Figure 3.73 Comparison of 24-hour average PM_{10} concentrations measured at the Waihi site from 2008 to 2011 relative to air quality indicator categories.

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2008 to 2011 is shown in Figure 3.74. There were no exceedances recorded over this monitoring period with the maximum 24-hour average PM_{10} concentrations ranging from 33 to 45 ug/m^3.

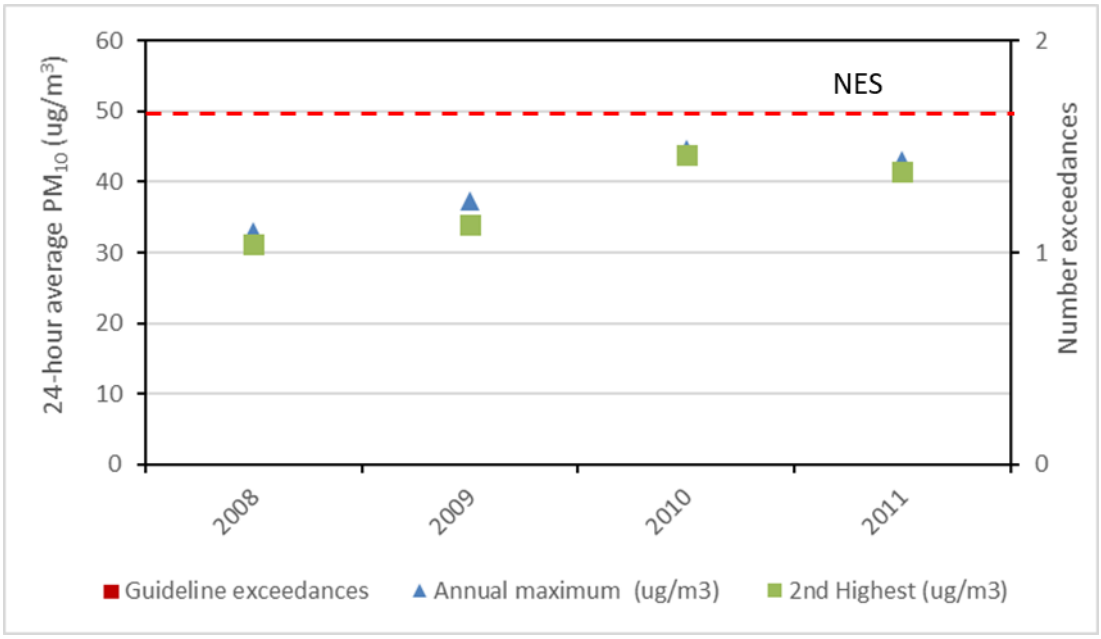


Figure 3.74 Number of days (right axis) when the 24-hour average standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd highest concentration (left axis) measured from 2008 to 2011 in Waihi.

An air emission inventory was carried out for Waihi in 2006 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. The main source of

PM_{10} emissions for Waihi was domestic home heating, which accounted for 59% of total winter daily emissions in 2006. It is estimated that industry contributes 37% of winter PM_{10} emissions at Waihi. However, caution is required due to considerable uncertainty of fugitive emissions from mining activity. Therefore, the magnitude of PM_{10} emissions and relative contribution from Waihi industry is uncertain. Outdoor burning contributed 2% and transport also contributed around 2% to total emissions. Around 346 kilograms of PM_{10} are discharged on an average winter's day from these sources in Waihi (Smith & Wilton, 2007).

3.19 PM_{10} monitoring in Huntly

The annual average PM_{10} concentrations for the two ambient air quality monitoring stations in Huntly airshed (Croft Tce and i-Site Centre) and the two stations in rural areas outside the Huntly airshed (Pukekapia Road and Frost Road) are provided in Figure 3.75. Note that the Frost Road site is a replacement station for an earlier nearby station on Ralph Road. These stations are owned and managed by Genesis Energy. Up until 2012, data was reported by Genesis on a per calendar basis. From 2012 onwards, reporting was per financial year (1 July to 30 June) and therefore the summary statistics provided to Waikato Regional Council straddle two years from this point onwards. PM_{10} concentrations are compared against the 2005 WHO annual average guideline of 20 $\mu g/m^3$ (equivalent to the 2002 MfE guideline) and the recently introduced 2021 WHO annual average guideline of 15 $\mu g/m^3$. Annual average PM_{10} concentrations at these stations have all complied with both the 2005 and 2021 WHO annual average guidelines except for two minor exceedances in 2006 and 2008 at the i-Site Centre. The annual averages have been gradually decreasing with this decrease most noticeable in the two Huntly urban areas.

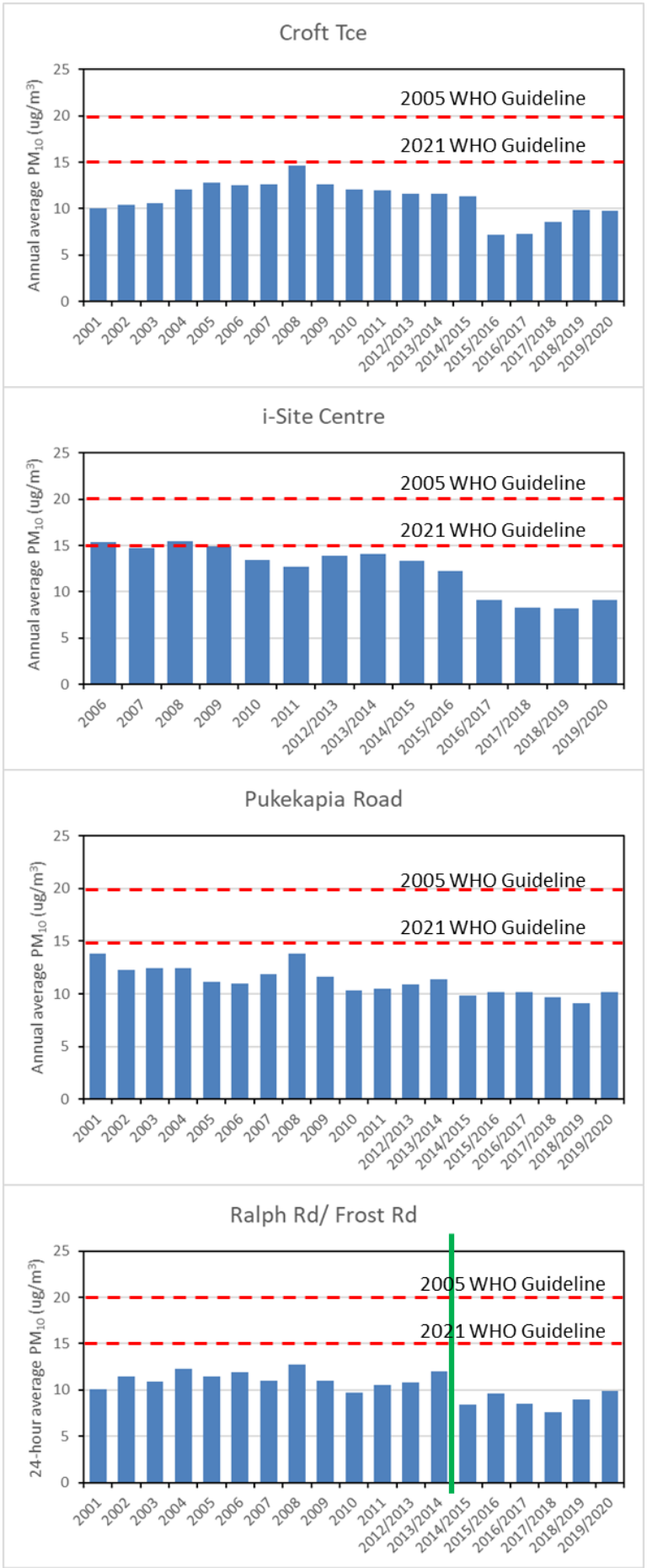


Figure 3.75 **Annual average PM_{10} concentrations measured at the four Huntly stations for the period 2001 to 2020 (note the green line identifies when the Ralph Road station was replaced with the Frost Road station).**

Figure 3.76 shows variations in the 24-hour average PM_{10} concentrations relative to air quality indicator categories in Huntly from 2001 to 2020. As for the observed recent reductions in annual averages, the proportion of PM_{10} data falling within the "good" category has increased from about 2015 to more than 95%. An interesting, but unexplainable anomaly to this is the increase in data falling within the alert range in 2017/2018 at the rural Pukekapia Station.

The number of days when the PM_{10} standard of 50 $\mu g/m^3$ as a 24-hour average was exceeded, the maximum 24-hour average concentration and the second highest 24-hour average concentration over the period 2001 to 2020 at the four Huntly stations is shown in Figure 3.77

The exceedances identified in 2009 and 2019/2020 at all four stations were linked to the 2009 Australian dust storm and the 2019 Australian bush fires respectively when similar exceedances were recorded at other monitoring sites within the upper North Island.

An analysis of the other exceedance at the Croft Terrace site, on 10 June 2006, and the other three exceedances at the i-Site Centre site, on 28 June 2006, 29 June 2006 and 24 June 2009, indicate that they were probably caused by domestic heating during cold, calm winter weather conditions (Genesis Energy, 2011).

This analysis is supported by comparing the i-Site monitoring data with the monitoring data from Ngaruawahia which share similar geographic properties. Ngaruawahia's PM_{10} concentrations are dominated by home heating and are not influenced by a large discharge such as the Huntly Power Station, indicating that a similar situation exists in Huntly (Genesis Energy, 2011).

The series of exceedances over the period 2003 to 2008 at the Pukekapia Rd station were identified as being likely caused by non-power station related sources at the time due to analysis of wind direction at the time (Smith, 2006b; Genesis Energy, 2008). Excluding these exceedances, maximum PM_{10} concentrations have typically been below 40 ug/m^3 at all four stations.

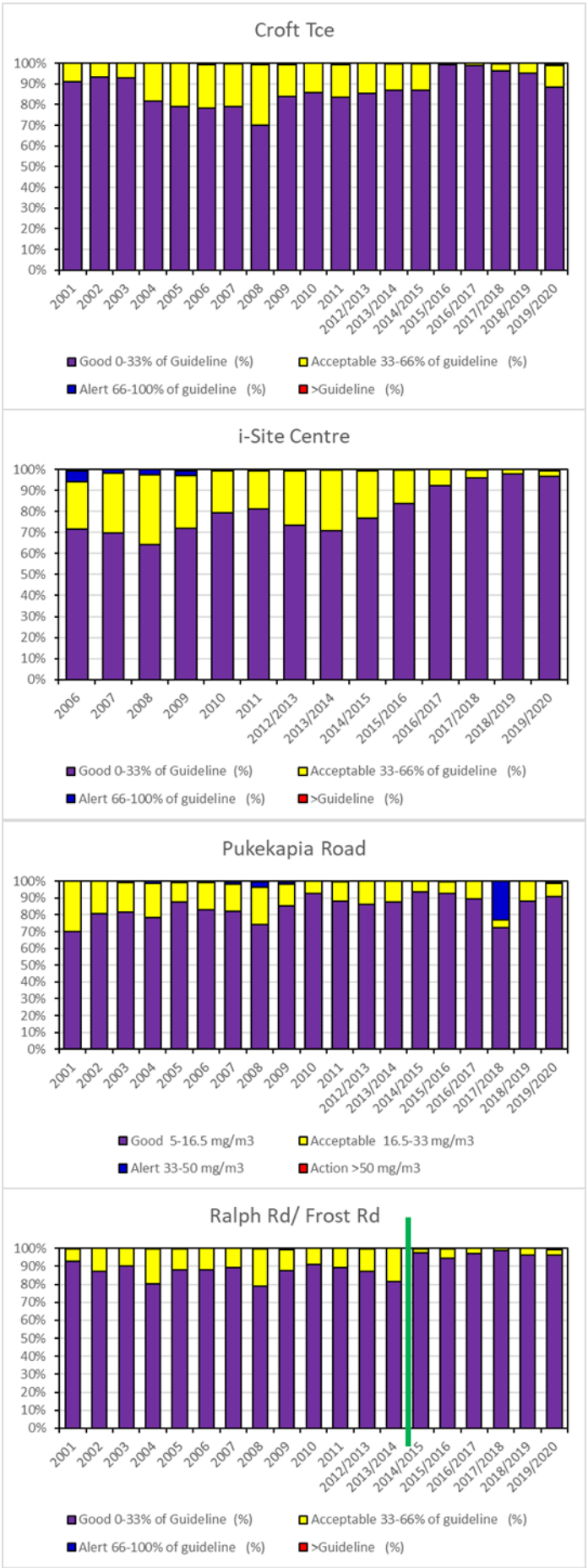


Figure 3.76 Comparison of 24-hour average PM_{10} concentrations at the four Huntly stations for the period 2001 to 2020 relative to air quality indicator categories (note the green line identifies when the Ralph Road station was replaced with the Frost Road station).

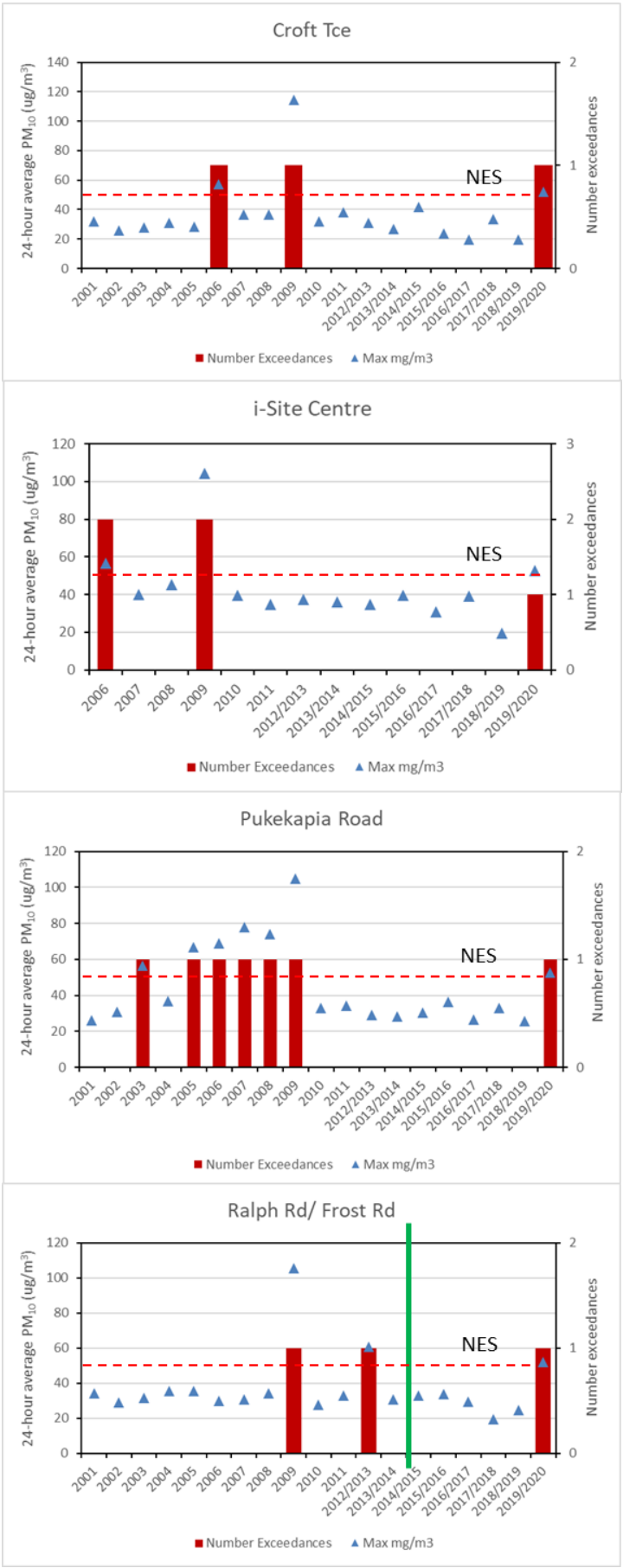


Figure 3.77 **Number of days (right axis) when the 24-hour average PM_{10} standard of 50 µg/m³ was exceeded compared with the maximum concentration and the 2nd highest concentration (left axis) measured at the four Huntly stations from 2001 to 2020 (note the green line identifies when the Ralph Road station was replaced with the Frost Road station).**

An air emission inventory was carried out for Huntly in 2001 and 2009 to estimate the amount of emissions of air contaminants, in particular PM_{10}, occurring during the year from domestic heating, motor vehicles, industrial and commercial activities and outdoor burning sources. It should be noted that this inventory did not include emissions from the Huntly Power Station, which is located outside the Huntly airshed boundary. Domestic heating was the main source of PM_{10} emissions from within the Huntly airshed in 2009, accounting for 91% of total emissions. Other sources in Huntly included outdoor burning (6%) motor vehicles (2%) and industry (1%). On an average winter's day, around 512 kilograms of PM_{10} are discharged from these sources (Wilton & Baynes, 2010).

3.20 NO_2 monitoring in Huntly

Variations in the 1-hour average NO_2 concentrations for Genesis Energy's i-Site Centre and Frost Road ambient air quality monitoring stations relative to MfE's air quality indicator categories in Huntly from 2006 to 2020 are provided in Figure 3.78. Because the NES air quality standard for NO_2 is based on a 1-hour average, the comparison includes the additional air quality indicator category "Excellent" which represents 0 to 10% of the air quality standard. For the Frost Road station, nearly 100% of the data has fallen within this "Excellent" category except for the 2016/2017 year where it dropped slightly to 98%. For the i-Site Centre, the NO_2 data falling within the "Excellent" category has been a lot more variable, ranging from 62 to 88% with no obvious trend. However, close to 100% of the data recorded at the i-Site Centre has fallen within the "Good" category over the full monitoring period since 2006.

Figure 3.78 Comparison of 1-hour average NO_2 concentrations at the Frost Road and i-Site Centre Huntly stations for the period 2006 to 2020 relative to air quality indicator categories.

The annual maximum 1-hour average NO_2 concentrations recorded at Genesis Energy's i-Site Centre and Frost Road ambient air quality monitoring stations are compared against the NES air quality standard of 200 µg/m^3 (refer to Figure 3.79). No exceedances of the standard have been recorded at either station with the maximum concentrations ranging from 13 to 49 ug/m^3 at Frost Road and 52 to 117 ug/m^3 at the i-Site Centre.

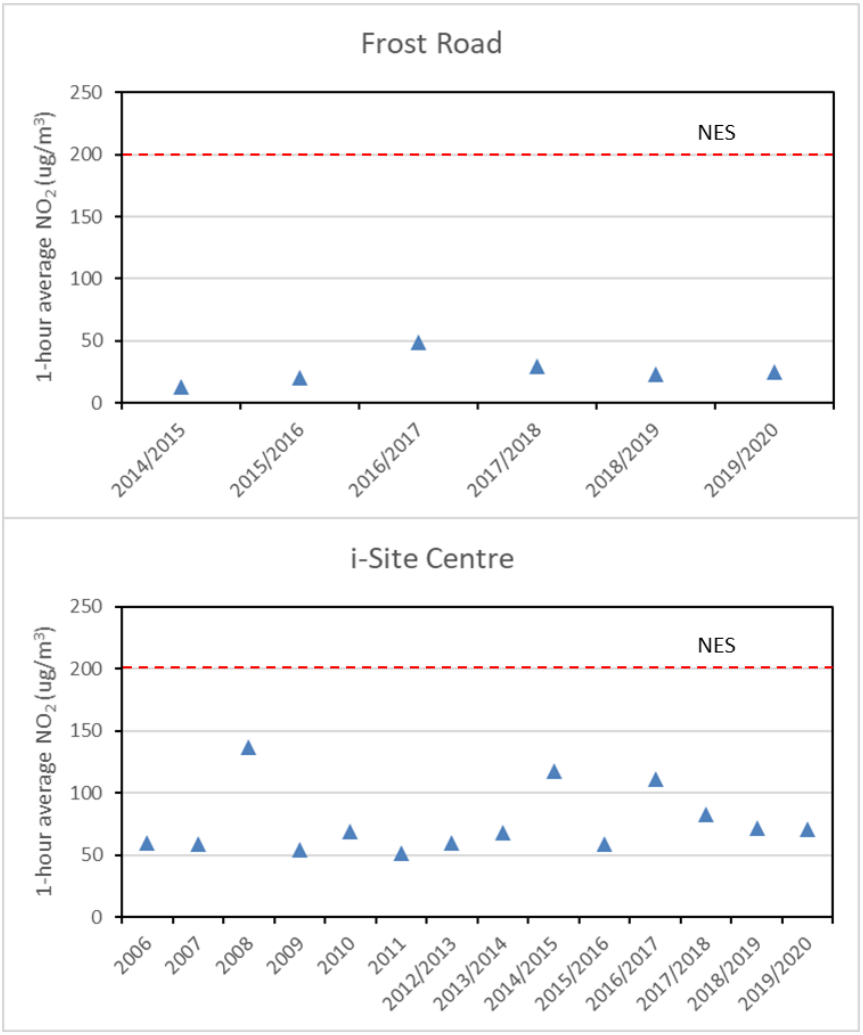


Figure 3.79 Maximum 1-hour average NO_2 concentrations measured at the Frost Road and i-Site Centre Huntly stations for the period 2006 to 2020.

3.21 SO_2 monitoring in Huntly

Variations in the 1-hour average SO_2 concentrations for Genesis Energy's i-Site Centre, Croft Terrace, Pukekapia Road and Frost Road ambient air quality monitoring stations relative to MfE's air quality indicator categories in Huntly from 2003 to 2020 are provided in Figure 3.80. Because the NES air quality standard for SO_2 is based on a 1-hour average, the comparison includes the additional air quality indicator category "Excellent" which represents 0 to 10% of the air quality standard. Nearly 100% of the data for all four stations has fallen within the "Excellent" category over the full monitoring period.

The annual maximum 1-hour average SO_2 concentrations recorded at Genesis Energy's i-Site Centre, Croft Terrace, Pukekapia Road and Frost Road ambient air quality monitoring stations are compared against the NES air quality standard of 350 µg/m^3 (refer to Figure 3.81). No exceedances of the standard have been recorded at any of the four stations with the maximum concentrations ranging from 11 to 141 ug/m^3 at Pukekapia Road, 8 to 53 ug/m^3 at Frost Road, 18 to 109 ug/m^3 at the i-Site Centre and 16 to 128 ug/m^3 at Croft Terrace.

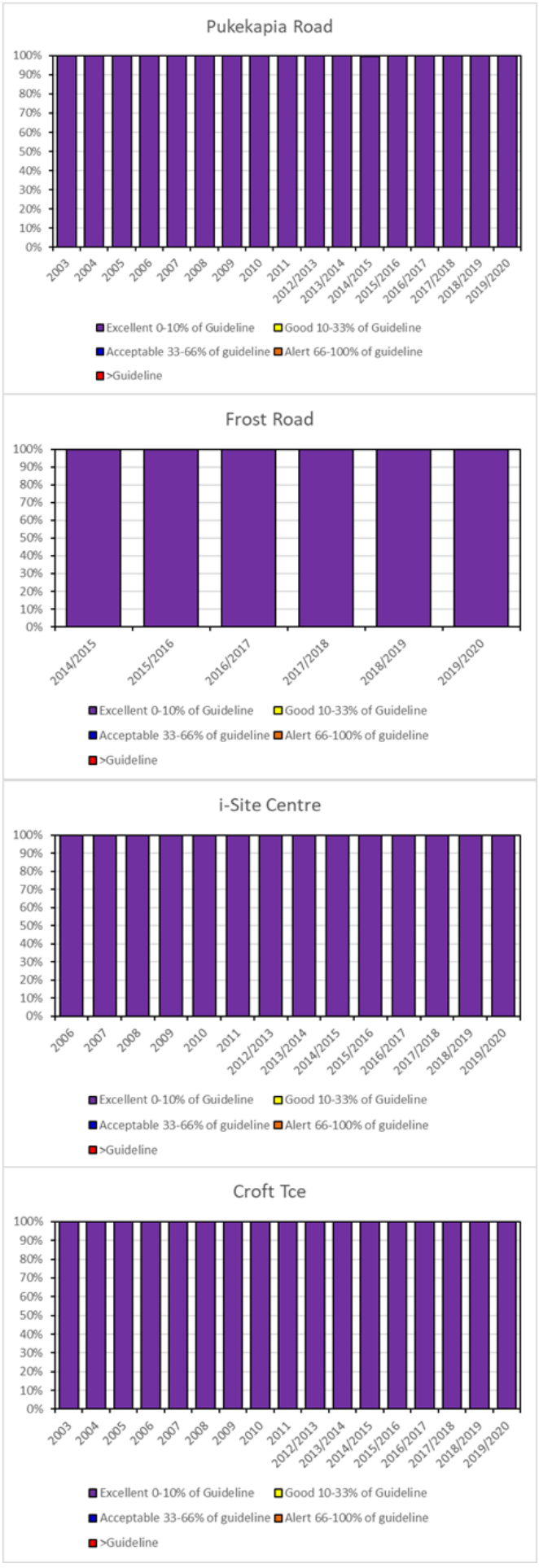


Figure 3.80 Comparison of 1-hour average SO_2 concentrations at the four Huntly stations for the period 2003 to 2020 relative to air quality indicator categories.

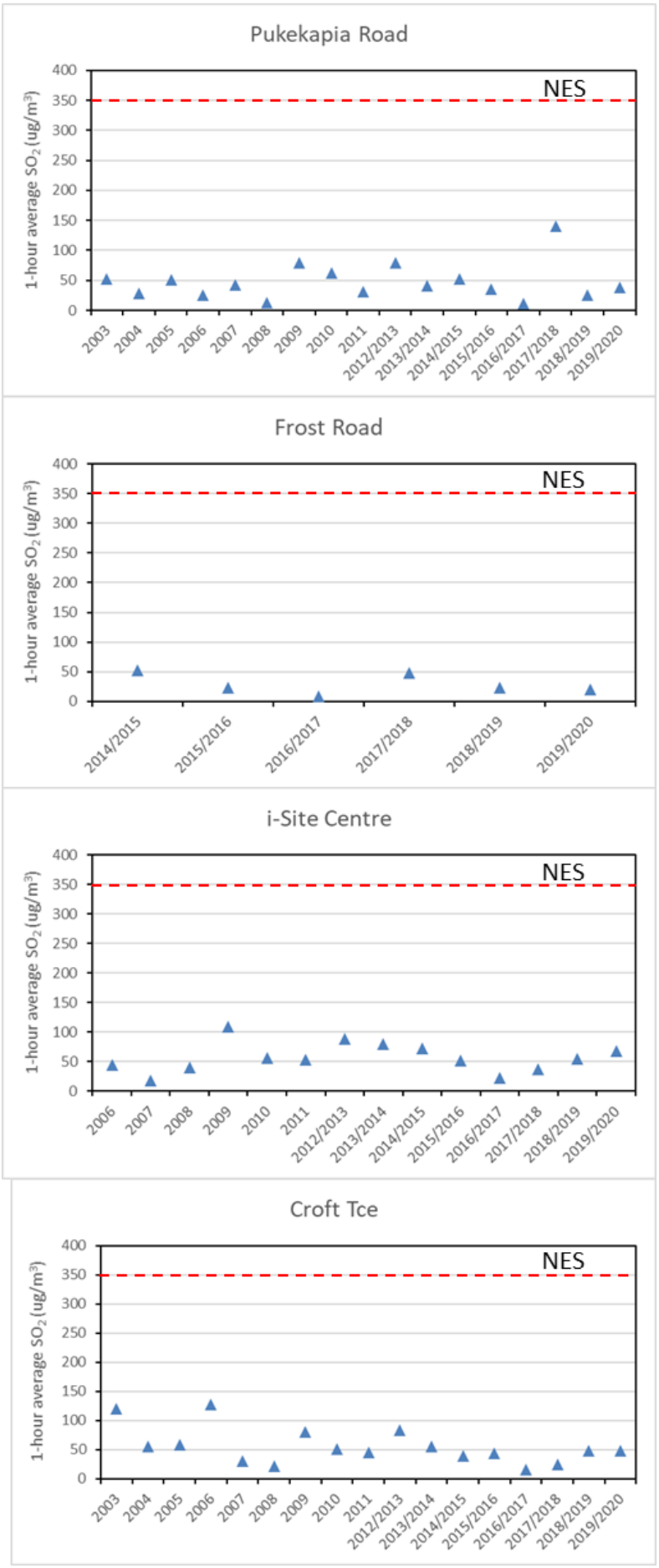


Figure 3.81 Maximum 1-hour average SO_2 concentrations measured at the four Huntly stations for the period 2003 to 2020.

4 Summary and conclusions

A total of 14 out of 20 gazetted airsheds in the Waikato region have been monitored for PM_{10} over the period 1998 to 2020 with monitoring of $PM_{2.5}$ in Tokoroa since 2015 and monitoring of $PM_{2.5}$ in Hamilton and Te Kuiti since 2019. Monitoring of benzene in Hamilton and nitrogen dioxide (NO_2) in Cambridge, Hamilton, Te Awamutu and Taupō has also occurred over this reporting period.

Table 4.1 provides a summary of compliance for all monitored airsheds within the Waikato region against the NES air quality standards and 2021 WHO guidelines for PM_{10}, $PM_{2.5}$ and NO_2 over the five-year period 2016 to 2020 along with an indication of the main PM_{10} sources identified for that airshed with significant secondary sources identified in brackets.

Table 4.1 Summary of compliance with PM_{10}, $PM_{2.5}$ & NO_2 guidelines and PM_{10} sources.

Airshed	NES 24-hour average standard		2021 WHO annual average guideline			Source
	PM_{10}	NO_2	PM_{10}	$PM_{2.5}$	NO_2	
Hamilton	✓	✓	✓	x	x	Home heating (& traffic)
Tokoroa	x	NA	x	x	NA	Home heating
Taupō	✓	NA	✓	NA	x	Home heating
Te Kuiti	✓	NA	x	x	NA	Home heating (& industry)
Putaruru	✓	NA	✓	NA	NA	Home heating
Morrinsville	✓	NA	✓	NA	NA	Home heating (& industry)
Thames	✓	NA	✓	NA	NA	Home heating
Turangi	✓	NA	✓	NA	NA	Home heating
Matamata	✓	NA	✓	NA	NA	Home heating
Huntly	✓	NA	✓	NA	?	Home heating
Cambridge	✓	NA	✓	NA	x	Home heating
Te Awamutu	✓	NA	✓	NA	x	Home heating (& industry)
Ngaruawahia	✓	NA	✓	NA	NA	Home heating
Waihi	✓	NA	✓	NA	NA	Home heating (& industry)

NA – no data available to make assessment against guideline

? – data has not been provided in a form that allows assessment against guideline

Table 4.2 provides a summary of the trend analyses undertaken for currently monitored stations and sites within the Waikato region for which at least six years of data was available.

Table 4.2 Summary of PM_{10} trend analyses for each of the currently monitored airsheds for which sufficient data was available

Airshed	Trend
Hamilton – Ohaupo Rd	
Hamilton – Claudelands	
Tokoroa	
Taupō	
Te Kuiti	
Putaruru	
Morrinsville	

Table 4.3 provides a summary of the trend analyses undertaken for currently monitored passive NO_2 sites by NZTA within the Waikato region for which at least six years of data was available.

Table 4.3 Summary of NO_2 trend analyses for NZTA's 12 passive NO_2 sites

Airshed	Location	Trend
Hamilton	Cambridge Rd/Morrinsville Rd	
Hamilton	Bridge St/Cobham Dr	
Hamilton	Brooklyn Rd/Peachgrove Rd	
Hamilton	Victoria St/Ulster St	
Hamilton	Greenwood St/Killarney Rd	
Hamilton	Lorne St/Ohaupo Rd	
Hamilton	Avalon Dr/Grandview Rd	
Hamilton	Seamer Place	
Hamilton	Te Rapa Rd/Ann Michele St	
Cambridge	Victoria St/Queen St	
Te Awamutu	Ohaupo Rd/Albert Drive	
Taupo	Tongariro St/Norman Smith St	

Te Kuiti, Taupō and Putaruru airsheds, after earlier breaches of the PM_{10} standard, have been identified as meeting compliance with the NES since 2016, 2018 and 2019 respectively with an improving trend identified in Te Kuiti and Taupō which have mainly been attributed to reductions in emissions from home heating sources. While Taupō and Putaruru airsheds have also complied with the 2021 WHO annual average PM_{10} guideline of 15 ug/m^3 since 2017, the guideline was exceeded in Te Kuiti in 2020.

An improving trend in PM_{10} concentrations has been identified in the Tokoroa airshed attributed mainly to reductions in emissions from home heating sources. Despite this, the 24-hour PM_{10} and $PM_{2.5}$ concentrations continue to exceed the NES standard and 2021 WHO guideline multiple times during the winter season. The annual average concentrations also exceed the 2021 WHO guideline. Domestic home heating has been identified as the primary source of PM_{10} and $PM_{2.5}$ in the Tokoroa airshed and there is evidence of arsenic and lead contamination from the burning of treated and painted wood.

In Hamilton the 24-hour average PM_{10} concentrations have been compliant with the NES standard and WHO guidelines since 2013 when all exceedances were caused by an exceptional event and were allowed to be discounted by the Minister for the Environment. The annual average PM_{10} concentrations have been compliant with the previous WHO guideline (20 $\mu g/m^3$) and the 2021 annual average guideline (15 $\mu g/m^3$) since 2007. There is evidence of an improving trend at the Ohaupo Road station but there is no statistically significant change identified for the Claudelands station. An analysis of the hourly, weekly and seasonal PM_{10} profiles for both stations indicates a higher contribution from home heating at the Claudelands station compared to potentially a higher traffic contribution at the Ohaupo Road station. The seasonal profile for both stations in Hamilton includes both a summer and winter peak which is inconsistent with the typical only-winter time peak observed at most airsheds within the region and within other regions of NZ and will require further investigation to identify the underlying causes.

A 2018 air emission inventory estimates that domestic home heating is the main source of PM_{10} emissions within the Hamilton airshed. However, monitoring sites can be more or less affected by different sources depending on their locations. A recent 2020 airshed modelling exercise has identified that transport is the next dominant source of PM_{10} concentrations after domestic heating.

Benzene concentrations have been complying with the Ministry for the Environment guideline at all eight traffic monitoring sites within Hamilton and have been steadily improving since monitoring began in 2003. However, while the 1-hour average NO_2 concentrations recorded in Hamilton have met the NES 1-hour standard since 2011, NZTA's nine passive NO_2 monitoring sites in Hamilton all exceed the 2021 WHO annual average guideline with exceedances also identified at passive NO_2 sites in Taupō, Te Awamutu and Cambridge.

Trend analyses undertaken for the 12 passive NO_2 sites monitored by NZTA in Hamilton, Cambridge, Te Awamutu and Taupō has identified only one site (Hamilton) with a worsening trend and five sites with an improving trend (four in Hamilton and one in Te Awamutu).

In Hamilton, Te Kuiti and Tokoroa, where $PM_{2.5}$ monitoring only began in recent years, the monitoring shows that both the annual average and 24-hour average 2021 WHO guidelines are being exceeded with 24-hour average guidelines being exceeded multiple times per year in all three of these airsheds.

5 Future outlook

While woodburners for domestic home heating have been identified as the main source of elevated PM_{10}/ $PM_{2.5}$ in all airsheds within the Waikato region, traffic sources in Hamilton have also been identified as significant contributors to both PM_{10}/ $PM_{2.5}$ and NO_2 in localised areas close to busy traffic routes and intersections. Population growth, particularly in Hamilton City and Waikato District (Cameron and Cochrane, 2021) is anticipated to increase the density of vehicle emissions at key intersections and along key traffic routes leading to increased PM_{10}/ $PM_{2.5}$ and NO_2 concentrations. However, increased residential development may not necessarily result in an increase in emissions associated with domestic home heating as new residential developments are less likely to include solid fuel burners.

With the continued significant non-compliance against the NES and WHO standards and guidelines for PM_{10} and $PM_{2.5}$ in Tokoroa, in addition to the recent introduction of $PM_{2.5}$ monitoring in Hamilton and Te Kuiti (since 2019) and Taupo (since 2021) and the imminent introduction of long and short term $PM_{2.5}$ standards in New Zealand, it will be important to actively manage domestic home heating in these airsheds. Currently WRC operates a clean heat incentives programme in Tokoroa which helps fund the replacement of non-compliant woodburners with either NES-compliant woodburners or heat pumps. Some targeted education campaigns around improving woodburning behaviours is also implemented in Tokoroa. Additional actions are likely to be necessary to help accelerate air quality improvements in Tokoroa but also to extend these actions to these other airsheds where it is anticipated that the new $PM_{2.5}$ standards will also not be met.

Significant increases in social deprivation have been identified for the South Waikato and Waitomo districts (Chiang and Colbert, 2021) which could result in continued challenges for encouraging change to clean home heating appliances and good woodburning behaviours in airsheds such as Tokoroa and Te Kuiti. People living in those areas of lower social deprivation are also likely to be more vulnerable to the effects of poor air quality due to existing poorer health and living conditions and therefore improving air quality in those areas could result in greater health benefits.

With regards to the impact of traffic related NO_2 emissions in Hamilton, electric vehicles are a good choice for reducing impacts on the environment because of our use of renewable energy sources in NZ. However, EVs can still produce significant particulate emissions from tyre wear, brake pads and resuspension of roadside dust (Harrison et al., 2021). It will therefore, still be important to limit the flow of vehicles through built up areas.

Localised impacts from traffic emissions could be better managed through appropriate setbacks from busy roadways for sensitive receptors such as early childhood centres and schools. For example, the University of Minnesota recommends a 200 metre setback for residential areas, schools, and day care facilities from a major road (University of Minnesota, 2007). However, it is not clear how relevant those setbacks would be for the New Zealand context. Modelling work by Beca on NOx concentrations at some busy intersections in Auckland predicted that the highest concentrations are within 30 to 40 metres from an intersection and reduce significantly to acceptable levels after 50 metres (Needham & Noonan, 2014).

More use of vegetation as a means of mitigation of air pollution is important but needs careful design specific to the circumstances. For example, thick, dense and tall vegetation is best for open road conditions while low-level dense vegetation such as hedges are best for mitigating air pollutants in street canyon situations (Abhijith et al., 2017).

Air quality in the region is sensitive to changes in emissions and air pollutant sources as well as changes in localised weather patterns as a result of more rapid climate changes. Climate change in the Waikato region is anticipated to reduce the cold, calm, inversion conditions that typically

result in poor air pollution, coupled with shorter, less intense heating seasons meaning fires may be used less often and for shorter periods of time. This may result in an improvement in wintertime air quality. However, it is less clear how air quality will be impacted at other times of the year as a result of other air pollutant sources. For example, drier, windier weather in springtime or summer and or changes in prevailing wind directions could result in more dust impacts on air quality. Wildfires may also be more frequent (MOH, 2021) as well as increasing prevalence of hayfever and thunderstorm asthma events arising from changes in sources of airborne pollen (Newnham, 2021).

References

Abhijith KV, Kumar P, Gallagher J, McNabola A, Baldauf R, Pill F, Broderick B, Di Sabatino S, Pulvirenti B, 2017. Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments – A review. Atmospheric Environment 162: 71-86.

Ancelet T, Davy P 2015. Multi-elemental analysis of PM_{10} and apportionment of contributing sources – Tokoroa 2014. Waikato Regional Council Technical Report 2017/29. Hamilton, Waikato Regional Council.

Caldwell J 2015. Air quality monitoring report for Hamilton, Tokoroa, Taupo, Te Kuiti, Putaruru, Turangi, Cambridge and Te Awamutu-Kihikihi – 2014. Waikato Regional Council Technical Report 2015/05. Hamilton, Waikato Regional Council.

Cameron MP, Cochrane W 2021. 2018-base SA2-level population, family and household, and labour force projections for the Waikato region, 2018-2068. Waikato Regional Council Technical Report 2021/24. Hamilton, Waikato Regional Council.

Chiang A, Colbert J 2021. Socio-economic deprivation in the Waikato Region. Waikato Regional Council Technical Report 2021/14. Hamilton, Waikato Regional Council.

Davy P, Trompetter W 2017(a). Apportionment of PM_{10} sources in the Tokoroa airshed, Waikato Region. GNS Science Consultancy Report 2017/75 July 2017. WRC Doc# 23699131.

Davy, P., Trompetter W., 2017(b). Apportionment of PM and PM sources in the Richmond airshed, Tasman District. GNS Science Consultancy Report 2017/86 November 2017. Search Results | Tasman District Council [accessed 4 March 2022].

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. Wellington, Ministry of Transport.

Genesis Energy 2011. Huntly Power Station assessment of environmental effects, 13 September 2011. WRC Doc# 2056487.

Genesis Energy 2008. Huntly Power Station annual air monitoring report, 2008. WRC Doc#1585879.

Golder Associates 2020. Airshed modelling for Hamilton City. Report prepared for Waikato Regional Council by Golder Associates (NZ) Ltd, April 2020. Doc#16180675.

Harrison RM, Allan J, Carruthers D, Heal MR, Lewis AC, Marner B, Murrells T, Williams A 2021. Non-exhaust vehicle emissions of particulate matter and VOC from road traffic: A review. Atmospheric Environment 262: 118592.

Kuschel G, Wilton E, Guria J, Hales S, Rolfe K, Woodward A 2012. Updated health and air pollution in New Zealand study: volume 2. Prepared for the Health Research Council of New Zealand, Ministry of Transport, Ministry for the Environment, and New Zealand Transport Agency. Updated health and air pollution in New Zealand study 2012 - Technical report | Ministry for the Environment [accessed 4 March 2022].

Longley I, Somervell E 2020. Nitrogen dioxide monitoring in Hamilton. Prepared for Waikato Regional Council by NIWA, January 2020. WRC Doc# 23735569.

Mathieson T 2010. Validation of Environment Waikato BTEX monitoring by comparison of approaches. Environment Waikato Internal Series 2010/16. Hamilton, Waikato Regional Council (Environment Waikato).

Ministry for the Environment 2000. Proposals for revised and new ambient air quality guidelines: Discussion document. Air Quality Technical Report 16. Wellington, Ministry for the Environment.

Ministry for the Environment 2002. Ambient air quality guidelines. Wellington, Ministry for the Environment.

Ministry for the Environment 2004. The Resource Management (National Environmental Standards for Air Quality) Regulations 2004. Wellington, Ministry for the Environment.

Ministry for the Environment 2009. Good practice guide for air quality monitoring and data management. Wellington, Ministry for the Environment.

Ministry of Health 2021. Response to wildfires. Guidelines for Public Health Units. Wellington, Ministry of Health.

Needham C, Noonan M 2014. At the crossroads for modelling. CASANZ Transport Workshop, Auckland, December 2014.

Newnham R 2021. Monitoring airborne pollen in New Zealand. Journal of the Royal Society of New Zealand. 52: 192-211.

Smith J, Wilton E 2007. Air emission inventory – Matamata, Putaruru and Waihi 2006. Environment Waikato Technical Report 2007/13. Hamilton, Waikato Regional Council (Environment Waikato).

Smith J 2006a. Air quality monitoring report 2006. Environment Waikato Technical Report 2006/52. Hamilton, Waikato Regional Council (Environment Waikato).

Smith J 2006b. Waikato Regional Council Memo by Jeff Smith, November 2006, WRC Doc# 1121750.

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

Stevenson C, Narsey H 1999. Benzene and other toxic organics. Report prepared for the Ministry of Health. Wellington, Ministry of Health.

Trompetter WJ, Davy PK, Markwitz A 2010. Influence of environmental conditions on carbonaceous particle concentrations within New Zealand. Journal of Aerosol Science. 41(1): 134-142.

University of Minnesota 2007. Design for health, University of Minnesota, August 2007. Key Questions: Air Quality, Version 2.0.

Wilton E 2006. Air emission inventory – Te Awamutu, Turangi and Ngaruawahia 2006. Environment Waikato Technical Report 2006/43. Hamilton, Waikato Regional Council (Environment Waikato).

Wilton E, Baynes M 2008. Air quality monitoring 2007 for Hamilton, Tokoroa, Taupo, Te Kuiti, Matamata and Putaruru. Environment Waikato Technical Report 2008/11. Hamilton, Waikato Regional Council (Environment Waikato).

Wilton E, Baynes M 2009. Air quality monitoring 2008 for Hamilton, Tokoroa, Taupo, Te Kuiti, Matamata, Putaruru, Nguaruwahia, Waihi. Environment Waikato Technical Report 2009/04. Hamilton, Waikato Regional Council (Environment Waikato).

Wilton E, Baynes M 2010. Air Emission Inventory – Taupo, Thames and Huntly 2009. Environment Waikato Technical Report 2010/13. Hamilton, Waikato Regional Council (Environment Waikato).

Wilton E 2011. Solid fuel replacements in Tokoroa, Taupo, Te Kuiti and Putaruru – meeting the NES for air quality. Report prepared for Waikato Regional Council. WRC Doc#1978150.

Wilton E 2013a. Assessing trends in PM10 concentrations at Tokoroa. Report prepared for Waikato Regional Council. WRC Doc#3141882.

Wilton E 2013b. Assessing trends in PM10 concentrations at Taupo. Report prepared for Waikato Regional Council. WRC Doc#11834434.

Wilton E 2014. Personal communication based on reassessment of 'Assessing trends in PM_{10} concentrations at Taupo Report' using second highest concentration recorded in 2013. 14 April 2014.

Wilton E 2015a. Air emission inventory – Taupo 2014. Waikato Regional Council Technical Report 2015/01. Hamilton, Waikato Regional Council.

Wilton E 2015b. Air emission inventory – Te Kuiti and Putaruru 2015. Waikato Regional Council Technical Report 2015/29. Hamilton, Waikato Regional Council.

Wilton E 2016. Air emission inventory – Tokoroa and Morrinsville 2016. Waikato Regional Council Technical Report 2016/31. Hamilton, Waikato Regional Council.

Wilton E 2018. Hamilton air emission inventory – 2018. Prepared for Waikato Regional Council by Emily Wilton, Environet Ltd, August 2018. WRC Doc#12944007.

Wilton E 2019. Tokoroa air emission inventory – 2019. Prepared for Waikato Regional Council by Emily Wilton, Environet Ltd, October 2019. WRC Doc#23711593

Appendix 1: Summary data Hamilton

Summary of PM_{10} concentrations measured at Ohaupo Road station in Hamilton for 2012 to 2020.

Indicator	2012	2013	2014	2015	2016	2017	2018	2019	2020
"Good" 0-33% of Guideline	74%	77%	74%	80%	81%	84%	80%	73%	86.9
"Acceptable" 33-66% of guideline	25%	23%	26%	19%	19%	15%	20%	24%	13.1
"Alert" 66-100% of guideline	1%	0%	0%	1%	0%	1%	0%	3%	0
"Action" >Guideline	0%	0%	0%	0%	0%	0%	0%	0%	0
Percentage of valid data	73%	100%	100%	100%	99%	97%	99%	99%	96.2
Annual average (µg/m^3)	13.5	13.3	13.4	12.9	12.5	12.1	12.2	14.3	11.3
Number exceedances	0	0	0	0	0	0	0	0	0
2nd Highest	35	29	31	37	30	33	32	44.1	25.6
Annual maximum (µg/m^3)	41	32	32	39	31	40	34	44.5	31.9
Number records	266	365	364	364	363	353	360	360	352

Summary of PM_{10} concentrations measured at Claudelands Event Centre station in Hamilton for 2014 to 2020.

Indicator	2014	2015	2016	2017	2018	2019	2020
"Good" 0-33% of Guideline	78%	87%	85%	89%	82.6%	65.5%	73.6%
"Acceptable" 33-66% of guideline	21%	13%	15%	11%	16.8%	35.5%	26.2%
"Alert" 66-100% of guideline	1%	0%	0%	0%	0.00%	0.9%	0.3%
"Action" >Guideline	0%	0%	0%	0%	0.00%	0.00%	0.00%
Percentage of valid data	69.0%	99%	99%	97.8%	99.5	89.9	99.2
Annual average (mg/m^3)	14.1	11.3	11.5	11.0	11.6	15.1	14.1
Number exceedances	0	0	0	0	0	0	0
2nd Highest	37	33	30	30	30.9	36.3	25.6
Annual maximum (mg/m^3)	46	36	32	30	32	48	43.2
Number records	252	361	361	357	363	328	363

1. Winter average rather than annual average due to limited dataset.

Summary of PM_{10} concentrations measured using a TEOM at Peachgrove Road station in Hamilton from 1998 to 2005.

Indicator	1998	1999	2000	2001	2002	2003	2004	2005
"Good" 0-33% of guideline	57%	67%	72.5%	78.5%	61%	67%	56%	70%
"Acceptable" 33-66% of guideline	42%	31%	25.4%	17.6%	38%	29%	41%	29%
"Alert" 66-100% of guideline	1%	3%	2.1%	2.3%	1%	3%	3%	1%
“Action” >Guideline	0%	0%	0%	1.2%	0%	1%	0%	0%
Percentage of valid data	47%	99%	91.3%	69.9%	93%	91%	94%	77%
Annual average (µg/m^3)	15.2	15.7	14.7	15.5	15.3	16.9	15.5	16.3
Measured exceedances	0	0	0	3	0	4	1	0
2nd highest 24 hr average (µg/m^3)	33	43	36	64	34	54	43	34
Maximum 24 hr average (µg/m^3)	35	44	48	76	36	62	55	37
Number of records	172	361	334	256	340	331	344	281

Summary of PM_{10} concentrations measured using a TEOM at Peachgrove Road station in Hamilton from 2006 to 2013 (gravimetric correction of data applied[1]).

Indicator	2006	2007	2008	2009	2010	2011	2012	2013
"Good" 0-33% of guideline	58%	67%	64%	70%	77%	66%	75%	65%
"Acceptable" 33-66% of guideline	38%	31%	34%	26%	23%	32%	23%	31%
"Alert" 66-100% of guideline	4%	2%	2%	3%	0%	2%	2%	1%
"Action" >Guideline	1%	0%	0%	0.8%	0%	0.3%	0%	3%
Percentage of valid data	99%	100%	100%	100%	99%	100%	100%	80%
Annual average ($\mu g/m^3$)	16.6	14.7	15.3	14.4	13.1	14.4	13.4	13.7[2]
Measured exceedances	2	0	0	3	0	1	0	8
2nd highest 24 hr average ($\mu g/m^3$)	58	45	46	52	30	37	37	127
Maximum 24 hr average ($\mu g/m^3$)	66	46	48	101	30	64	42	136
Number of records	363	364	364	363	361	364	364	291

1. Corrected PM_{10} data = 1.19975 x RawTEOMdata - 3.9182.
2. Winter average rather than annual average due to limited dataset.

Appendix 2: Summary data Tokoroa

Summary of PM_{10} concentrations measured at the Tokoroa monitoring station from 2001 to 2008[1].

Indicator	2001	2002	2003	2004	2005	2006	2007	2008
"Good" 0-33% of guideline	12%	15%	25%	12%	28%	60%	66%	67%
"Acceptable" 33-66% of guideline	64%	71%	58%	54%	49%	26%	24%	25%
"Alert" 66-100% of guideline	17%	9%	13%	23%	13%	8%	7%	6%
"Action" >Guideline	8%	4%	4%	11%	9%	6%	3%	3%
Percentage of valid data	47%	97%	55%	96%	88%	99%	99%	99%
Annual average ($\mu g/m^3$)	26.6	24.0	24.1	31.0	24.8	18.6	16.3	16.5
Measured exceedances	13	14	8	38	33	20	10	11
2nd highest 24 hr average ($\mu g/m^3$)	66	66	57	92	83	70	71	60
Maximum 24 hr average ($\mu g/m^3$)	75	70	62	97	89	76	86	85
Number of records	173	353	199	349	321	360	360	360

1. Gravimetric correction of data applied from 2006 onwards.

Summary of PM_{10} concentrations measured at the Tokoroa monitoring station from 2009 to 2017[1].

Indicator	2009	2010	2011	2012	2013	2014	2015	2016	2017
"Good" 0-33% of guideline	61%	63%	60%	63%	63%	68%	68%	69%	72%
"Acceptable" 33-66% of guideline	29%	26%	27%	25%	26%	23%	22%	25%	18%
"Alert" 66-100% of guideline	5%	7%	9%	8%	8%	7%	7%	5%	7%
“Action” >Guideline	5%	4%	4%	4%	3%	2%	3%	1.5%	3%
Percentage of valid data	100%	99%	99%	100%	100%	100%	100%	93%	92%
Annual average (µg/m^3)	17.5	18.0	18.0	17.2	16.8	15.9	16.6	14.5	15.4
Measured exceedances	17	16	16	15	10	9	10	5	10
2nd highest 24 hr average (µg/m^3)	77	87	72	66	59	67	66	56	63
Maximum 24 hr average (µg/m^3)	80	99	73	75	59	69	69	60	75
Number of records	364	360	362	366	364	365	364	341	337

1. Gravimetric correction of data applied from 2006 onwards.

Summary of PM_{10} concentrations measured at the Tokoroa monitoring station from 2018 to 2020[1]

Indicator	2018	2019	2020
"Good" 0-33% of guideline	71	61	59
"Acceptable" 33-66% of guideline	22	31	29
"Alert" 66-100% of guideline	6	7	9
“Action” >Guideline	1	1	3
Percentage of valid data	93	95	98
Annual average (µg/m^3)	14.5	17.3	19.2
Measured exceedances	2	6	12
2nd highest 24 hr average (µg/m^3)	52	55	86
Maximum 24 hr average (µg/m^3)	53	59	88
Number of records	340	346	359

1. Gravimetric correction of data applied for 2018 and 2019.

Summary of $PM_{2.5}$ concentrations measured at the Tokoroa monitoring station from 2015 to 2017

Indicator	2015	2016	2017	2018	2019	2020
Good (0-33% of guideline)	59%	46%	48%	63%	60%	55%
Acceptable (33-66% of guideline)	25%	23%	19%	17%	28%	24%
Alert (66-100% of guideline)	6%	12%	13%	9%	8%	10%
Action (> guideline)	11%	18%	20%	11%	4%	11%
Percentage of valid data	44%	63%	74%	77%	41%	98%
Annual average (µg/m^3)	n/a	n/a	15.0	10.2	9.9	11.4
Measured exceedances (2005 WHO)	17	42	53	31	6	39
Maximum 24 hr average (µg/m^3)	50	66	65	41	41.5	64.3
2nd highest 24 hr average (µg/m^3)	43	62	60	40.3	39.1	61.5
Number of records	153	228	271	280	148	359

Appendix 3: Summary data Taupo

Summary of PM_{10} concentrations measured at the Taupo monitoring station from 2001 to 2008[1].

Indicator	2001	2002	2003	2004	2005	2006	2007	2008
"Good" 0-33% of guideline	43%	59%	52%	55%	56%	47%	65%	66%
"Acceptable" 33-66% of guideline	36%	33%	32%	30%	36%	38%	29%	24%
"Alert" 66-100% of guideline	18%	7%	12%	12%	7%	10%	5%	7%
“Action” >Guideline	2%	1%	4%	2%	1%	5%	1%	3%
Percentage of valid data	12%	21%	29%	29%	30%	27%	83%	99%
Annual average[2] (µg/m^3)	19.7	15.9	18.5	17.8	15.8	20.4	15.4	16.7
Measured exceedances[3]	1 (7)	1 (6)	4 (12)	2 (6)	1 (3)	5 (15)	3	10
Maximum 24 hr average (µg/m^3)	57	54	62	65	52	89	64	73
2nd highest 24 hr average (µg/m^3)	55	51	62	62	50	80	60	68
Number of records	44	76	106	105	111	98	303	362

1. 2007 - 2008 data have 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 post 2006 adjusted for gravimetric equivalency. 2008 monitoring report used a different equation and reported six exceedances of 50 µg m^{-3} for 2007 compared with three exceedances reported here.
2. To avoid seasonal bias in missing data, annual averages for gravimetric data collected prior to 2007 have been calculated based on average of the individual seasonal averages (i.e. Jan to Apr, May to Aug, Sep to Dec). Annual average calculations from 2007 onwards have been based on averaging of all data (makes no difference which method is used because very little missing data).
3. For the years 2001 to 2006 both measured and reported exceedences are shown (in brackets). Reported exceedences are a statistical extrapolation of measured exceedences after accounting for non sample days.

Summary of PM_{10} concentrations measured at the Taupo monitoring station from 2009 to 2017.

Indicator	2009	2010	2011	2012	2013	2014	2015	2016	2017
"Good" 0-33% of guideline	71%	73%	69%	76%	73%	77%	77%	80%	72%
"Acceptable" 33-66% of guideline	22%	20%	26%	19%	24%	21%	19%	17%	24%
"Alert" 66-100% of guideline	5%	6%	5%	5%	3%	3%	4%	3%	3%
“Action” >Guideline	2%	0%	0%	0%	1%	0%	0%	0%	0%
Percentage of valid data	99%	100%	99%	99%	99%	98%	99%	97%	96%
Annual average[2] (µg/m^3)	14.7	14.0	14.2	12.9	13.4	12.4	12.5	11.9	13.5
Measured exceedances[3]	7	1	1	1	2	0	0	0	1
Maximum 24 hr average (µg/m^3)	66	55	51	51	65	45	44	50	52
2nd highest 24 hr average (µg/m^3)	66	48	50	50	62	43	43	41	47
Number of records	363	364	361	362	363	358	362	353	349

Summary of PM_{10} concentrations measured at the Taupo monitoring station from 2018 to 2020.

Indicator	2018	2019	2020
"Good" 0-33% of guideline	83	78	80
"Acceptable" 33-66% of guideline	15	20	17
"Alert" 66-100% of guideline	3	2	3
“Action” >Guideline	0	0	0
Percentage of valid data	97	100	95
Annual average (µg/m^3)	11.2	12.2	11.4
Measured exceedances	0	0	0
2nd highest 24 hr average (µg/m^3)	46.1	40.2	37.3
Maximum 24 hr average (µg/m^3)	46.2	40.4	44.5
Number of records	354	363	349

Appendix 4: Summary data Te Kuiti

Summary of PM_{10} concentrations measured at the Te Kuiti monitoring station from 2003 to 2009.

Indicator	2003	2004	2005	2006	2007	2008	2009
Good 0-33% of Guideline	48%	51%	59%	58%	54%	55%	63%
Acceptable 33-66% of guideline	32%	40%	34%	31%	38%	35%	29%
Alert 66-100% of guideline	17%	8%	7%	9%	7%	9%	8%
Action >Guideline	2%	1%	1%	2%	1%	1%	1%
Percentage of valid data	63%	95%	92%	100%	99%	99%	99%
Annual average (µg/m3)	18.0	18.0	17.0	17.7	17.8	18.2	16.8
Number exceedances	4	5	2	7	4	3	4
Maximum 24 hr average (µg/m^3)	59	61	54	69	58	74	53
2nd highest 24 hr average (µg/m^3)	56	56	52	67	58	53	52
Number records	229	346	337	363	360	362	360

Summary of PM_{10} concentrations measured at the Te Kuiti monitoring station from 2010 to 2017.

Indicator	2010	2011	2012	2013	2014	2015	2016	2017
Good 0-33% of Guideline	65%	65%	64%	60%	64%	65%	67%	75%
Acceptable 33-66% of guideline	28%	32%	29%	37%	30%	31%	29%	22%
Alert 66-100% of guideline	6%	3%	7%	3%	6%	4%	4%	3%
Action >Guideline	1%	0%	0%	0%	0%	0%	0%	0%
Percentage of valid data	99%	100%	99%	98%	100%	100%	98%	99%
Annual average (µg/m^3)	16.1	15.1	16.4	16.3	15.9	15.4	15.2	14.1
Number exceedances	3	1	1	0	0	0	0	0
Maximum 24 hr average (µg/m^3)	56	51	61	47	48	49	41	46
2nd highest 24 hr average (µg/m^3)	53	41	50	40	44	45	41	43
Number records	360	363	363	358	364	364	359	361

Summary of PM_{10} concentrations measured at the Te Kuiti monitoring station from 2018 to 2020.

Indicator	2018	2019	2020
"Good" 0-33% of guideline	76	70	70
"Acceptable" 33-66% of guideline	23	27	27
"Alert" 66-100% of guideline	1	3	3
“Action” >Guideline	0	0	0
Percentage of valid data	99	94	98
Annual average (µg/m^3)	13.4	14.9	15.1
Measured exceedances	0	0	0
2nd highest 24 hr average (µg/m^3)	36	43	42
Maximum 24 hr average (µg/m^3)	38	49	43
Number of records	360	342	358

Appendix 5: Summary data Putaruru

Summary of PM_{10} concentrations measured at the Putaruru monitoring station from 2006 to 2016.

Indicator	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Good 0-33% of Guideline	65%	67%	61%	71%	72%	78%	79%	74%	66%	70%	81%
Acceptable 33-66% of guideline	30%	27%	31%	23%	25%	20%	20%	24%	30%	25%	18%
Alert 66-100% of guideline	5%	5%	7%	6%	3%	2%	1%	2%	4%	5%	1%
Action > Guideline	0%	1%	1%	1%	0.3%	0.3%	0%	0%	1%	0%	0%
Percentage of valid data	46%	100%	100%	100%	100%	95%	99%	99%	98%	93%	94%
Annual average (µg/m^3)	n/a	15.1	17.2	13.6	14.2	12.5	11.8	13.2	15.3	14.0	12.0
Number exceedances	0	3	4	3	1	1	0	0	2	0	0
Maximum 24 hr average (µg/m^3)	42	60	78	54	53	54	38	46	73	50	43
2nd highest 24 hr average (µg/m^3)	40	56	60	54	50	50	35	41	55	45	38
Number records	166	365	364	364	363	346	361	360	359	340	343

Summary of PM_{10} concentrations measured at the Putaruru monitoring station from 2017 to 2020.

Indicator	2017	2018	2019	2020
"Good" 0-33% of guideline	82%	83%	74%	81%
"Acceptable" 33-66% of guideline	16%	16%	25%	18%
"Alert" 66-100% of guideline	2%	1%	0.6%	1%
“Action” >Guideline	0.3%	0%	0.3%	0.3%
Percentage of valid data	85%	98%	95%	95%
Annual average (µg/m^3)	11.6	11.2	13.2	11.2
Measured exceedances	1	0	1	1
2nd highest 24 hr average (µg/m^3)	55	35	36	47
Maximum 24 hr average (µg/m^3)	50	36	51	63
Number of records	311	357	347	348

Appendix 6: Summary data Turangi

Summary of PM_{10} concentrations measured at the Turangi monitoring station from 2009 to 2017.

Indicator	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Good (0-33% of guideline)	88%	87%	87%	90%	85%	89%	91%	90%	87%	96%
Acceptable (33-66% of guideline)	12%	13%	13%	10%	15%	7%	9%	10%	13%	4%
Alert (66-100% of guideline)	0%	0%	0%	0%	0%	1%	1%	0%	0%	0%
Action > guideline	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Percentage of valid data	79%	84%	85%	99%	100%	95%	99%	97%	100%	81%
Annual average (µg/m3)	9.8	10.8	10.2	10.0	10.8	9.9	10.0	10.1	9.8	9.0
Measured exceedances	0	0	0	0	0	0	0	0	0	0
Maximum 24 hr average (µg/m^3)	25	32	33	31	33	40	41	29	28	27
2nd highest 24 hr average (µg/m^3)	25	30	28	28	31	33	38	26	28	23
Number of records	288	305	312	362	363	346	362	353	365	296

Appendix 7: Summary data Morrinsville

Summary of PM_{10} concentrations measured at the Morrinsville monitoring station from 2015 to 2017.

Indicator	2015	2016	2017	2018	2019	2020
Good (0-33% of guideline)	80%	88%	88%	71%	84%	94%
Acceptable (33-66% of guideline)	18%	12%	11%	10%	17%	6%
Alert (66-100% of guideline)	2%	1%	1%	0%	0%	0%
Action (> guideline)	0%	0%	0%	0%	0%	0%
Percentage of valid data	59%	84%	99%	55%	93%	99%
Annual average (µg/m^3)	12	11.5	11.3	11.1	12.1	9.5
Measured exceedances	0	0	0	0	0	0
Maximum 24 hr average (µg/m^3)	45	36	35	26	30	28
2nd highest 24 hr average (µg/m^3)	38	33	33	24	28	28
Number of records	217	308	360	202	339	362

Appendix 8: Summary data Thames

Summary of PM_{10} concentrations measured at the Thames monitoring station from 2016 to 2020.

Indicator	2016	2017	2018	2019	2020
Good (0-33% of guideline)	77%	93%	99.5%	86%	93%
Acceptable (33-66% of guideline)	22%	7%	0.5%	14%	7%
Alert (66-100% of guideline)	1%	0%	0%	0.3%	0%
Action (> guideline)	0%	0%	0%	0%	0%
Percentage of valid data	72%	98%	100%	95%	99.5%
Annual average (µg/m^3)	12.6	8.5	5.4	11.1	9.7
Measured exceedances	0	0	0	0	0
Maximum 24 hr average (µg/m^3)	34	29	17	44	26
2nd highest 24 hr average (µg/m^3)	33	25	17	33	25
Number of records	262	356	365	347	364

Appendix 9: Summary data Cambridge

Summary of PM_{10} concentrations measured at the Cambridge monitoring station from 2013 to 2016.

Indicator	2013	2014	2015	2016
"Good" 0-33% of guideline	83%	79%	90%	77%
"Acceptable" 33-66% of guideline	17%	21%	10%	22%
"Alert" 66-100% of guideline	0%	0%	0%	1%
“Action” >Guideline	0%	0%	0%	0%
Percentage of valid data	60%	99.5%	98%	53%
Annual average (µg/m^3)	11.8	12.4	10.8	12.9
Measured exceedances	0	0	0	0
2nd highest 24 hr average (µg/m^3)	26	30	25	35
Maximum 24 hr average (µg/m^3)	28	42	31	39
Number of records	217	363	357	195

Appendix 10: Summary data Te Awamutu

Summary of PM_{10} concentrations measured at the Te Awamutu monitoring station from 2013 to 2016.

Indicator	2013	2014	2015	2016
"Good" 0-33% of guideline	85%	81%	85%	82%
"Acceptable" 33-66% of guideline	15%	18%	15%	17%
"Alert" 66-100% of guideline	0%	0%	0%	0%
“Action” >Guideline	0%	0%	0%	0%
Percentage of valid data	51%	99%	98%	81%
Annual average (µg/m^3)	11.8	12.3	11.8	12.2
Measured exceedances	0	0	0	0
2nd highest 24 hr average (µg/m^3)	25	30	30	30
Maximum 24 hr average (µg/m^3)	32	38	34	45
Number of records	186	362	356	295

Appendix 11: Summary data Matamata

Summary of PM_{10} concentrations measured at the Matamata monitoring station from 2005 to 2012.

Indicator	2005	2006	2007	2008	2009	2010	2011	2012
Good 0-33% of Guideline	81%	77%	83%	69%	78%	79%	80%	80%
Acceptable 33-66% of guideline	18%	23%	16%	29%	21%	20%	20%	19%
Alert 66-100% of guideline	1%	1%	0%	2%	1%	0%	0%	1%
Action >Guideline	0%	0%	0%	0%	0%	0%	0%	0%
Percentage of valid data	51%	99%	79%	100%	98%	99%	97%	98%
Annual average (µg/m^3)	12	13	12	15	13	13	12	13
Number exceedances	0	0	0	0	0	0	0	0
Maximum 24 hr average (µg/m^3)	36	38	34	45	93	40	31	35
2nd highest 24 hr average (µg/m^3)	34	34	33	38	36	29	30	34
Number records	187	362	287	364	359	361	359	358

Appendix 12: Summary data Ngaruawahia

Summary of PM_{10} concentrations measured at the Ngaruawahia monitoring station from 2008 to 2012.

Indicator	2008	2009	2010	2011	2012
Good (0-33% of guideline)	69%	77%	80%	76%	75%
Acceptable (33-66% of guideline)	31%	22%	20%	23%	25%
Alert (66-100% of guideline)	0%	1%	0%	1%	0%
Action (> guideline)	0%	0%	0%	0%	0%
Percentage of valid data	65%	100%	97%	99%	100%
Annual average (µg/m^3)	14	14	13	13	13
Measured exceedances	0	1	0	0	0
Maximum 24 hr average (µg/m^3)	32	113	29	44	31
2nd highest 24 hr average (µg/m^3)	32	42	28	35	30
Number of records	238	364	355	363	366

Appendix 13: Summary data Waihi

Summary of PM_{10} concentrations measured at the Waihi monitoring station from 2008 to 2011.

Indicator	2008	2009	2010	2011
"Good" 0-33% of guideline	86.8%	81.1%	80.9%	79.4%
"Acceptable" 33-66% of guideline	13.2%	18.0%	18.5%	18.8%
"Alert" 66-100% of guideline	0.0%	0.9%	0.6%	1.8%
"Action" >Guideline	0%	0%	0%	0%
Percentage of valid data	84.7%	86.8%	96.2%	90.4%
Annual average (µg/m^3)	11.8	12.1	12.3	13.1
Measured exceedances	0	0	0	0
2nd highest 24 hr average (µg/m^3)	31	34	44	42
Maximum 24 hr average (µg/m^3)	33	37	45	43
Number of records	310	317	351	330

Appendix 14: Summary data Huntly

Summary of PM_{10} concentrations measured at the Ralph Rd monitoring station from 2001 to 2014.

Year	Valid Data	Excellent < 5 µg/m^3	Good 5-16.5 µg/m^3	Acceptable 16.5-33 µg/m^3	Alert 33-50 µg/m^3	Action >50 µg/m^3	2nd Highest µg/m^3	Max µg/m^3	Annual Average µg/m^3	Number Exceedances
2001	78.0%	5.3%	87.3%	7.0%	0.4%	0.0%	28.0	34.0	10.1	0
2002	98.0%	2.5%	84.6%	12.9%	0.0%	0.0%	27.0	29.0	11.5	0
2003	97.0%	5.1%	85.0%	9.9%	0.0%	0.0%	27.5	31.8	10.9	0
2004	90.0%	3.0%	77.1%	19.5%	0.3%	0.0%	27.9	35.4	12.3	0
2005	99.0%	2.8%	85.0%	11.9%	0.3%	0.0%	29.7	35.7	11.5	0
2006	47.9%	33.7%	54.3%	12.0%	0.0%	0.0%	29.0	29.7	11.9	0
2007	92.6%	11.8%	77.2%	10.9%	0.0%	0.0%	27.7	30.8	11.0	0
2008	92.3%	6.8%	72.2%	20.7%	0.3%	0.0%	28.6	34.2	12.7	0
2009	94.5%	16.5%	71.0%	11.8%	0.3%	0.3%	33.4	105.3	11.0	1
2010	98.1%	12.0%	79.1%	8.9%	0.0%	0.0%	25.3	27.6	9.7	0
2011	98.4%	13.4%	76.0%	10.6%	0.0%	0.0%	29.2	32.7	10.5	0
2012/2013	99.5%	16.5%	70.5%	12.7%	0.0%	0.3%	–	60.7	10.8	1
2013/2014	91.9%	3.9%	77.6%	18.5%	0.0%	0.0%	–	30.9	12.0	0

Summary of PM_{10} concentrations measured at the Pukekapia Rd monitoring station from 2001 to 2020.

Year	Valid Data	Excellent < 5 µg/m³	Good 5-16.5 µg/m³	Acceptable 16.5-33 µg/m³	Alert 33-50 µg/m³	Action >50 µg/m³	2nd Highest µg/m³	Max µg/m³	Annual Average µg/m³	Number Exceedances
2001	5.0%	0.0%	70.0%	30.0%	0.0%	0.0%	9.0	26.0	13.8	0
2002	99.7%	7.7%	72.8%	19.5%	0.0%	0.0%	29.0	31.0	12.3	0
2003	98.0%	11.5%	70.2%	17.4%	0.6%	0.3%	42.6	56.5	12.4	1
2004	83.0%	7.9%	70.5%	20.3%	1.3%	0.0%	36.0	37.0	12.4	0
2005	85.0%	8.7%	79.0%	11.7%	0.3%	0.3%	36.2	66.9	11.1	1
2006	97.0%	10.6%	72.5%	16.3%	0.3%	0.3%	34.5	68.8	11.0	1
2007	97.0%	16.1%	65.8%	16.4%	1.4%	0.3%	39.9	77.8	11.9	1
2008	98.4%	9.7%	64.4%	22.5%	3.1%	0.3%	41.0	73.9	13.8	1
2009	97.5%	15.7%	69.4%	13.2%	1.4%	0.3%	47.7	104.9	11.6	1
2010	97.3%	13.0%	79.7%	7.3%	0.0%	0.0%	24.8	32.8	10.3	0
2011	99.5%	14.0%	74.1%	11.6%	0.3%	0.0%	30.0	34.4	10.5	0
2012/2013	94.5%	15.1%	71.3%	13.6%	0.0%	0.0%	–	29.2	10.9	0
2013/2014	95.6%	4.6%	83.0%	12.3%	0.0%	0.0%	–	28.3	11.4	0
2014/2015	99.2%	5.8%	87.3%	6.3%	0.0%	0.0%	–	30.4	9.8	0
2015/2016	98.9%	9.6%	82.2%	6.8%	0.3%	0.0%	–	36.5	10.2	0
2016/2017	99.7%	12.6%	77.0%	10.4%	0.0%	0.0%	–	26.4	10.2	0
2017/2018	99.2%	11.9%	81.8%	6.1%	30.0%	0.0%	–	33.1	9.7	0
2018/2019	99.2%	9.1%	79.0%	11.9%	0.0%	0.0%	–	25.5	9.1	0
2019/2020	99.8%	9.8%	80.9%	8.2%	0.8%	0.3%	–	52.5	10.2	1

Summary of PM_{10} concentrations measured at the Croft Tce monitoring station from 2001 to 2020.

Year	Valid Data	Excellent < 5 µg/m³	Good 5-16.5 µg/m³	Acceptable 16.5-33 µg/m³	Alert 33-50 µg/m³	Action >50 µg/m³	2nd Highest µg/m³	Max µg/m³	Annual Average µg/m³	Number Exceedances
2001	93.0%	9.7%	81.2%	9.1%	0.0%	0.0%	20.9	32.0	10.0	0
2002	91.0%	5.1%	87.9%	6.9%	0.0%	0.0%	29.3	26.0	10.4	0
2003	90.0%	9.7%	83.0%	7.3%	0.0%	0.0%	28.0	28.0	10.6	0
2004	96.0%	2.0%	79.5%	18.5%	0.0%	0.0%	24.0	31.0	12.1	0
2005	92.0%	5.8%	73.4%	20.8%	0.0%	0.0%	24.3	28.5	12.8	0
2006	92.0%	5.6%	72.6%	21.2%	0.3%	0.3%	30.0	57.0	12.5	1
2007	94.5%	11.0%	68.1%	20.6%	0.3%	0.0%	26.3	36.6	12.6	0
2008	93.2%	3.5%	66.6%	29.3%	0.6%	0.0%	33.7	36.4	14.6	0
2009	99.7%	9.1%	74.7%	15.7%	0.3%	0.3%	29.7	114.4	12.6	1
2010	97.0%	3.7%	81.9%	14.4%	0.0%	0.0%	25.1	32.1	12.1	0
2011	92.3%	7.1%	76.6%	15.7%	0.6%	0.0%	32.3	37.9	12.0	0
2012/2013	98.1%	9.5%	76.0%	14.5%	0.0%	0.0%	–	30.7	11.6	0
2013/2014	99.5%	7.4%	79.3%	12.7%	0.3%	0.0%	–	26.8	11.6	0
2014/2015	99.5%	7.4%	79.3%	12.7%	0.3%	0.0%	–	41.9	11.3	0
2015/2016	98.9%	24.0%	74.0%	0.8%	0.0%	0.0%	–	23.6	7.2	0
2016/2017	99.5%	24.1%	74.5%	1.1%	0.0%	0.0%	–	19.5	7.3	0
2017/2018	99.5%	19.3%	76.9%	3.6%	0.3%	0.0%	–	33.6	8.6	0
2018/2019	98.6%	6.1%	89.2%	4.7%	0.0%	0.0%	–	19.7	9.9	0
2019/2020	99.6%	15.6%	72.1%	10.4%	0.8%	0.3%	–	52.2	9.8	1

Summary of PM_{10} concentrations measured at the i-Site centre monitoring station from 2006 to 2020.

Year	Valid Data	Excellent < 5 µg/m³	Good 5-16.5 µg/m³	Acceptable 16.5-33 µg/m³	Alert 33-50 µg/m³	Action >50 µg/m³	2nd Highest µg/m³	Max µg/m³	Annual Average µg/m³	Number Exceedances
2006	74.0%	2.4%	69.3%	22.4%	5.1%	0.8%	50.6	56.8	15.4	2
2007	83.0%	1.3%	68.6%	28.1%	2.0%	0.0%	38.8	40.0	14.7	0
2008	96.4%	0.8%	63.2%	33.4%	2.5%	0.0%	40.0	45.2	15.5	0
2009	99.5%	4.4%	67.8%	25.1%	2.2%	0.6%	51.6	104.1	14.9	2
2010	99.2%	3.0%	76.2%	19.9%	0.8%	0.0%	35.1	39.5	13.4	0
2011	98.6%	5.8%	75.3%	18.3%	0.6%	0.0%	34.0	34.8	12.7	0
2012/2013	98.9%	3.9%	69.5%	25.8%	0.8%	0.0%	–	37.3	13.9	0
2013/2014	96.6%	1.9%	68.7%	28.7%	0.5%	0.0%	–	36.2	14.1	0
2014/2015	99.9%	2.2%	74.9%	22.6%	0.6%	0.0%	–	34.7	13.3	0
2015/2016	100.0%	4.9%	79.0%	15.6%	0.5%	0.0%	–	39.5	12.2	0
2016/2017	99.7%	17.3%	74.8%	7.9%	0.0%	0.0%	–	30.7	9.1	0
2017/2018	100.0%	18.9%	77.3%	3.6%	0.3%	0.0%	–	39.0	8.3	0
2018/2019	99.7%	14.3%	83.5%	2.2%	0.0%	0.0%	–	19.6	8.2	0
2019/2020	99.9%	8.7%	87.7%	2.5%	0.5%	0.3%	–	52.7	9.1	1

Summary of PM_{10} concentrations measured at the Frost Rd monitoring station from 2014 to 2020.

Year	Valid Data	Excellent < 5 µg/m³	Good 5-16.5 µg/m³	Acceptable 16.5-33 µg/m³	Alert 33-50 µg/m³	Action >50 µg/m³	2nd Highest µg/m³	Max µg/m³	Annual Average µg/m³	Number Exceedances
2014/2015	62.9%	15.7%	81.7%	2.2%	0.4%	0.0%	–	33.0	8.4	0
2015/2016	100.0%	9.3%	85.2%	5.2%	0.3%	0.0%	–	33.6	9.6	0
2016/2017	99.7%	14.2%	82.7%	3.0%	0.0%	0.0%	–	29.4	8.5	0
2017/2018	99.5%	22.6%	76.3%	1.1%	0.0%	0.0%	–	19.5	7.6	0
2018/2019	100.0%	9.3%	86.8%	3.8%	0.0%	0.0%	–	24.5	9.0	0
2019/2020	99.8%	1.6%	94.5%	3.3%	0.3%	0.3%	–	51.9	9.9	1

Summary of SO_2 concentrations measured at the Pukekapia Rd monitoring station from 2003 to 2020.

	Excellent 0-10% of Guideline	Good 10-33% of Guideline	Acceptable 33-66% of guideline	Alert 66-100% of guideline	>Guideline	Valid Data
2003	99.8%	0.2%	0.0%	0.0%	0.0%	88.0%
2004	100.0%	0.0%	0.0%	0.0%	0.0%	92.0%
2005	100.0%	0.0%	0.0%	0.0%	0.0%	97.0%
2006	100.0%	0.0%	0.0%	0.0%	0.0%	88.0%
2007	100.0%	0.0%	0.0%	0.0%	0.0%	96.0%
2008	100.0%	0.0%	0.0%	0.0%	0.0%	99.0%
2009	99.9%	0.1%	0.0%	0.0%	0.0%	95.0%
2010	99.9%	0.1%	0.0%	0.0%	0.0%	95.0%
2011	100.0%	0.0%	0.0%	0.0%	0.0%	94.0%
2012/2013	99.9%	0.1%	0.0%	0.0%	0.0%	95.0%
2013/2014	99.8%	0.0%	0.0%	0.0%	0.0%	95.2%
2014/2015	99.8%	0.3%	0.0%	0.0%	0.0%	95.1%
2015/2016	100.0%	0.0%	0.0%	0.0%	0.0%	95.6%
2016/2017	100.0%	0.0%	0.0%	0.0%	0.0%	95.3%
2017/2018	100.0%	0.0%	0.0%	0.0%	0.0%	95.2%
2018/2019	100.0%	0.0%	0.0%	0.0%	0.0%	95.7%
2019/2020	100.0%	0.0%	0.0%	0.0%	0.0%	95.1%

Summary of SO_2 concentrations measured at the Croft Tce monitoring station from 2003 to 2020.

	Excellent 0-10% of Guideline	Good 10-33% of Guideline	Acceptable 33-66% of guideline	Alert 66-100% of guideline	>Guideline	Valid Data
2003	99.8%	0.2%	0.0%	0.0%	0.0%	95.0%
2004	100.0%	0.0%	0.0%	0.0%	0.0%	94.0%
2005	99.8%	0.2%	0.0%	0.0%	0.0%	95.0%
2006	99.9%	0.1%	0.0%	0.0%	0.0%	72.0%
2007	100.0%	0.0%	0.0%	0.0%	0.0%	95.0%
2008	100.0%	0.0%	0.0%	0.0%	0.0%	73.0%
2009	99.9%	0.1%	0.0%	0.0%	0.0%	95.0%
2010	100.0%	0.0%	0.0%	0.0%	0.0%	94.0%
2011	100.0%	0.0%	0.0%	0.0%	0.0%	94.0%
2012/2013	99.9%	0.1%	0.0%	0.0%	0.0%	94.0%
2013/2014	100.0%	0.0%	0.0%	0.0%	0.0%	96.6%
2014/2015	100.0%	0.0%	0.0%	0.0%	0.0%	95.4%
2015/2016	100.0%	0.0%	0.0%	0.0%	0.0%	95.3%
2016/2017	100.0%	0.0%	0.0%	0.0%	0.0%	95.2%
2017/2018	100.0%	0.0%	0.0%	0.0%	0.0%	95.3%
2018/2019	100.0%	0.0%	0.0%	0.0%	0.0%	94.7%
2019/2020	100.0%	0.0%	0.0%	0.0%	0.0%	95.5%

Summary of SO_2 concentrations measured at the i-Site centre monitoring station from 2006 to 2020.

	Excellent 0-10% of Guideline	Good 10-33% of Guideline	Acceptable 33-66% of guideline	Alert 66-100% of guideline	>Guideline	Valid Data
2006	100.0%	0.0%	0.0%	0.0%	0.0%	64.0%
2007	100.0%	0.0%	0.0%	0.0%	0.0%	84.0%
2008	100.0%	0.0%	0.0%	0.0%	0.0%	83.0%
2009	99.8%	0.2%	0.0%	0.0%	0.0%	95.0%
2010	99.9%	0.1%	0.0%	0.0%	0.0%	95.0%
2011	99.9%	0.1%	0.0%	0.0%	0.0%	95.0%
2012/2013	99.8%	0.2%	0.0%	0.0%	0.0%	93.0%
2013/2014	99.9%	0.1%	0.0%	0.0%	0.0%	93.8%
2014/2015	99.8%	0.2%	0.0%	0.0%	0.0%	99.4%
2015/2016	100.0%	0.0%	0.0%	0.0%	0.0%	95.4%
2016/2017	100.0%	0.0%	0.0%	0.0%	0.0%	95.4%
2017/2018	100.0%	0.0%	0.0%	0.0%	0.0%	95.6%
2018/2019	99.9%	0.1%	0.0%	0.0%	0.0%	95.7%
2019/2020	100.0%	0.0%	0.0%	0.0%	0.0%	96.2%

Summary of SO_2 concentrations measured at the Frost Rd monitoring station from 2014 to 2020.

	Excellent 0-10% of Guideline	Good 10-33% of Guideline	Acceptable 33-66% of guideline	Alert 66-100% of guideline	>Guideline	Valid Data
2014/2015	99.9%	0.1%	0.0%	0.0%	0.0%	61.8%
2015/2016	100.0%	0.0%	0.0%	0.0%	0.0%	95.6%
2016/2017	100.0%	0.0%	0.0%	0.0%	0.0%	85.1%
2017/2018	100.0%	0.0%	0.0%	0.0%	0.0%	95.4%
2018/2019	100.0%	0.0%	0.0%	0.0%	0.0%	93.6%
2019/2020	100.0%	0.0%	0.0%	0.0%	0.0%	94.1%

Summary of NO_2 concentrations measured at the i-Site centre monitoring station from 2006 to 2020.

	Excellent 0-10% of Guideline	Good 10-33% of Guideline	Acceptable 33-66% of guideline	Alert 66-100% of guideline	>Guideline	Valid Data
2006	86.2%	13.8%	0.0%	0.0%	0.0%	31.0%
2007	78.6%	21.4%	0.0%	0.0%	0.0%	77.0%
2008	87.4%	12.5%	0.0%	0.0%	0.0%	31.0%
2009	82.5%	17.7%	0.0%	0.0%	0.0%	93.0%
2010	67.3%	32.7%	0.0%	0.0%	0.0%	94.0%
2011	88.2%	11.8%	0.0%	0.0%	0.0%	93.0%
2012/2013	70.2%	29.8%	0.0%	0.0%	0.0%	93.0%
2013/2014	80.2%	19.8%	0.0%	0.0%	0.0%	94.0%
2014/2015	83.4%	14.3%	0.4%	0.0%	0.0%	95.9%
2015/2016	83.1%	16.9%	0.0%	0.0%	0.0%	95.1%
2016/2017	73.5%	26.4%	0.1%	0.0%	0.0%	95.3%
2017/2018	62.4%	37.6%	0.0%	0.0%	0.0%	95.6%
2018/2019	64.1%	35.9%	0.0%	0.0%	0.0%	96.1%
2019/2020	88.0%	12.0%	0.0%	0.0%	0.0%	96.1%

Summary of NO_2 concentrations measured at the Frost Rd monitoring station from 2014 to 2020.

	Excellent 0-10% of Guideline	Good 10-33% of Guideline	Acceptable 33-66% of guideline	Alert 66-100% of guideline	>Guideline	Valid Data
2014/2015	99.8%	0.2%	0.0%	0.0%	0.0%	58.3%
2015/2016	100.0%	0.0%	0.0%	0.0%	0.0%	95.4%
2016/2017	98.0%	2.1%	0.0%	0.0%	0.0%	94.3%
2017/2018	99.5%	0.6%	0.0%	0.0%	0.0%	93.2%
2018/2019	100.0%	0.0%	0.0%	0.0%	0.0%	93.6%
2019/2020	99.9%	0.2%	0.0%	0.0%	0.0%	94.0%