Science for Communities

Mount Maunganui Air Quality Monitoring Review 2022

22 June 2023

PREPARED FOR: **Toi Te Ora Public Health**

CLIENT REPORT No: **FW23020**

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EXECUTIVE SUMMARY

This report summarises and reviews Bay of Plenty Regional Council ambient air quality monitoring data from the Mount Maunganui Airshed for the years 2019 through 2022. The focus is on particulate matter (PM_{10} and $PM_{2.5}$) and sulphur dioxide (SO_2) which have previously exceeded national environmental standards for air quality. A brief review of Waka Kotahi NZ Transport Agency long-term monitoring data for nitrogen dioxide (NO_2) in the Mount Maunganui Airshed for the period 2007 – 2021 is also provided.

It should be noted that border controls and measures introduced by the New Zealand Government in 2020 and 2021 in response to the COVID-19 pandemic may have impacted shipping, industrial activities and transport and reduced emissions in the Mount Maunganui Airshed during this period.

The monitoring data shows that ambient air quality in some parts of the Mount Maunganui Airshed remains impacted by industry, port activities and traffic. However, there have been some notable reductions:

- Annual PM_{10} concentrations averaged over the seven monitoring locations in the Mount Maunganui Airshed have reduced by 15% since 2019 (20 µg/m^3 to 17 µg/m^3). Maximum daily levels of PM_{10} have also significantly reduced since 2019, with only one exceedance of the NES for PM_{10} in 2022 compared with 19 exceedances in 2019. Schedule 1 of the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 permits one exceedance in any 12-month period.

- Annual levels of $PM_{2.5}$ measured at Totara Street (only)[1] have significantly reduced (35%) over the last four years, from 6.9 µg/m^3 in 2019 to 5.2 µg/m^3 in 2022. Maximum daily levels of $PM_{2.5}$ have also significantly reduced since 2019, with 99th percentile daily concentrations reducing by 33% (15 µg/m^3 to 10 µg/m^3).[2]

- Short-term levels of SO_2 have significantly reduced in the Mount Maunganui Airshed since 2019. There were no exceedances of the hourly national environmental standards for SO_2, or the 10-minute WHO guideline for SO_2, anywhere in the Mount Maunganui Airshed in 2022. The WHO daily guideline for SO_2 was exceeded once in 2022.[3]

Of note, there has been a significant decline in measured concentrations of PM_{10} at Whareroa Marae. Annual levels of PM_{10} at Whareroa Marae have reduced by 43% in 2022 compared with 2019 and are now well below health-based guidelines, with zero exceedances of the national environmental standard for PM_{10} in 2022. The extent of this reduction appears unique to Whareroa Marae, amongst all the monitoring sites in the Mount Maunganui Airshed, and may reflect mitigation undertaken by neighbouring industrial activities. There are multiple sources of industrial PM_{10} emissions adjacent to Whareroa Marae.

This review of monitoring data and meteorology suggests that long-term concentrations of PM_{10} in the Mount Maunganui Airshed are influenced by proximity to shipping activities and industrial sources with an increasing trend from west (predominantly upwind of the Mount

[1] There is only one site measuring $PM_{2.5}$ in the Mount Maunganui Airshed.

[2] The 99th percentile concentration is a more stable statistic for trend analysis than maximum daily concentration as it excludes outlier maximum concentrations due to extraordinary meteorology.

[3] 3 – 4 exceedances are permitted in a year (WHO, 2021). It should be noted that exceedance of a WHO (global) air quality guideline has no regulatory status in New Zealand (which is different to a 'breach' of a national environmental standard).

Maunganui Airshed) to east (predominantly downwind). Rail Yard South, located closest to, and predominantly downwind of, the Port of Tauranga, consistently records the highest annual average PM_{10} concentrations in the airshed.

The annual concentration of PM_{10} averaged over the Mount Maunganui Airshed (17 µg/m^3 in 2022) still exceeds the WHO guideline (15 µg/m^3) with higher levels being recorded in more industrial locations. Further work is likely to be needed to achieve annual and maximum daily concentrations of PM_{10} consistently below relevant standards and guidelines in all parts of the airshed.

The introduction of MARPOL Annex VI, which mandated reductions in emissions of SO_2 from ships, resulted in a step-change reduction in short-term concentrations of SO_2 at all bar two monitoring locations in the Mount Maunganui Airshed. Closer investigation of the data suggests that elevated short-term levels of SO_2 at Whareroa Marae and Tauranga Bridge Marina remain influenced primarily by emissions from the neighbouring fertiliser manufacturer.

SO_2 is a precursor pollutant that contributes to the formation of $PM_{2.5}$. Trend analysis suggests the introduction of MARPOL Annex VI in early January 2020 may have supported the reductions in $PM_{2.5}$ in the Mount Maunganui Airshed between 2019 and 2022. Current levels of $PM_{2.5}$ measured at Totara Street comply with the WHO daily guideline and are only just over the WHO annual guideline.

A brief review of available monitoring data appears to show a long-term *increase* in annual NO_2 concentrations measured at a roadside site in the Mount Maunganui Airshed over the period 2007 – 2018, with no clear trend since then. This is inconsistent with trends in the remainder of New Zealand, which show clear reductions in annual NO_2 despite increases in annual vehicle kilometres travelled. NO_2 is also a precursor pollutant that contributes to the formation of $PM_{2.5}$. Bearing in mind the limitations of the (non-regulatory) monitoring data, and potential confounding factors such as road construction, ambient concentrations of NO_2 in Mount Maunganui warrant additional monitoring and investigation.

1. Introduction

The Mount Maunganui Airshed is home to the largest port in New Zealand (Port of Tauranga Ltd, POTL) and a significant industrial estate. Residents of Mount Maunganui, including Whareroa Marae,[4] have made multiple complaints of poor air quality to Bay of Plenty Regional Council (BOPRC) about industrial discharges to air over the years.

BOPRC has been monitoring air quality at the Totara Street site shown in Figure 1 since 2006. In 2015, BOPRC commenced air quality monitoring for particulate matter less than 10 micrometres in diameter (PM_{10}) and sulphur dioxide (SO_2) at Whareroa Marae (refer Figure 1). This monitoring showed that ambient levels of PM_{10} and SO_2 exceeded health-based air quality criteria. Exceedances of the national environmental standard for PM_{10} at multiple locations in the Mount Maunganui Airshed are a result of emissions from multiple industrial sources and port activities. Some of the SO_2 exceedances were attributed to emissions from a fertiliser manufacturer (Ballance Agri-Nutrients Ltd) located adjacent and to the north of Whareroa Marae as shown in Figure 2. Regulatory action by BOPRC and mitigation by Ballance Agri-Nutrients Ltd resulted in significant reductions in short-term concentrations of SO_2 measured at Whareroa Marae in 2016.

In late 2018, BOPRC commenced air quality monitoring at five additional monitoring locations shown in Figure 1. BOPRC also commenced monitoring for particulate matter less than 2.5 micrometres in diameter ($PM_{2.5}$) at Totara Street (only). On 31 October 2019, BOPRC gazetted the Mount Maunganui Airshed, which was deemed to be polluted for the purposes of the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (NESAQ).[5]

There are now four full calendar years of ambient air quality data from seven monitoring locations in the Mount Maunganui Airshed. This report summarises and reviews BOPRC PM_{10} and SO_2 monitoring data for the years 2019 through 2022. Available monitoring data for $PM_{2.5}$ are also reviewed and discussed.

Following publication of the third Health and Air Pollution in New Zealand study (Kuschel *et al.*, 2022) there is significant public health interest in ambient levels of nitrogen dioxide (NO_2). BOPRC does not undertake monitoring for NO_2 in the Mount Maunganui Airshed. However, Waka Kotahi NZ Transport Agency has undertaken long-term (non-regulatory) monitoring for NO_2 at a site on the eastern boundary of the Mount Maunganui Airshed as shown in Figure 1. Long-term NO_2 data from this monitoring location are reviewed and discussed.

From a broader public health perspective, we note there are five childcare facilities inside the Mount Maunganui Airshed (including a kohanga reo at Whareroa Marae).[6] There are also people living at the marinas located at Tauranga Bridge and Sulphur Point and adjacent to the airport in De Havilland Way. Summary data for all monitoring locations, and overall airshed averages, are also presented.

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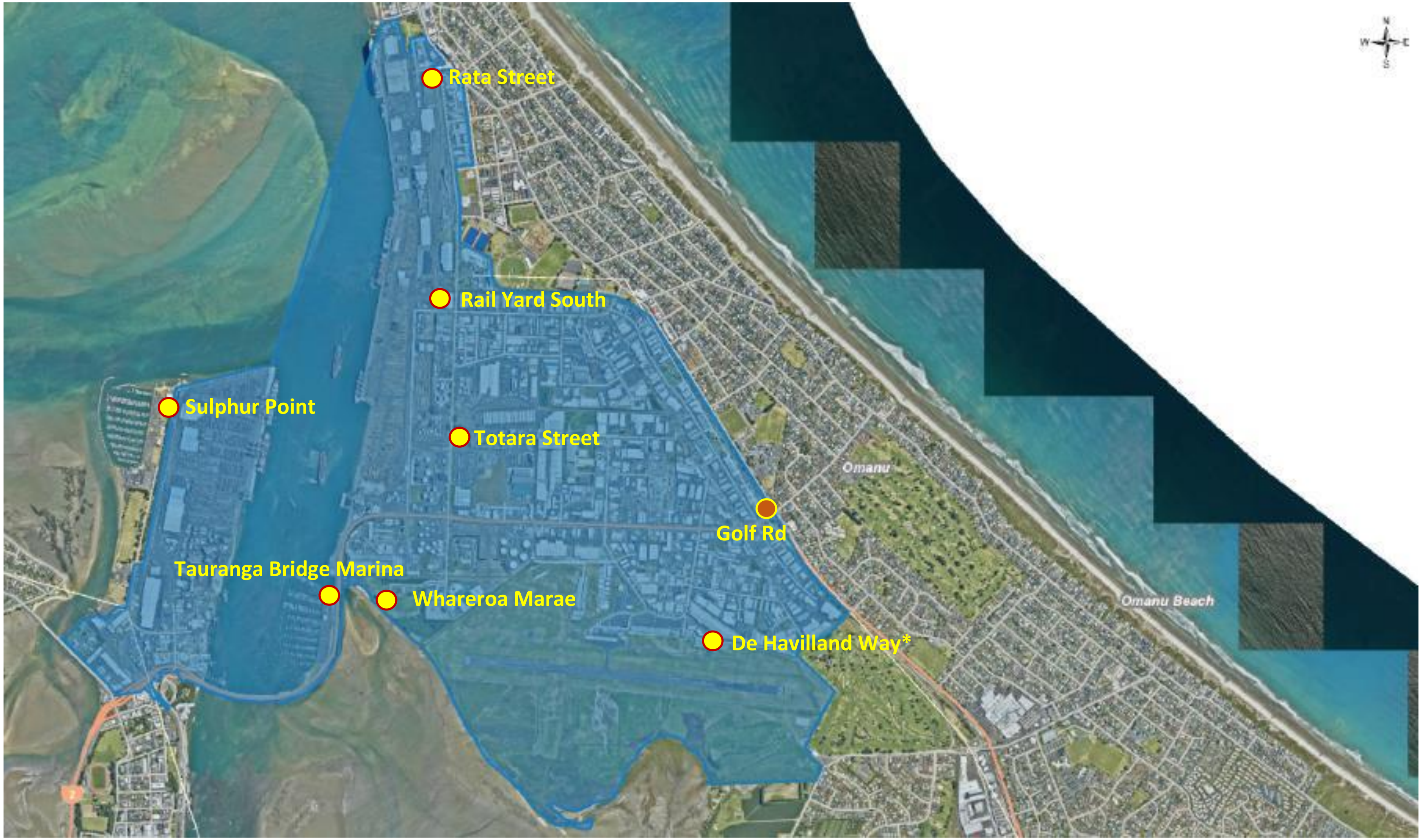
[4] Whareroa Marae and the adjoining community are situated on the shore of Tauranga Harbour. Whareroa Marae is a traditional pa site and key marae for Ngai Tukairangi and Ngāti Kuku hapū of the Ngāi Te Rangi Iwi. Whareroa Pā has been present for around 150 years, making it one of the oldest kāinga (settlements) in the area.

[5] Regulation 17(4) of the NESAQ provides that an airshed is polluted if there is, on average, more than one exceedance of the ambient standard for PM_{10} in any 12-month period. (Schedule 1 of the NESAQ permits one exceedance of the ambient standard in any 12-month period).

[6] Bambinos Early Childhood Centre (Tawa St), Newton Street Childcare Ltd, Little Einsteins Montessori (MacDonald St), BestStart MacDonald Street and Te Kohanga Reo o Whareroa (Whareroa Marae).

FIGURE 1: BOPRC PM, SO_2 (yellow)* and NZTA NO_2 (brown) monitoring locations in the Mount Maunganui Airshed (blue)



*PM_{10} only (no SO_2 monitoring at De Havilland Way)

FIGURE 2: Whareroa Marae, Tauranga Bridge Marina and Totara Street air quality monitoring locations

1.1 KEY CONTAMINANTS

This report reviews and discusses available ambient air quality monitoring data for PM_{10}, $PM_{2.5}$, SO_2 and NO_2.

BOPRC also carried out monitoring for hydrogen sulphide (H_2S) at Whareroa Marae between September 2015 and October 2020. Whilst H_2S is a toxic contaminant, the purpose of the monitoring was to support odour investigations and in 2020 BOPRC switched to monitoring total reduced sulphur (TRS) compounds instead. There are no health-based ambient criteria for TRS compounds and so this monitoring is excluded from this review.

We also note that BOPRC also undertakes ambient monitoring of hydrogen fluoride (HF) at Whareroa Marae, however, due to instrument failure there are insufficient data to currently assess levels. This monitoring is excluded from this review.

There are other pollutants with harmful effects on health that may be present in the Mount Maunganui Airshed at elevated concentrations. These include toxic pollutants such as benzene and polycyclic aromatic hydrocarbons. These cannot be reviewed because there are no robust ambient air quality monitoring data available.

Methyl bromide was also excluded from this review.

The following sections provide a brief overview of adverse health effects known to be caused by, or associated, with public exposure to key contaminants.

1.1.1 Particulate matter

Particulate Matter (PM) is a collective term for solid and liquid particles suspended in the air and small enough to be inhaled. The major components of PM are sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water.

PM is classified by particle size defined through aerodynamic diameter as follows:

- **PM_{10}** – particulate less than 10 microns; known as coarse particulate
- **$PM_{2.5}$** – particulate less than 2.5 microns; known as fine particulate
- **PM_1** – particulate less than 1 micron; known as ultrafine particulate

In general, $PM_{2.5}$ and smaller tend to be more closely associated with anthropogenic activities, whereas $PM_{10-2.5}$ can have a substantial natural source component. The primary anthropogenic sources of PM in the Mount Maunganui Airshed are industry, shipping and port activities (including cargo and bulk solid materials storage and handling) and transport. BOPRC has concluded that natural sources, such as marine sea salt, can also be significant on occasion.[7]

Different sizes of PM can result in different health effects. This is because they deposit in different parts of the respiratory tract, they have diverse sources, and they can interact through different biological mechanisms (WHO, 2013). In general, the smaller a particle is, the farther into the respiratory tract it can penetrate to interact and cause adverse health effects.

There is scientific consensus that exposure to particulate pollution causes predominantly respiratory and cardiovascular effects, ranging from subclinical functional changes (e.g. reduced lung function) to symptoms (increased cough, exacerbated asthma) and impaired activities (e.g. school or work absenteeism) through to doctors' or emergency room visits, hospital admissions and death (WHO, 2006). The effects, in terms of escalating severity, are described as increased visits to doctors for many individuals, hospital admission for some

[7] In 2022, BOPRC concluded that an exceedance of the national environmental standard for PM_{10} in the Mount Maunganui Airshed was due to marine aerosols.

individuals and death for a few individuals. People with pre-existing heart or lung disease, young children, and the elderly, are most likely to suffer adverse health effects. The exposure-response relationship is essentially linear and there is no ‘safe’ threshold; adverse health effects are observed at all measured levels (US EPA 2020; WHO 2013, WHO, 2021).

In 2013, the International Agency for Research on Cancer (IARC) classified particulate matter (as a component of outdoor pollution) as carcinogenic based on an increased risk of lung cancer (IARC, 2013). Additional research further indicates particulate matter is associated with atherosclerosis, adverse birth outcomes, and childhood respiratory disease (WHO, 2013) as well as Alzheimer’s disease and other neurological endpoints, cognitive impairment, diabetes, systemic inflammation and aging (WHO, 2016).

More recently, WHO has concluded that chronic exposure to PM is causal, or likely to be causal, for (WHO, 2021):

- All-cause mortality
- Cardiovascular mortality (all, cerebrovascular, ischaemic heart disease)
- Respiratory mortality (any, chronic obstructive pulmonary disease, acute lower respiratory infections)
- Lung cancer

1.1.2 Sulphur Dioxide

Sulphur dioxide arises naturally from volcanic sources, with White Island being New Zealand’s largest source of sulphur dioxide (PAE, 2009). The main sources of sulphur dioxide in Mount Maunganui are shipping and industry. Away from industrial and volcanic sources, background levels of sulphur dioxide in New Zealand are typically very low, less than 5 µg/m^3 as a one-hour average.

Sulphur dioxide can cause respiratory problems, such as bronchitis, and it can irritate the nose, throat and lungs. This is because inhaled sulphur dioxide readily reacts with the moisture of mucous membranes to form sulphurous acid (which is a severe irritant). It may cause coughing, wheezing, phlegm and asthma attacks (MfE, 2014). The speed with which people show health effects from exposure to SO_2 necessitates a focus on acute exposure.

Studies have shown that asthmatics and people with lung disease are particularly sensitive to sulphur dioxide. Children may also be more sensitive to the effects of sulphur dioxide due to their relatively higher respiration rate and smaller body mass.

In 2021, WHO published two systematic reviews and meta-analyses on the effects of short-term exposure to ambient sulphur dioxide (SO_2). Orellano *et al.,*2021 found that short term increases in SO_2 increased the risk of all-cause mortality (daily SO_2) and respiratory mortality (1-hour SO_2) with a high certainty of evidence. In general, concentration response functions showed linear behaviour with no thresholds. Orellano *et al.,*2021 considered that the epidemiological evidence supported a causal relationship. Zheng *et al.,*2021 found that short term increases in SO_2 correlated with increased risk of asthma-associated emergency room visits and hospital admissions. Children and to a lesser extent the elderly are more susceptible. The positive correlation between daily SO_2 and asthma-associated emergency room visits and hospital admissions was judged as having a moderate certainty of evidence and warrants further investigation. SO_2 was not found to have a daily threshold of effects.

SO_2 is a precursor pollutant that contributes to the formation of $PM_{2.5}$.

1.1.3 Nitrogen Dioxide

Nitrogen dioxide (NO_2) is a reddish brown coloured acidic gas with a characteristic pungent odour. In New Zealand generally the main source of nitrogen dioxide is motor vehicles. In

Mount Maunganui, ships and industry are also likely to be significant sources of nitrogen dioxide.

Long-term exposure to NO_2 increases the risk of premature death (mortality) and respiratory illnesses (morbidity) (WHO, 2021). Epidemiolocal studies have also shown that symptoms of bronchitis in asthmatic children increase with long-term exposure to NO_2. Reduced lung function is also linked to measured levels within cities of Europe and North America (WHO, 2006). Recent evidence also suggests exposure may increase the risk of premature death and trigger heart attacks (USEPA, 2016).

Short-term exposure to high concentrations of nitrogen dioxide (NO_2) causes significant inflammation of the airways and respiratory problems and can also trigger asthma attacks (WHO, 2021).

NO_2 is both a primary and secondary pollutant i.e., it is both emitted directly and is created from other pollutants (for example, oxides of nitrogen) downwind. NO_2 is also a precursor pollutant that contributes to the formation of $PM_{2.5}$.

1.2 STANDARDS AND GUIDELINES

This report summarises and reviews available ambient air quality monitoring data on PM_{10}, $PM_{2.5}$, SO_2 and NO_2 from the Mount Maunganui Airshed for Toi Te Ora Public Health. Comparison is made with the ambient air quality standards in the NESAQ, specifically the short-term national environmental standards for PM_{10} and SO_2.[8]

New Zealand has no *long-term* national environmental standards. To address this gap, this review compares long-term monitoring data with global air quality guidelines published by the World Health Organisation (WHO, 2021). The WHO air quality guidelines (AQG) are based on the lowest long-term exposures that are, with at least moderate certainty, associated with adverse health effects and represent the most up to date science.

Reference is also made to the 10-minute and daily WHO AQG for SO_2 as these specifically address documented acute elevation of risk over timescales of minutes (WHO, 2000) to one or a few days (WHO, 2021).

It is important to note that the WHO AQG have no regulatory status in New Zealand. Where relevant, reference is also made to New Zealand air quality guidelines for annual PM_{10} and daily SO_2 (MfE 2002).

Table 1, which follows, presents air quality standards and health-based guidelines referenced in this report.

[8] No reference is made to short-term (1-hour) average standards or guidelines for NO_2 as there are no short-term ambient air quality monitoring data for NO_2 available.

TABLE 1: Ambient air quality standards and guidelines for PM_{10}, $PM_{2.5}$, SO_2 and NO_2

Time Average / Jurisdiction (Year)	Standard / Guideline (µg/m³)	Permitted Exceedances per Year
PM_{10}		
Annual WHO (2021) New Zealand (2002) [a]	 15 20	 0 0
24-hours WHO (2021) New Zealand (2004) [b]	 45 50	 3 – 4 1
$PM_{2.5}$		
Annual WHO (2021)	 5	 0
24-hours WHO (2021)	 15	 3 – 4
SO_2		
24-hours WHO (2021) New Zealand (2002) [a]	 40 120	 3-4 0
1-hour New Zealand (2004) [b]	 350 570	 9 0
10-minutes WHO (2000)	 500	 0
NO_2		
Annual WHO (2021)	 10	 0

[a] National ambient air quality guideline [b] National environmental standard

1.3 COVID-19

In 2020 and 2021, in response to the COVID-19 pandemic, the New Zealand Government shut international borders and imposed national and regional lockdowns restricting travel and movement except for essential services. The lockdowns affecting Mount Maunganui were phased in through a series of alert levels as shown in Table 2.

The lockdowns would have reduced manufacturing activity and associated vehicle movements in the Mount Maunganui Airshed resulting in reductions in particulate emissions and potentially some other pollutants, however, exact details are not known.

Figure 3 shows annual shipping for POTL for the years 2018 – 2022. Between April 2020 and January 2022, no passenger vessels visited the Port. Figure 3 shows that the global pandemic reduced ship visits through the Port with total ship visits down by 19% in the three years ending 31 December 2022, compared with 2018 and 2019.[9] However, this reduction was not evenly distributed as logging ship visits appear unaffected in 2021 as shown in Figure 4.

[9] Difference calculated from average total ship visits in 2018 and 2019 compared with the average total ship visits in 2020, 2021 and 2022.

On 3 December 2021, New Zealand moved to a traffic light COVID response system. Since this time there have been no social restrictions in the Mount Maunganui Airshed.

TABLE 2: COVID-19 Alert Levels affecting Mount Maunganui Airshed in 2020 - 2021

DATE	LEVEL	DURATION (DAYS)	DETAILS
23 Mar 2020	3	3	Schools shut. Essential activities & construction work only.
26 Mar 2020	4	33	Everything shut except essential activities*
28 Apr 2020	3	16	Schools shut. Essential activities & construction work only.
18 Aug 2021	4	14	Everything shut except essential activities*
1 Sep 2021	3	7	Schools shut. Essential activities & construction work only.
2020 - 2021		47	Days at Alert Level 4
		73	Days at Alert Level 3 & 4

*NB: The Port of Tauranga, an essential activity, remained open at all times

FIGURE 3: Total ship visits to the Port of Tauranga: 2018 – 2022 [Source: POTL]

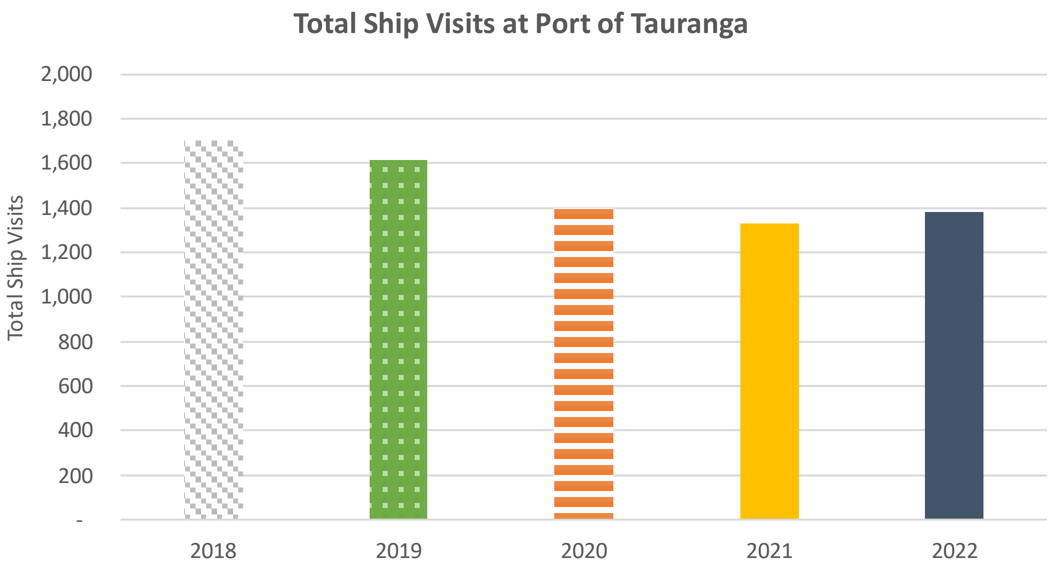
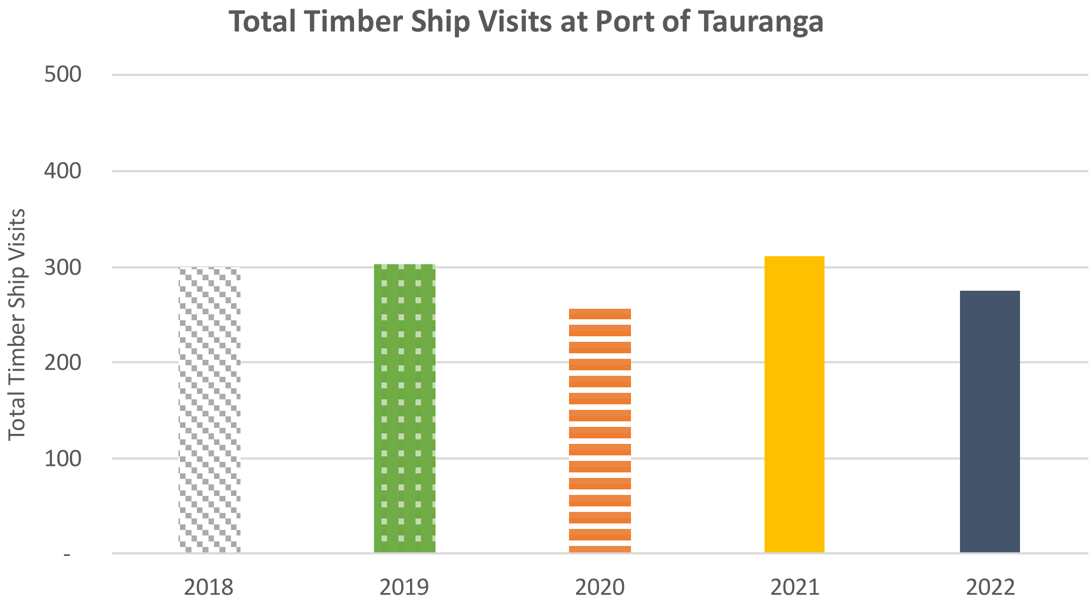


FIGURE 4: Total timber ship visits to the Port of Tauranga: 2018 – 2022 [Source: POTL]



1.4 MARPOL ANNEX VI

On 1 January 2020 new shipping regulations came into force, which require all ships flagged to states that have ratified Annex VI of the MARPOL treaty to burn low sulphur fuel or implement abatement technology to reduce emissions of SO_2 and NO_2. New Zealand ratified the treaty in 2022.

SO_2 and NO_2 are precursor pollutants that contribute to the formation of $PM_{2.5}$ in the atmosphere.

Most, if not all, ships visiting the Port of Tauranga are flagged to states other than New Zealand. This means the implementation of Annex VI on 1 January 2020 is likely to have impacted on ambient levels of key contaminants in the Mount Maunganui Airshed from that date.

1.5 REPORT LAYOUT AND METHODOLOGY

Summary ambient air quality monitoring data are tabulated in Appendix A. Additional graphs of monitoring data are provided in Appendix B.

The following sections review air quality against standards and guidelines and discuss trends apparent in the four years of monitoring data. Data are presented by pollutant for the Mount Maunganui Airshed first, and then by monitoring site in 'like' pairs (based on activities at and adjacent to the monitoring location) as reasonably practicable.[10]

All data are quality assured from BOPRC. Please note:

- Rail Yard South and Totara Street are entirely industrial locations. All other monitoring locations are a mix of residential, commercial and industrial activities (refer Figure 1 and Figure 2).

[10] PM_{10} data for Rata Street is discussed singly as there are an odd number of monitoring locations.

- All data exclude exceptional events approved by the Minister for the Environment.[11] Exceptional events are unusual or naturally occurring events that can affect air quality but are not reasonably controllable using techniques that regional councils may implement in order to attain and maintain the NES for PM_{10}. Appendix A provides further details on each event.

- Tabulated exceedances for the Mount Maunganui Airshed do not (double) count exceedances that occur at the same time at multiple locations. For example, an exceedance of the daily NES for PM_{10} that occurs at two monitoring stations on the same day is only one exceedance for the airshed. Appendix B tabulates exceedances for each site individually.

- Tabulated data include 99th percentile values for each pollutant for each time average. This is the value below which 99% of the data lies. When presented as an airshed value, this is the value calculated for all monitoring data at all sites in the airshed.

  For example, Table 3 shows the 99th percentile daily concentration of PM_{10} was 41 µg/m^3 for the Mount Maunganui Airshed in 2022. This means that 99% of the time in 2022 (361 out of 365 days), daily concentrations of PM_{10} were below 41 µg/m^3 at all of the seven sites monitoring PM_{10} in the Mount Maunganui Airshed.

[11] https://environment.govt.nz/acts-and-regulations/regulations/national-environmental-standards-for-air-quality/applying-to-have-a-breach-of-an-air-quality-standard-excluded/

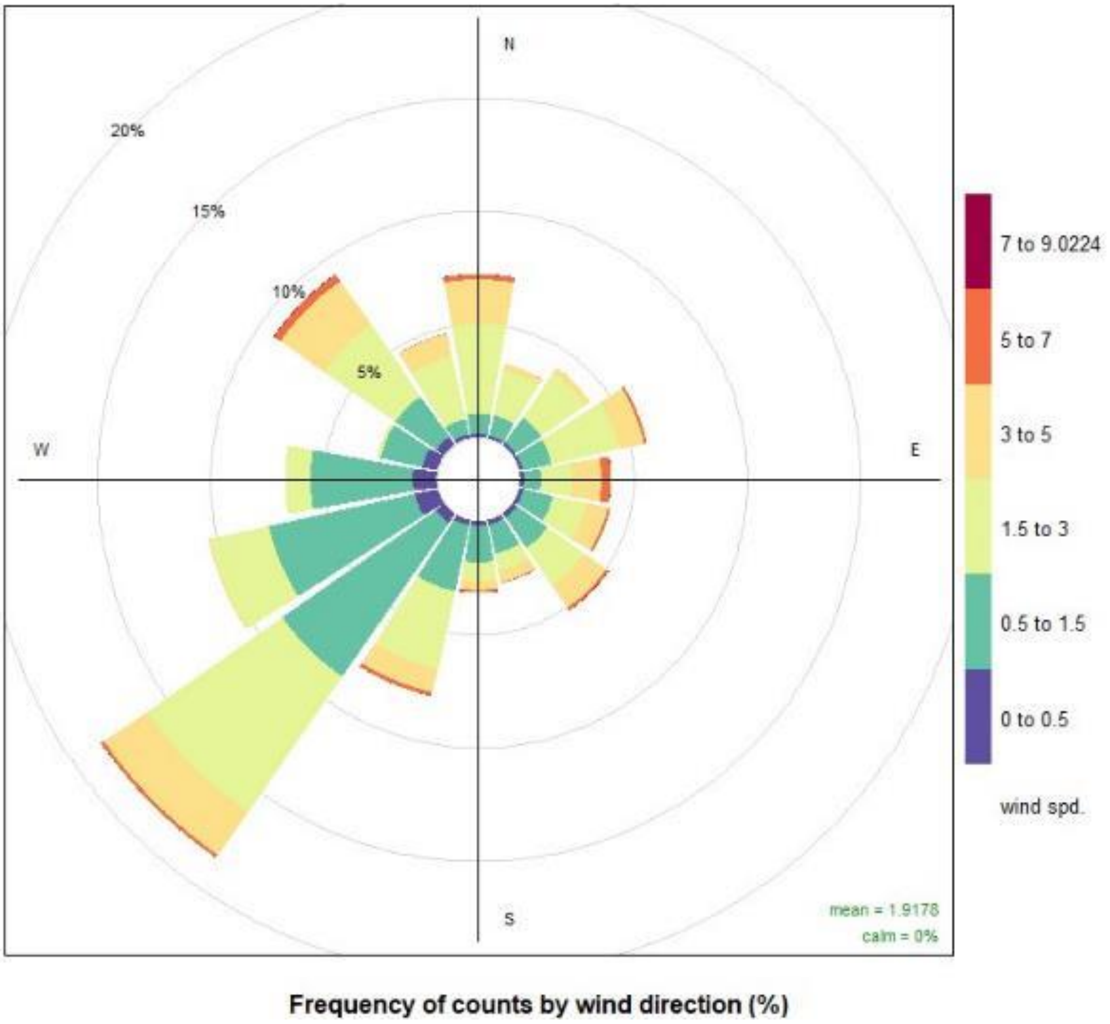
2. METEOROLOGY

Figure 5 presents a windrose prepared from 10-minute wind speed and wind direction data collected at Whareroa Marae between 2019 and 2022. Figure 6 presents the same data by season.

There is a predominance of winds from the south-west and west south-west (together ~30%) and, to a lesser extent, the north-west (nearly 10%). The fertiliser works is located immediately adjacent to Whareroa Marae, with key stack sources located to the north-west of the marae and to the north-east of Tauranga Bridge Marina (refer Figure 2).

Figure 7 presents annual precipitation data collected at Tauranga Airport.[12] This shows that, in contrast to previous years, 2022 was an exceptionally wet year (Chappell, 2013). In light of this variation determining trends, particularly for PM_{10}, has some risk.

FIGURE 5: Windrose of 10-minute wind speed (m/s) and wind direction measured at Whareroa Marae: 2019 – 2022



[12] Data from the rain gauge at Whareroa Marae are not quality assured.

FIGURE 6: Seasonal windroses of 10-minute wind speed (m/s) and wind direction measured at Whareroa Marae: 2019 – 2022

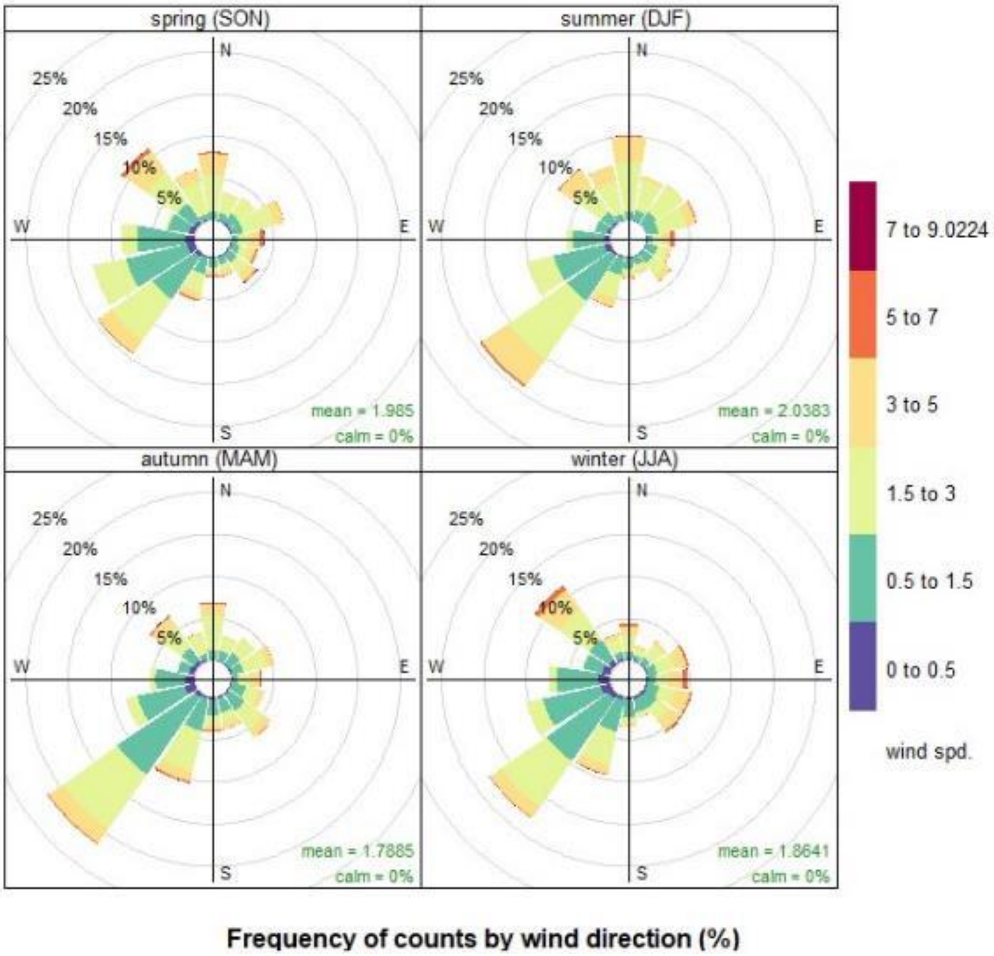
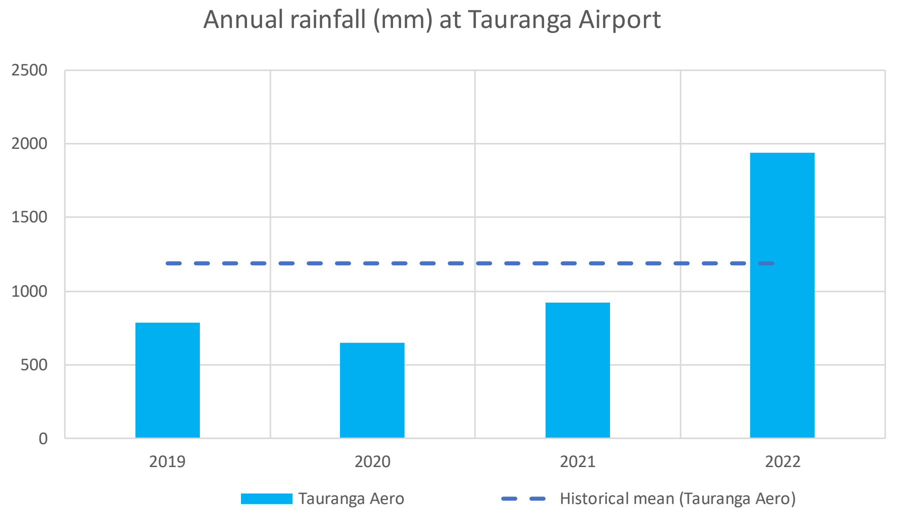


FIGURE 7: Annual precipitation from Tauranga Airport: 2019 – 2022. [Source: CliFlo]



3. PM_{10}

Tables A1 – A4 in Appendix A provide summary PM_{10} statistics for all sites for 2019 through 2022.

3.1 MOUNT MAUNGANUI AIRSHED

Table 3 provides summary statistics for annual and daily PM_{10} in the Mount Maunganui Airshed for comparison with air quality standards and guidelines. Data exclude exceptional events (e.g., the Australian bush fires caused an exceedance of the NES for PM_{10} on 6 December 2019).

Mount Maunganui Airshed values are calculated from all available monitoring sites (refer Figure 1). This includes seven sites monitoring PM_{10} (Sulphur Point, Tauranga Bridge Marina, Whareroa Marae, De Havilland Way, Rata Street, Rail Yard South and Totara Street).

TABLE 3: Mount Maunganui Airshed* PM_{10} summary statistics: 2019 – 2022

Year	Maximum daily PM_{10} ($\mu g/m^3$)	99th Percentile daily PM_{10} ($\mu g/m^3$)	Exceedances per year NES (no.)	Exceedances per year WHO AQG (no.)	Annual mean PM_{10} ($\mu g/m^3$)
	[NES = 50] [WHO AQG = 45]		[1 permitted]	[3-4 permitted]	[WHO AQG = 15]
2019	**70**	**49**	**19**	**37**	**20**
2020	**115**	40	**7**	**13**	**17**
2021	**52**	40	**2**	**6**	**18**
2022	62	41	1	**10**	**17**

*Calculated from data at seven sites: Sulphur Point, Tauranga Bridge Marina, Whareroa Marae, De Havilland Way, Rata Street, Rail Yard South and Totara Street.

Table 3 shows that annual PM_{10} concentrations averaged over the Mount Maunganui Airshed have reduced by 15% since 2019 (20 $\mu g/m^3$ to 17 $\mu g/m^3$).

Table 3 also shows that daily levels of PM_{10} have reduced since 2019. The Mount Maunganui Airshed recorded only one exceedance of the NES for PM_{10} in 2022, which is a significant improvement on 19 exceedances recorded in 2019. This exceedance was measured at two locations on 21 April 2022, with daily PM_{10} concentrations of 53 $\mu g/m^3$ and 62 $\mu g/m^3$ recorded at Rata Street and Tauranga Bridge Marina respectively. The NESAQ permits one exceedance of the daily PM_{10} standard (50 $\mu g/m^3$) in any 12-month period in an airshed.

As noted in section 2, 2022 was an exceptionally wet year, which may influence maximum daily and annual concentrations of PM_{10}.

Whilst the Mount Maunganui Airshed complied with the NES for PM_{10} in 2022, Regulation 17(4) requires 5 years of continued compliance before the airshed loses its “polluted” status.

Figure 8 presents annual average concentrations of PM_{10} measured at seven monitoring locations in the Mount Maunganui Airshed for comparison with the New Zealand and WHO guidelines. All monitoring locations except Rail Yard South and Totara Street met the New Zealand guideline (20 $\mu g/m^3$) for annual PM_{10} in 2022. However, only three locations; Sulphur Point, Tauranga Bridge Marina and Whareroa Marae, met the WHO guideline (15 $\mu g/m^3$) for annual PM_{10} in 2022.

It should be noted that exceedance of a WHO (global) air quality guideline has no regulatory status in New Zealand (which is different to a 'breach' of a national environmental standard for PM_{10}).

Figure 9 presents the 4-year mean (2019 – 2022) PM_{10} concentration (units are µg/m^3) for each monitoring location on a map.

FIGURE 8: Annual PM_{10} concentrations measured in the Mount Maunganui Airshed: 2019 – 2022

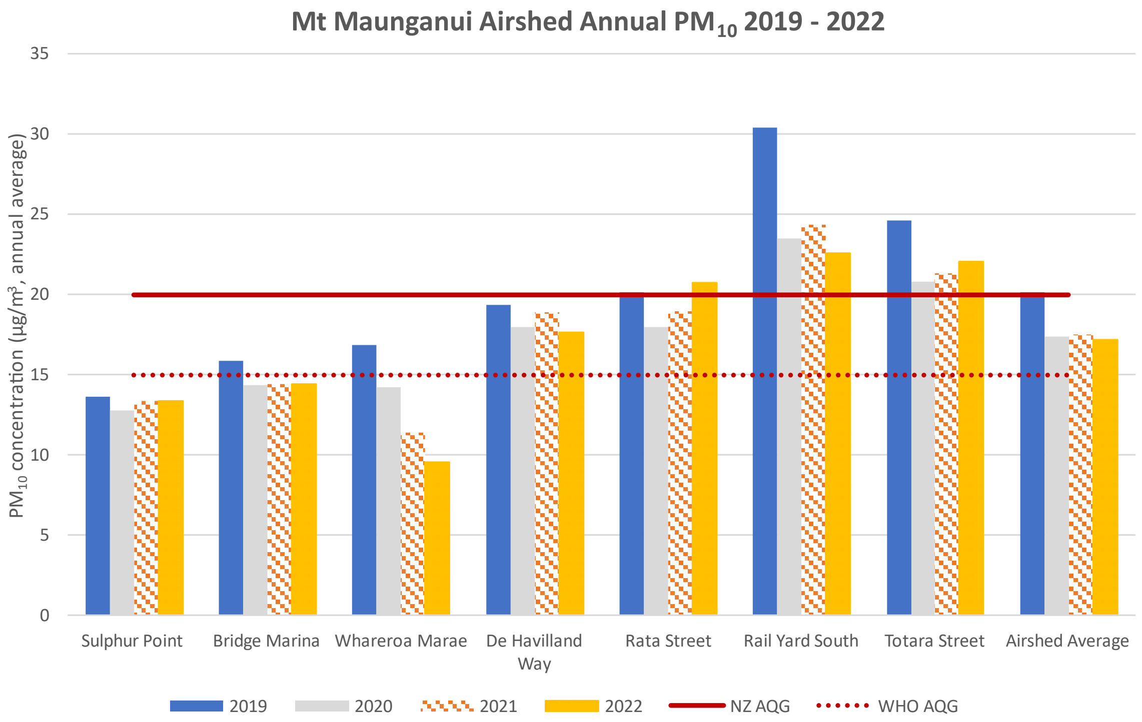
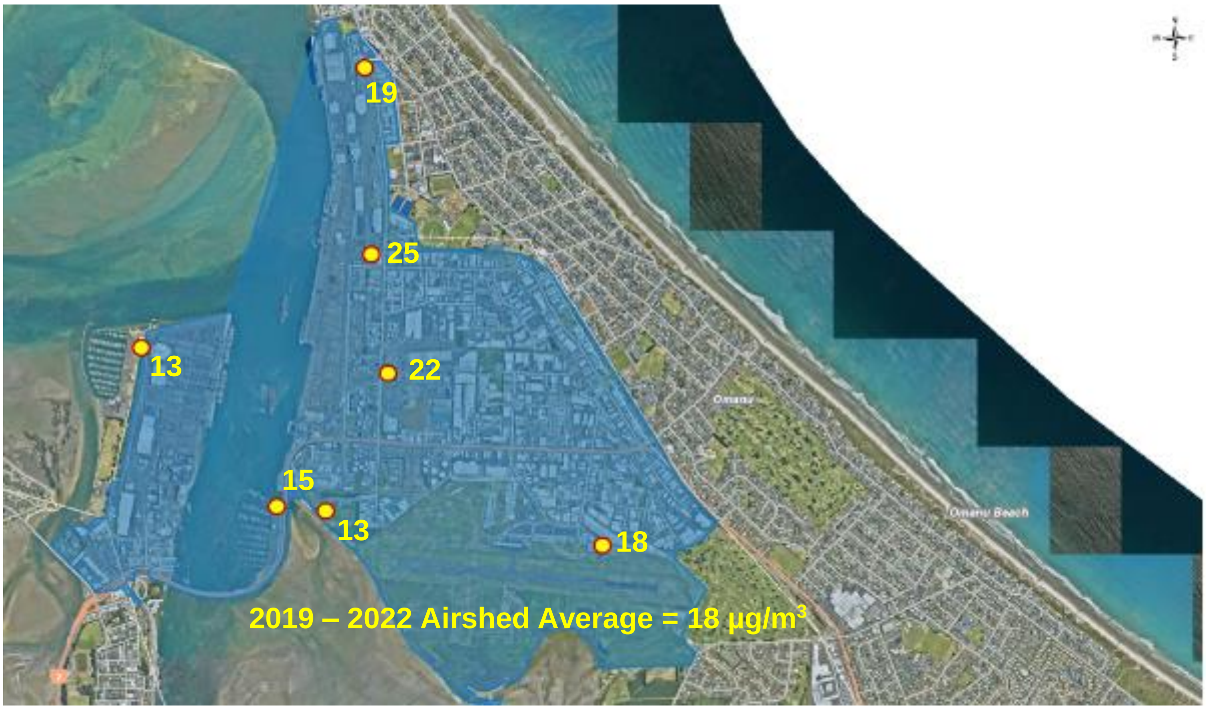


FIGURE 9: Four-year mean (2019 – 2022) PM_{10} concentrations (µg/m^3) measured in the Mount Maunganui Airshed



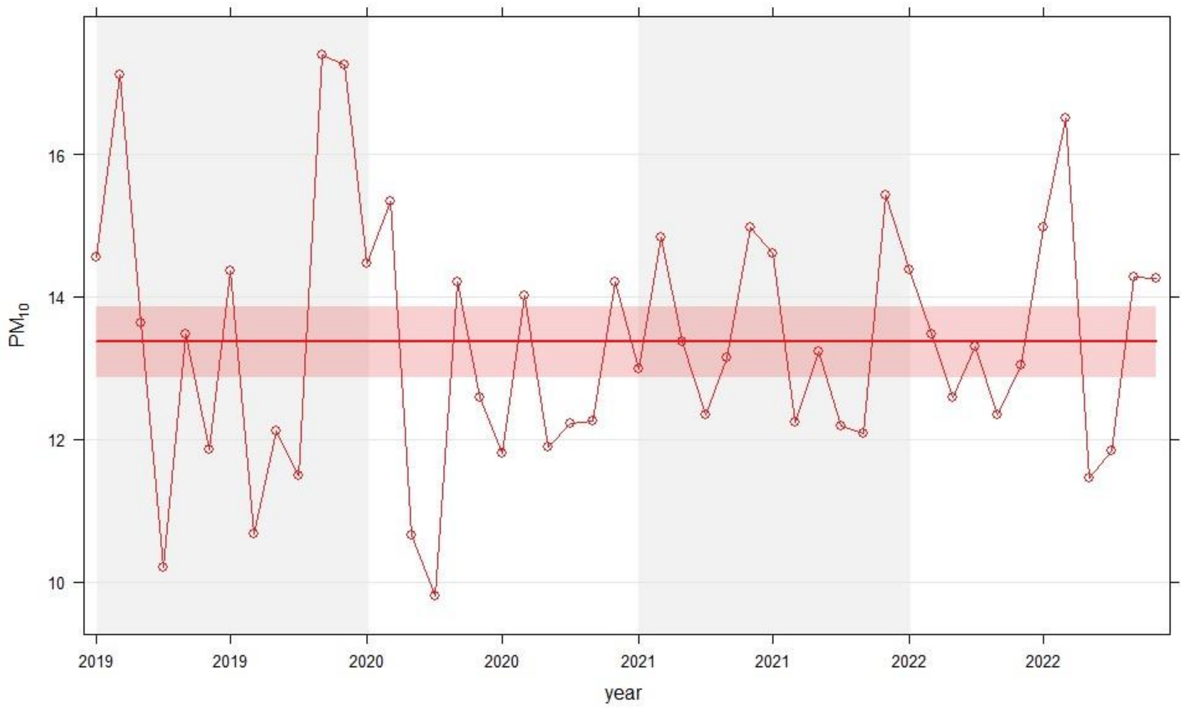
3.2 SULPHUR POINT AND TAURANGA BRIDGE MARINA

Annual levels of PM_{10} for Sulphur Point and Tauranga Bridge Marina are presented in Figure 8 for the period 2019 – 2022.

Figure 10 (Sulphur Point) and Figure 11 (Tauranga Bridge Marina) present monthly concentrations of PM_{10} with a smoothed trend line and 95% confidence intervals for the period 2019 – 2022.[13] These data show a flat, unchanging long-term exposure trend to PM_{10}, with Tauranga Bridge Marina being slightly (11%) higher on average than Sulphur Point.[14]

Figure 12 presents a time series plot of daily concentrations of PM_{10} measured at Sulphur Point and Tauranga Bridge Marina for comparison with the national environmental standard and the WHO guideline for PM_{10}. With the recent exception of two elevated days at Tauranga Bridge Marina in 2022, daily levels are typically below relevant standards and guidelines.

FIGURE 10: Long term trend - monthly PM_{10} concentrations (µg/m^3) measured at Sulphur Point with smoothed trend line and 95% confidence intervals for fit: 2019 – 2022



[13] Smoothed trend and 95% confidence intervals calculated using the OpenAir library in R statistical computing platform.

[14] Comparison of 4-year average values

FIGURE 11: Long term trend - monthly PM_{10} concentrations (µg/m^3) measured at Tauranga Bridge Marina with smoothed trend line and 95% confidence intervals for fit: 2019 – 2022

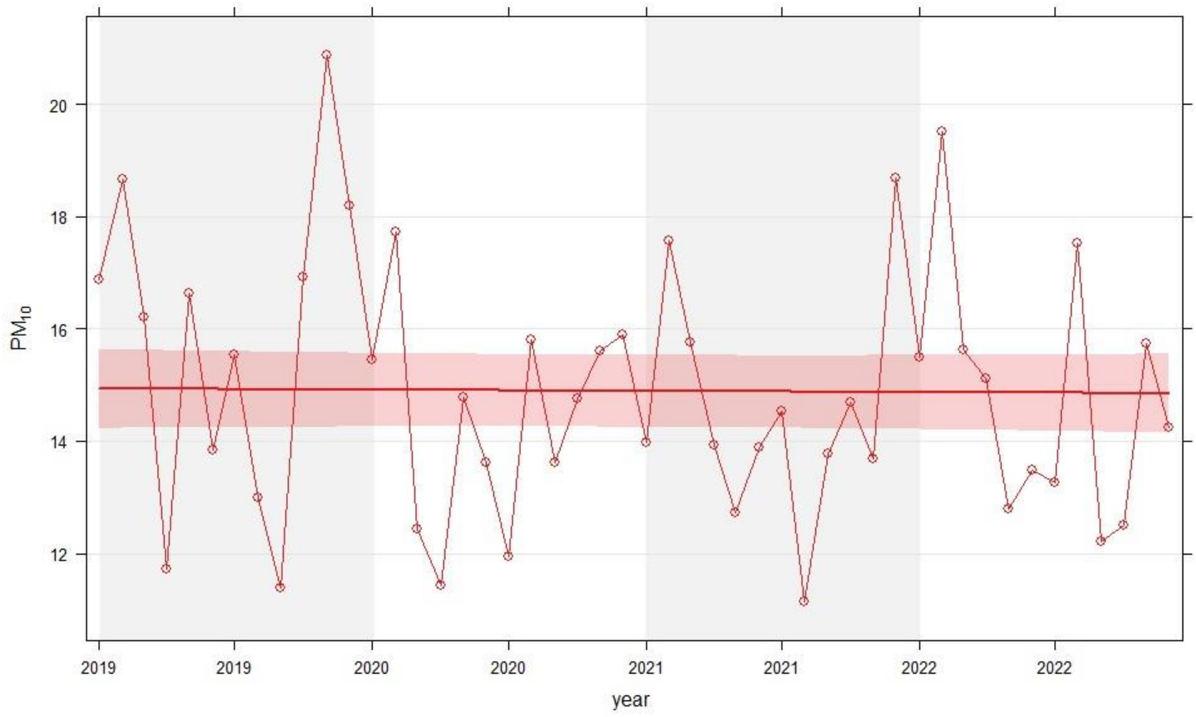
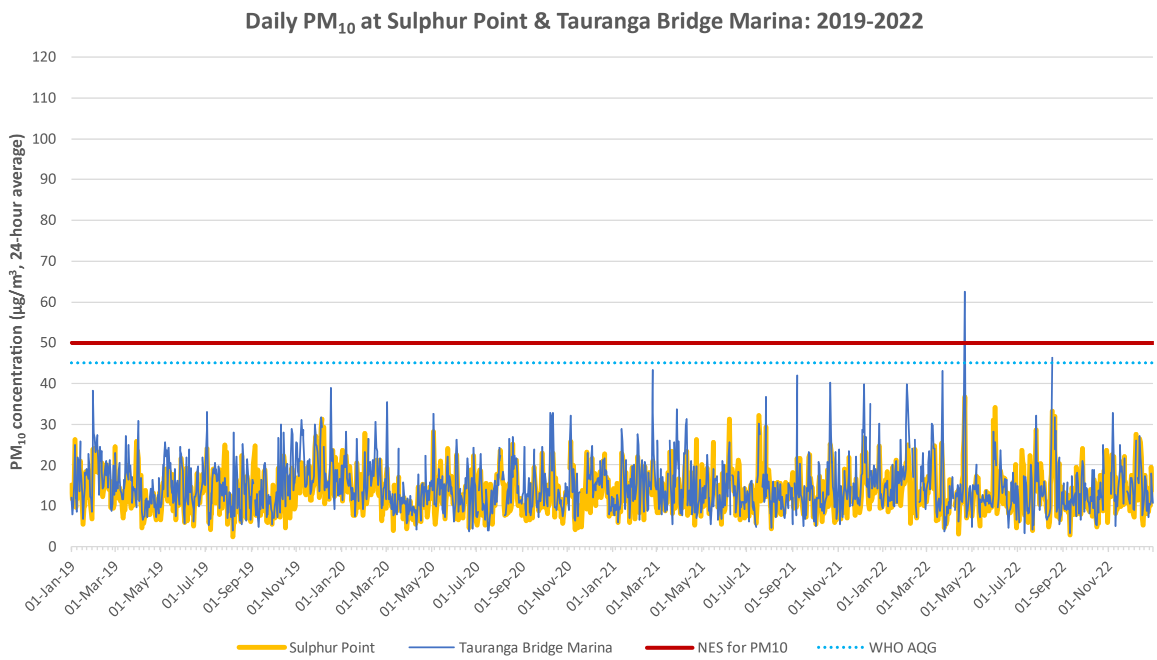


FIGURE 12: Time series plot of daily PM_{10} concentrations (µg/m^3) measured at Sulphur Point & Tauranga Bridge Marina: 2019 – 2022



3.3 WHAREROA MARAE AND DE HAVILLAND WAY

Whareroa Marae

Figure 13 presents annual PM_{10} measured at Whareroa Marae for the years 2019 – 2022 for comparison with the New Zealand (20 µg/m^3) and WHO (15 µg/m^3) guidelines. Figure 13 also has a fitted trend line which shows a strong linear correlation with year ($R^2 = 0.99$). Figure 14 presents monthly mean PM_{10} concentrations with 95% confidence intervals and a smoothed trend line for 2019 – 2022.

Figure 13 and Figure 14 show that annual levels of PM_{10} measured at Whareroa Marae have significantly declined (43%) over the last four years, with current levels well below New Zealand and WHO guidelines. This may reflect mitigation undertaken by neighbouring industrial activities. There are multiple sources of industrial PM_{10} emissions adjacent to Whareroa Marae.

Figure 15 presents monthly (left hand side) and daily (right hand side) mean concentrations of PM_{10}, with 95% confidence intervals, measured at Whareroa Marae for the years 2019 – 2022. Figure 15 shows that daily PM_{10} concentrations are higher during weekdays than weekends, which is consistent with industrial emissions being higher during the working week. Monthly levels of PM_{10} appear highest in the spring and summer time and lowest during the wetter parts of the year (winter). This is consistent with rain in winter and autumn reducing daily concentrations of PM_{10}.

Figure 16 presents a time series plot of daily concentrations of PM_{10} measured at Whareroa Marae (and De Havilland Way) between 2019 and 2022 for comparison with the national environmental standard and the WHO guideline for PM_{10}. Since early 2021 daily levels of PM_{10} at Whareroa Marae have remained below relevant standards and guidelines.

FIGURE 13: Annual concentrations of PM_{10} (µg/m^3) measured at Whareroa Marae: 2019 - 2022

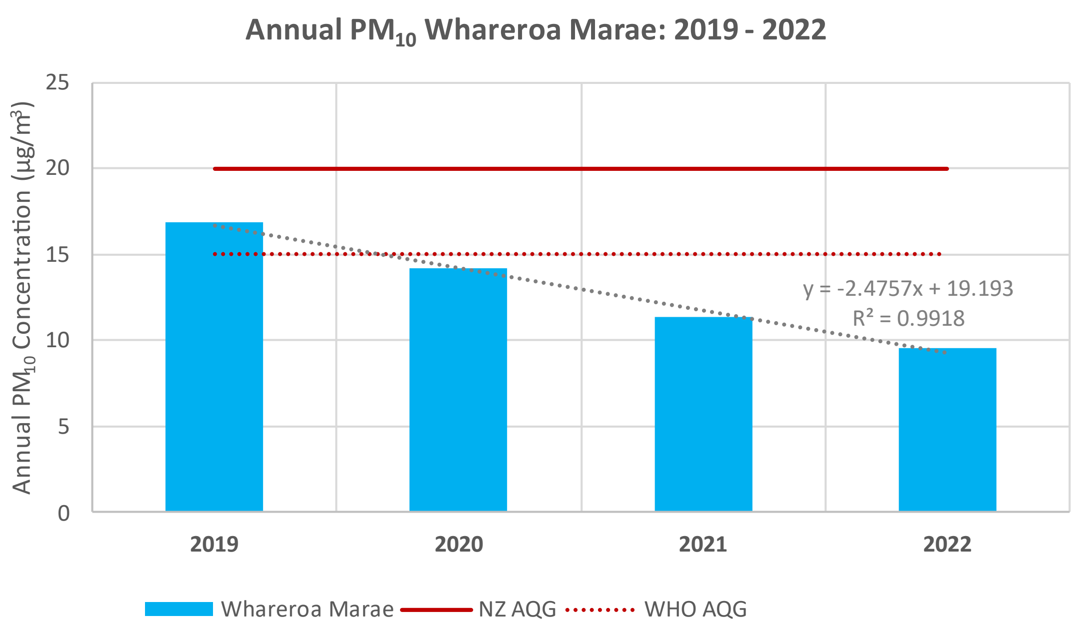


FIGURE 14: Long term trend - monthly PM_{10} concentrations (µg/m^3) measured at Whareroa Marae with smoothed trend line and 95% confidence intervals for fit: 2019 – 2022

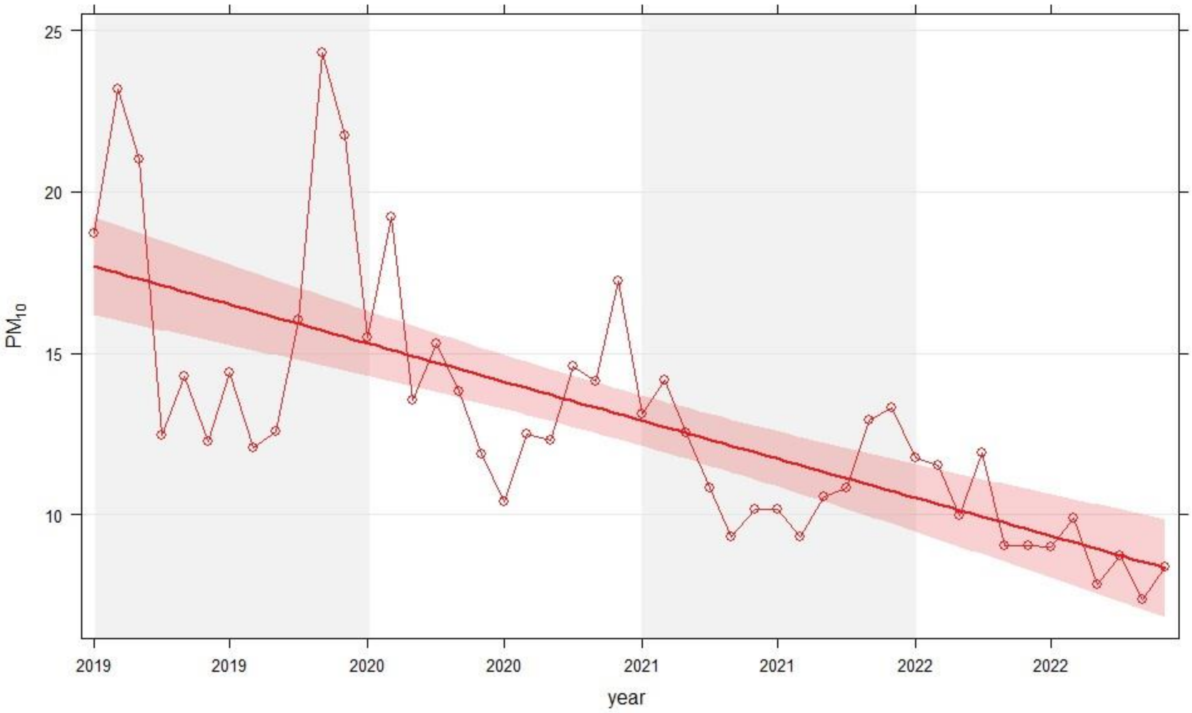


FIGURE 15: Time variation plot of PM_{10} (µg/m^3) with 95% confidence intervals measured at Whareroa Marae by month of year (left hand side) and day of week (right hand side): 2019 – 2022

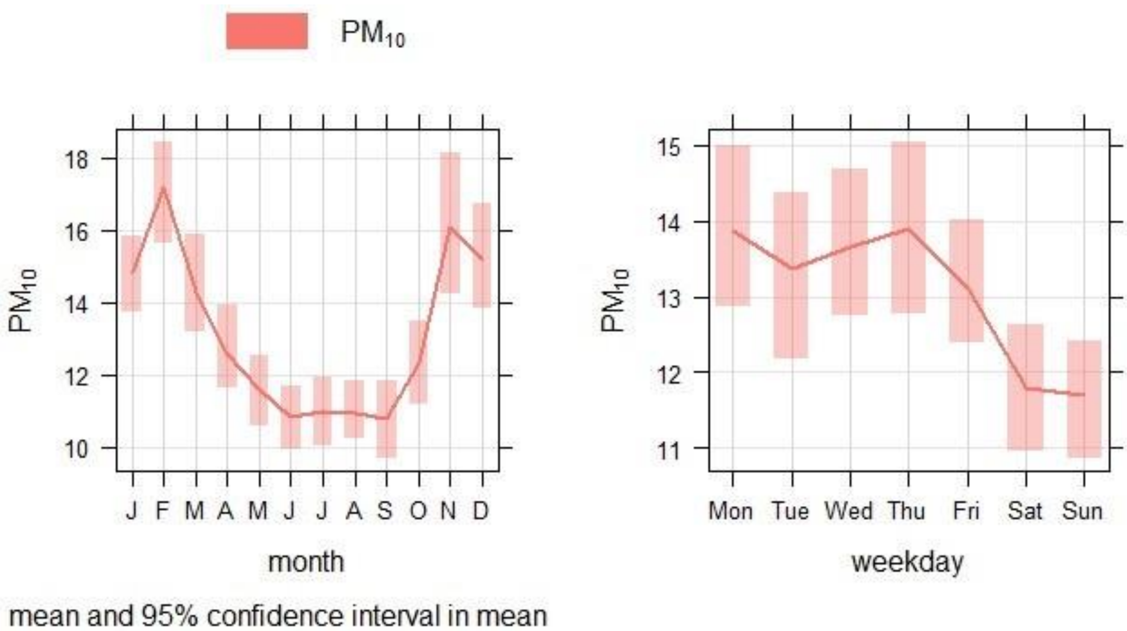
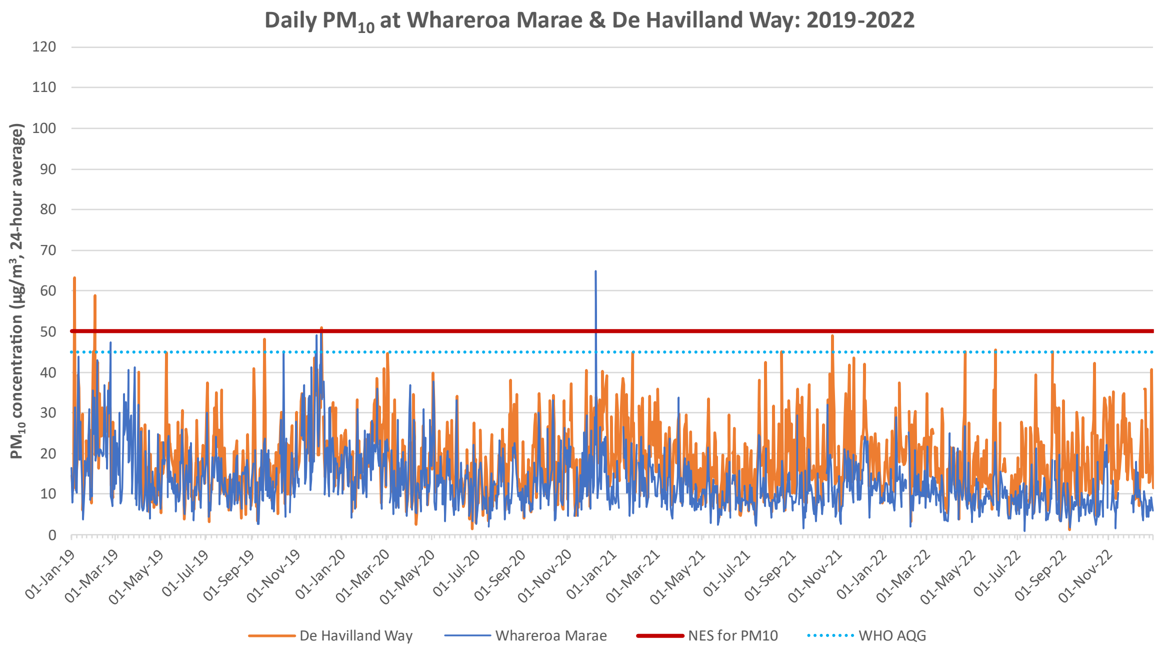


FIGURE 16: Time series plot of daily PM_{10} concentrations (µg/m³) measured at Whareroa Marae and De Havilland Way: 2019 – 2022



De Havilland Way

Annual levels of PM_{10} for De Havilland Way are presented in Figure 8 for the period 2019 – 2022.

Figure 17 presents monthly concentrations of PM_{10} with a smoothed trend line and 95% confidence intervals for the period 2019 – 2022 at De Havilland Way. This shows a flat, unchanging long-term exposure trend to PM_{10}.

Figure 18 presents monthly (left hand side) and daily (right hand side) mean concentrations of PM_{10}, with 95% confidence intervals, measured at De Havilland Way for the years 2019 – 2022. Figure 18 shows that daily PM_{10} concentrations are higher during weekdays than weekends, which is consistent with industrial emissions being higher during the working week. Monthly levels of PM_{10} are noticeably higher in the spring and summer time and lower during the wetter parts of the year (winter). This is consistent with rain in winter and autumn reducing daily concentrations of PM_{10}.

Figure 16 presents a time series plot of daily concentrations of PM_{10} measured at De Havilland Way (and Whareroa Marae) between 2019 and 2022 for comparison with the national environmental standard (50 µg/m³) and the WHO (45µg/m³) PM_{10} guideline. Since late 2021 daily levels of PM_{10} at De Havilland Way have remained below the national environmental standard.

FIGURE 17: Long term trend - monthly PM_{10} concentrations (µg/m^3) measured at De Havilland Way with smoothed trend line and 95% confidence intervals for fit: 2019 – 2022

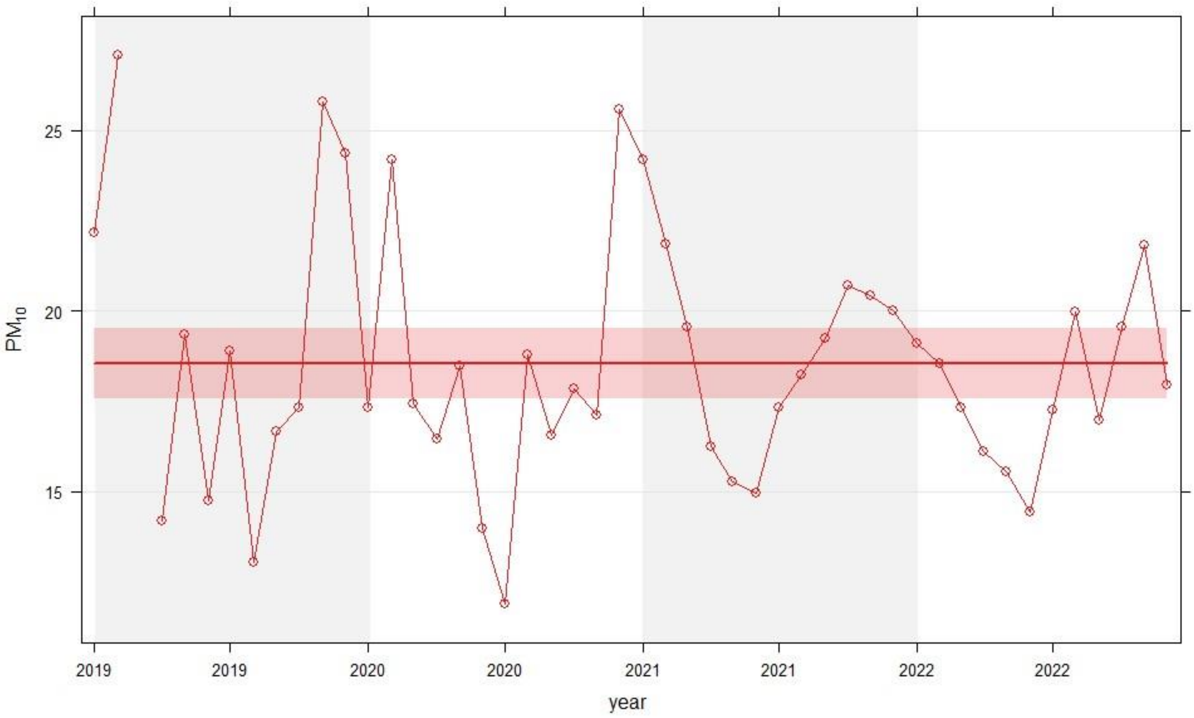
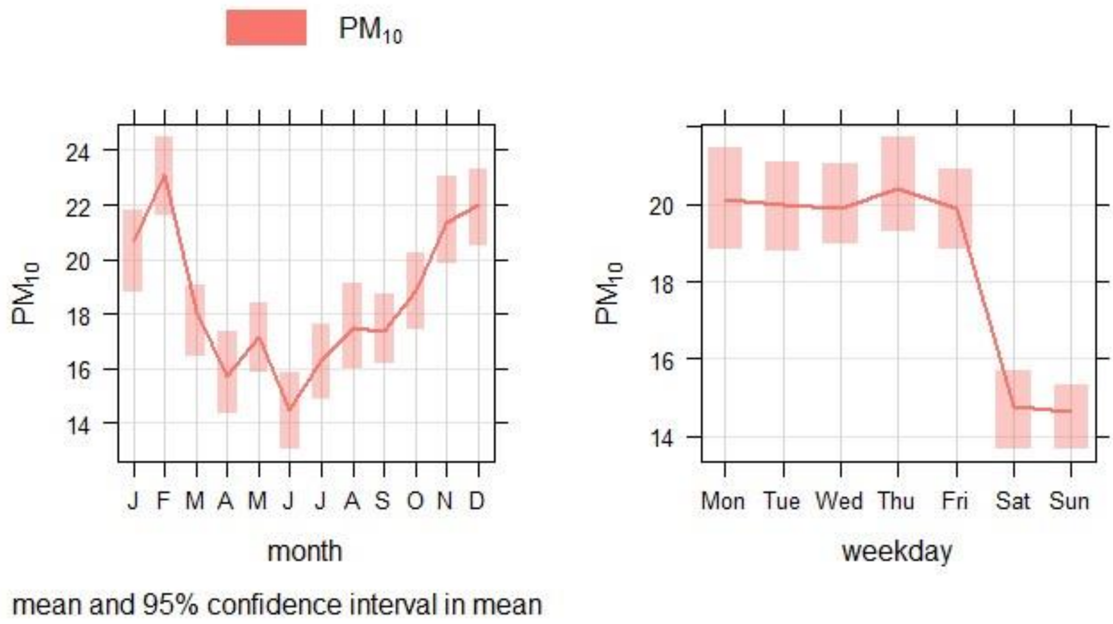


FIGURE 18: Time variation plot of PM_{10} concentrations (µg/m^3) measured at De Havilland Way with 95% confidence intervals: 2019 – 2022



3.4 RATA STREET

Annual levels of PM_{10} for Rata Street are presented in Figure 8 for the period 2019 – 2022.

Figure 19 presents monthly concentrations of PM_{10} with a smoothed trend line and 95% confidence intervals for the period 2019 – 2022 at Rata Street. This appears to show a decrease from 2019 in monthly concentrations (and variance) in 2020 and 2021, that has since returned to previous levels in 2022.

Figure 20 presents a time series plot of daily concentrations of PM_{10} at Rata Street between 2019 and 2022 for comparison with the national environmental standard and the WHO guideline for PM_{10}. Elevated daily concentrations of PM_{10} measured at Rata Street tend to occur in the summer months and occasionally exceed the national environmental standard for PM_{10} (50 µg/m^3). These incidents may coincide with passenger ship arrivals at the Port of Tauranga, however, there are insufficient (passenger ship) data on which to base any robust conclusions.

FIGURE 19: Long term trend - monthly PM_{10} concentrations (µg/m^3) measured at Rata Street with smoothed trend line and 95% confidence intervals for fit: 2019 – 2022

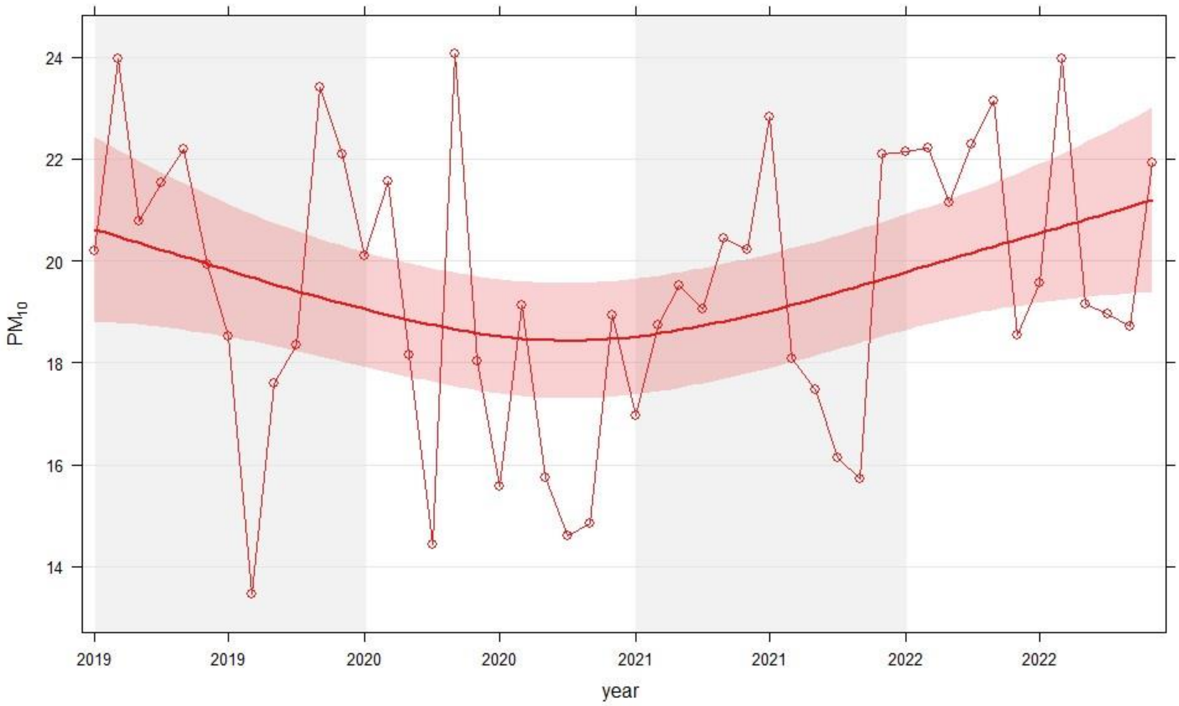
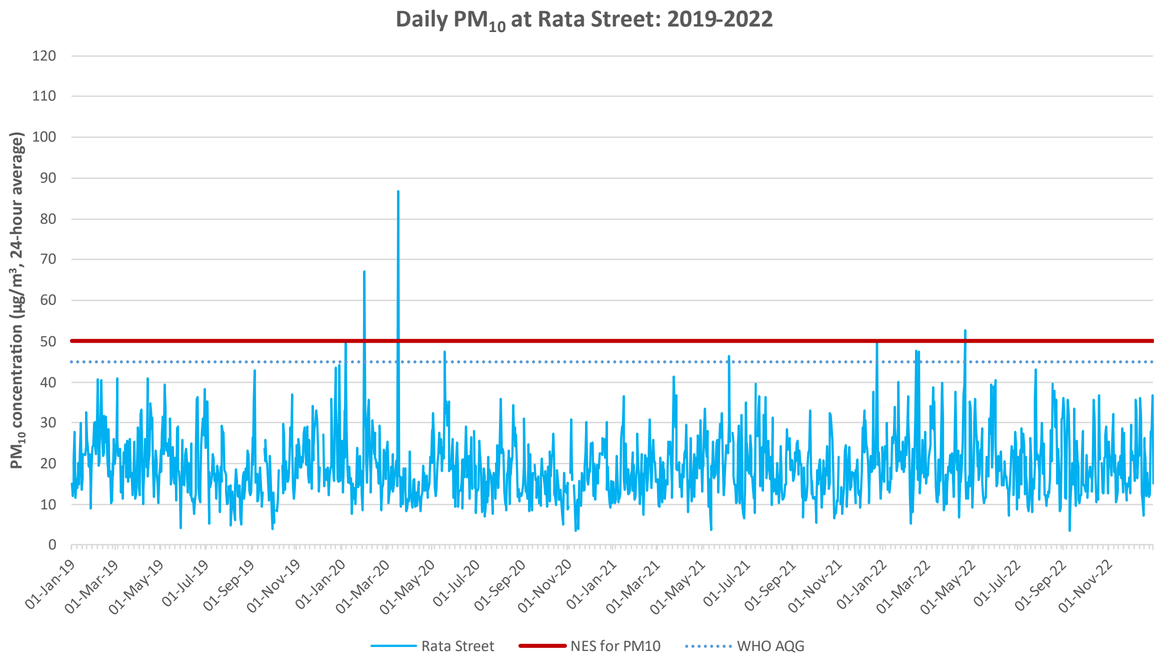


FIGURE 20: Time series plot of daily PM_{10} concentrations (µg/m³) measured at Rata Street: 2019 – 2022



3.5 RAIL YARD SOUTH AND TOTARA STREET

Annual levels of PM_{10} for Rail Yard South and Totara Street are presented in Figure 8 for the period 2019 – 2022.

Figure 21 (Rail Yard South) and Figure 22 (Totara Street) present monthly concentrations of PM_{10} with a smoothed trend line and 95% confidence intervals for the period 2019 – 2022. These both show a reduction in monthly PM_{10} concentrations since 2019 but there is otherwise no clear trend.

Figure 23 presents a time series plot of daily concentrations of PM_{10} measured at Rail Yard South and Totara Street between 2019 and 2022 for comparison with the national environmental standard and the WHO guideline for PM_{10}. This shows a significant reduction in maximum daily concentrations of PM_{10} at Rail Yard South (28%) and, to a lesser extent Totara Street (11%). This may reflect mitigation undertaken by neighbouring industrial and/or port activities. There are multiple PM_{10} sources adjacent to the monitors, both of which are in industrial locations.

FIGURE 21: Long term trend - monthly PM_{10} concentrations (µg/m^3) measured at Rail Yard South with smoothed trend line and 95% confidence intervals for fit: 2019 – 2022

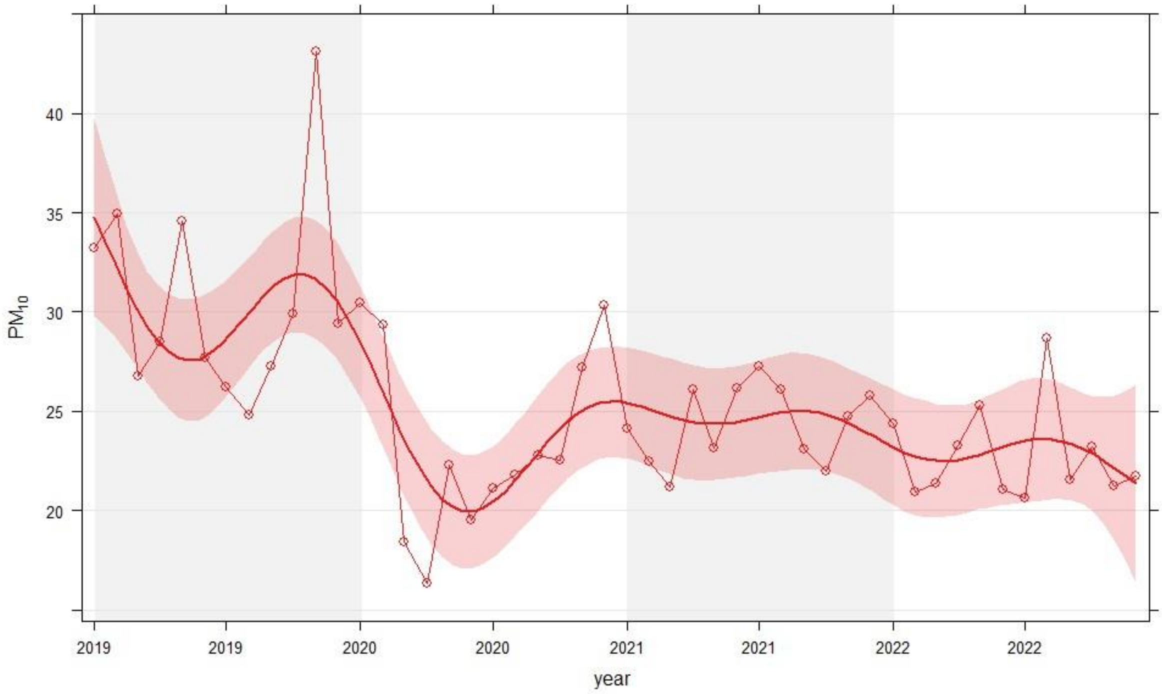


FIGURE 22: Long term trend - monthly PM_{10} concentrations (µg/m^3) measured at Totara Street with smoothed trend line and 95% confidence intervals for fit: 2019 – 2022

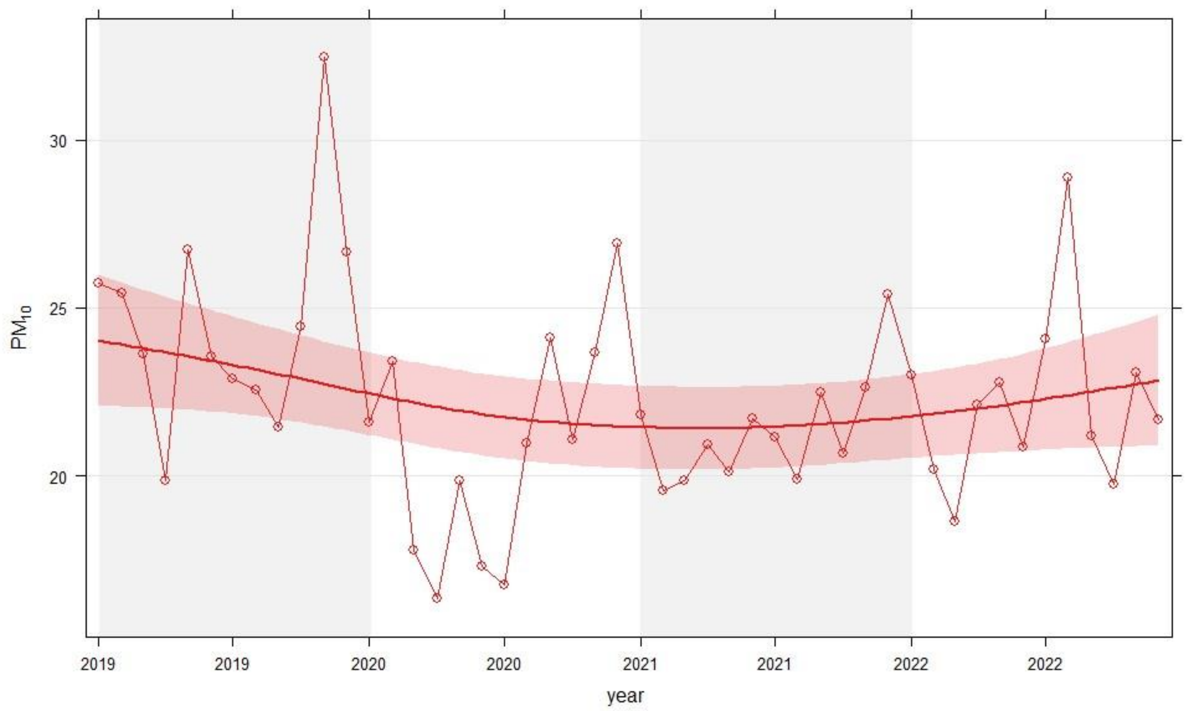
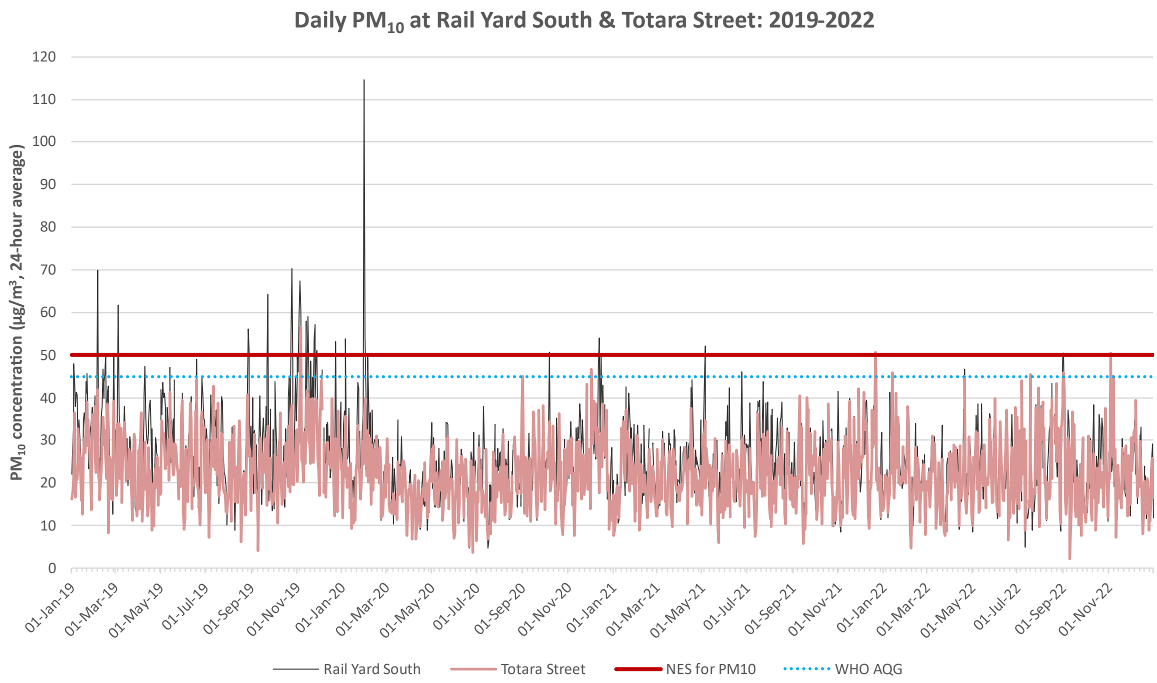


FIGURE 23: Time series plot of daily PM_{10} concentrations (µg/m^3) measured at Rail Yard South and Totara Street: 2019 – 2022



3.6 DISCUSSION

Figure 8 suggests Whareroa Marae is unique in experiencing such a significant (43%), and sustained, reduction in annual concentrations of PM_{10} over the monitoring period 2019 – 2022. Smoothed trend analyses of monthly PM_{10} concentrations with 95% confidence intervals for fit supports this hypothesis. The long-term trend for PM_{10} is flat at most monitoring locations in the Mount Maunganui Airshed (refer Figure 10 for Sulphur Point, Figure 11 for Tauranga Bridge Marina and Figure 17 De Havilland Way) or variable (refer Figure 19 for Rata Street and Figure 22 for Totara Street).[15] Rail Yard South had a significant reduction in annual levels in 2020 compared with 2019 (26%), but has been static since then (Figure 21).

The smoothed trend analyses further suggest a reduction in the variance of monthly PM_{10} concentrations measured over 2020-2021 at most monitoring sites located in proximity to shipping berths (Sulphur Point, Tauranga Bridge Marina, Rata Street and Rail Yard South). This period coincides with measures introduced to combat COVID-19 which likely resulted in reduced industrial/vehicle activity in the Mount Maunganui Airshed.

Figure 9, which shows the 4-year mean for each site, and Figure 5 which shows local wind direction, suggest that long-term concentrations of PM_{10} in the Mount Maunganui Airshed are influenced by proximity to shipping activities and industrial sources with an increasing trend from west (predominantly upwind of the Mount Maunganui Airshed) to east (predominantly downwind). Rail Yard South, located closest to, and predominantly downwind of, the Port of Tauranga, consistently records the highest annual average PM_{10} concentrations in the airshed.

The annual concentration of PM_{10} averaged over the Mount Maunganui Airshed (17 µg/m^3 in 2022) still exceeds the WHO guideline (15 µg/m^3) with higher levels being recorded in more

[15] Rata Street and Totara Street trended downwards in 2019 – 2020 but appear to be increasing again in 2021 – 2022.

industrial locations. Further work is likely to be needed to achieve annual and maximum daily levels of PM_{10} consistently below relevant standards and guidelines in all parts of the airshed.

4. $PM_{2.5}$

$PM_{2.5}$ is only measured at one site in the Mount Maunganui Airshed; Totara Street, which is an industrial location.

Table 4 provides summary statistics for annual and daily $PM_{2.5}$ measured at Totara Street for comparison with air quality standards and guidelines. Data exclude one known exceptional event (exceedance of the WHO guideline for $PM_{2.5}$ on 6 December 2019 due to the Australian Black Summer bush fires).

TABLE 4: Totara Street $PM_{2.5}$ summary statistics: 2019 – 2022*

Year	Maximum daily $PM_{2.5}$ ($\mu g/m^3$)	99th percentile daily $PM_{2.5}$ ($\mu g/m^3$)	Exceedances per year WHO AQG (no.)	Annual Mean $PM_{2.5}$ ($\mu g/m^3$)
	[WHO AQG = 15]		[3-4 permitted]	[WHO AQG = 5]
2019	17	15	2	**7.9**
2020	17	13	1	**6.2**
2021	18	11	2	**6.3**
2022	10	10	0	**5.2**

*Excludes one known exceptional event (6 Dec 2019 due to Australian bush fires).

Table 4 shows that annual $PM_{2.5}$ concentrations have declined significantly (35%) since 2019 (7.9 $\mu g/m^3$ to 5.2 $\mu g/m^3$). Table 4 also shows that the highest daily concentrations of $PM_{2.5}$ have reduced significantly since 2019, with a reduction of 15 $\mu g/m^3$ to 10 $\mu g/m^3$ in the 99th percentile daily concentration. The 99th percentile concentration is a more stable statistic for trend analysis than the maximum daily concentration as it excludes outlier maximum concentrations due to extraordinary meteorology.

Figure 24 presents annual $PM_{2.5}$ measured at Totara Street for the years 2019 – 2022 with fitted trend line for comparison with the WHO guideline (5 $\mu g/m^3$). Figure 24 shows that annual levels of $PM_{2.5}$ measured at Totara Street have declined significantly (35%) over the last four years.

Figure 25 presents monthly mean PM_{10} concentrations with 95% confidence intervals and a smoothed trend line for 2019 – 2022. Figure 25 has been annotated to show the date at which MARPOL Annex VI was introduced; 1 January 2020. This date appears to coincide with a reduction in monthly concentrations of $PM_{2.5}$.

Annex VI mandated reductions in emissions from ships of SO_2, a known precursor to the formation of $PM_{2.5}$. Figure 25 suggests that the reduction of SO_2 emissions from ships may have also reduced ambient levels of $PM_{2.5}$ at Totara Street.

This reduction is not evident in a time series plot of daily concentrations of $PM_{2.5}$ measured at Totara Street between 2019 – 2022 presented in Figure 26. This likely reflects emissions of $PM_{2.5}$ from other sources (e.g., vehicles and industry) impacting daily concentrations to create more variation or “noise”.

Figure 27 presents monthly (left hand side) and daily (right hand side) mean concentrations of $PM_{2.5}$, with 95% confidence intervals, measured at Totara Street for the years 2019 – 2022. Figure 27 shows that daily $PM_{2.5}$ concentrations are higher during weekdays than weekends, which is consistent with industrial and vehicle emissions being higher during the working week.

FIGURE 24: Mean annual concentrations of $PM_{2.5}$ (µg/m³) measured at Totara Street: 2019 - 2022

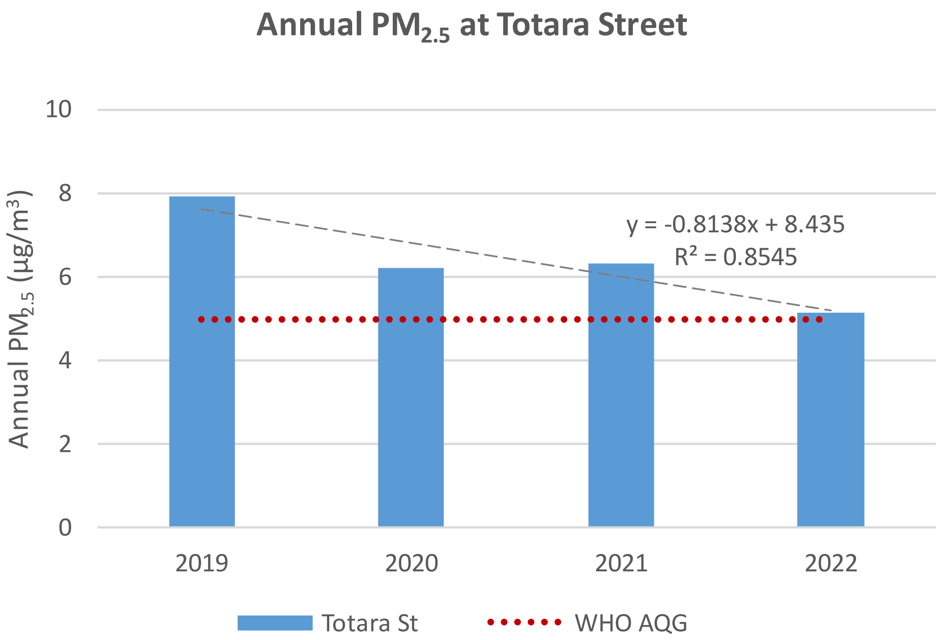


FIGURE 25: Long term trend - monthly $PM_{2.5}$ concentrations (µg/m³) measured at Totara Street with smoothed trend line and 95% confidence intervals for fit: 2019 – 2022

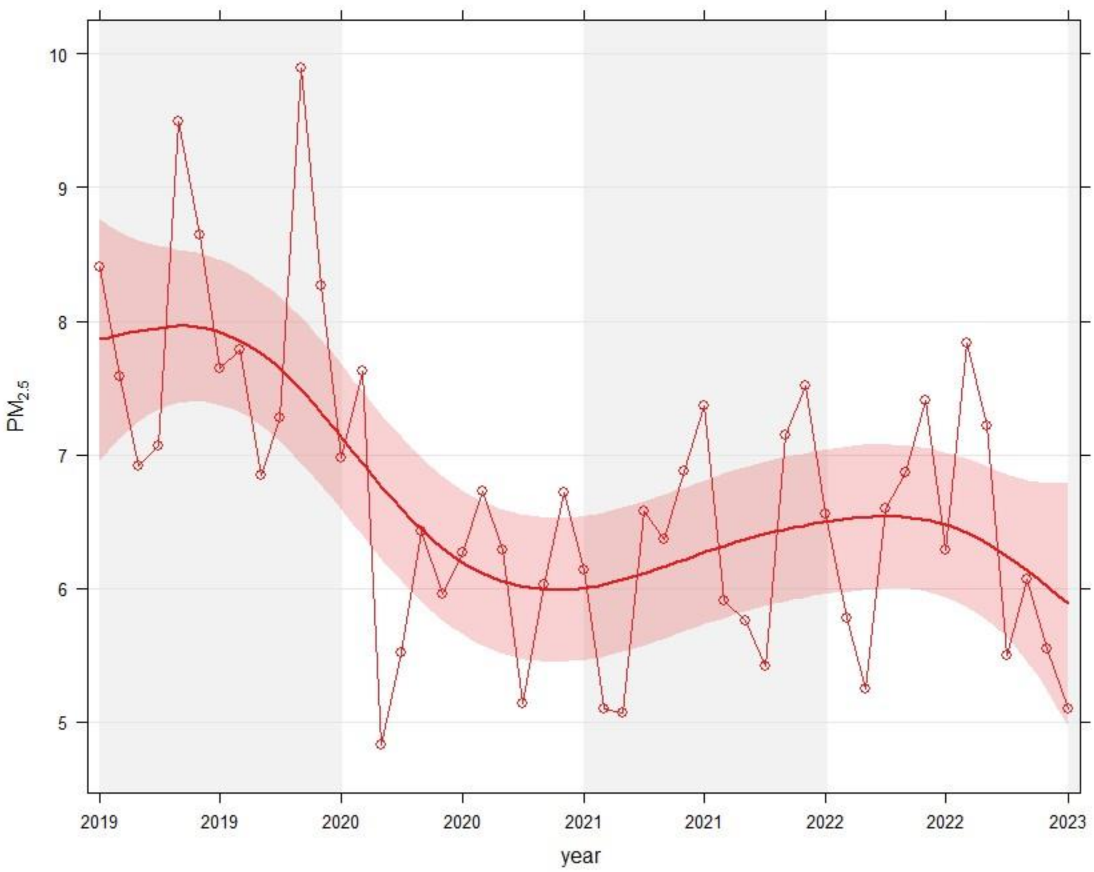


FIGURE 26: Time series plot of daily $PM_{2.5}$ concentrations (µg/m³) measured at Totara Street: 2019 – 2022

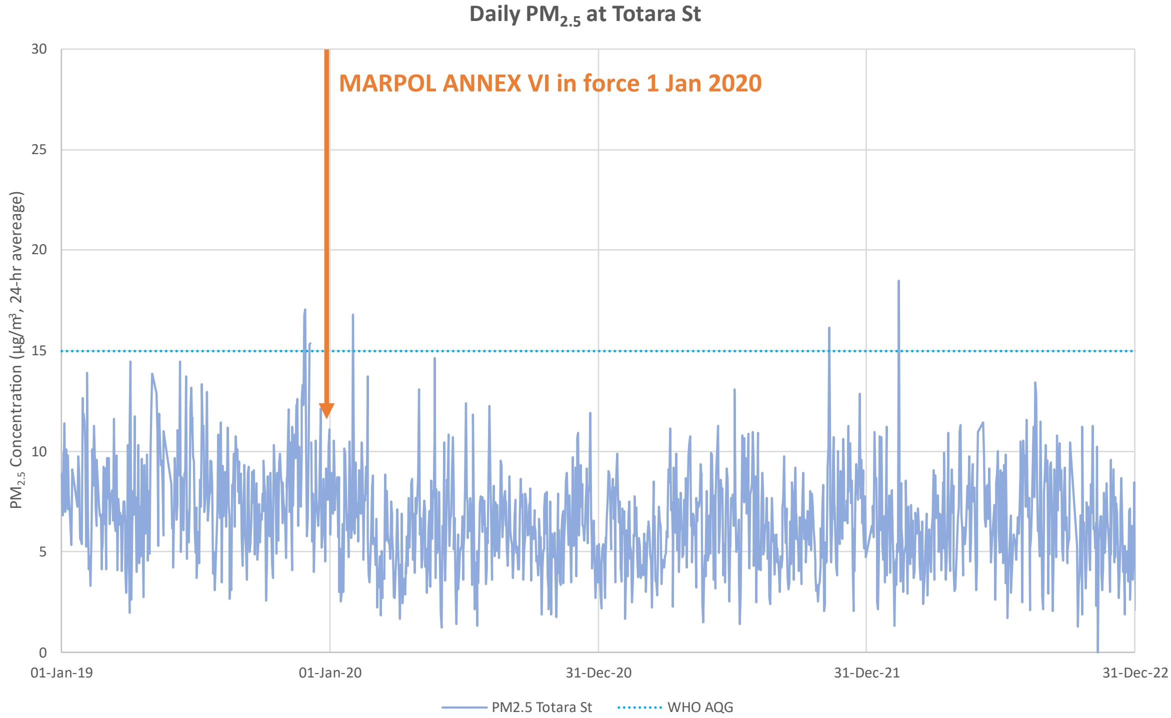
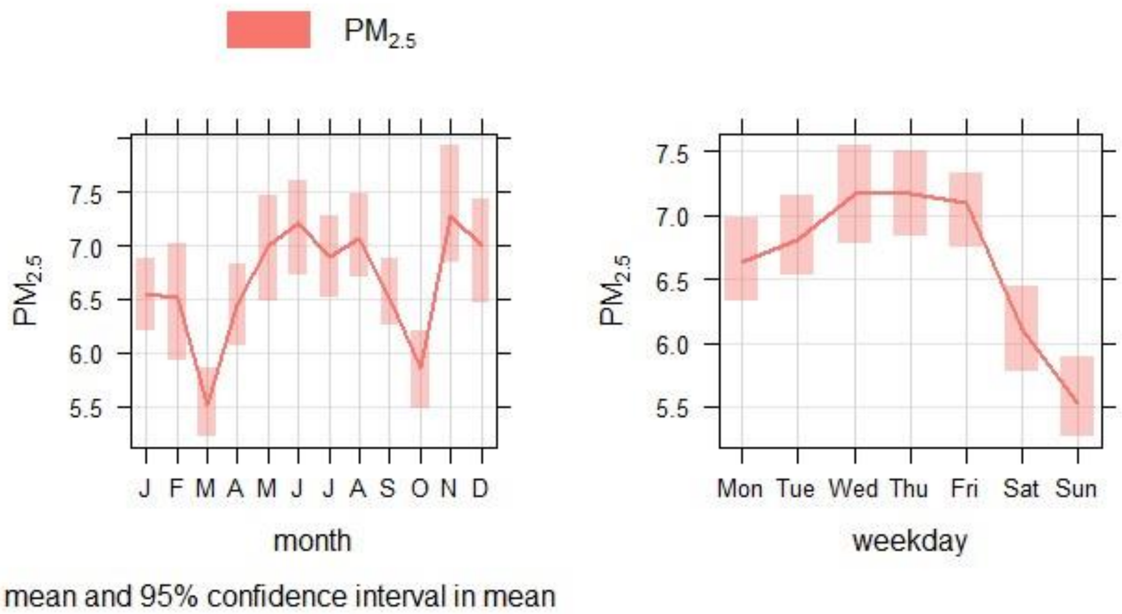


FIGURE 27: Time variation plot of $PM_{2.5}$ (µg/m³) with 95% confidence intervals measured at Totara Street by month of year (left hand side) and day of week (right hand side): 2019 – 2022



4.1 DISCUSSION

Less obvious from the time series of daily data (Figure 26), the annual plots (Figure 24) and smoothed trend analysis (Figure 25) show a significant decline (35%) in annual $PM_{2.5}$ in the Mount Maunganui Airshed. This appears to be correlated with the introduction of MARPOL Annex VI in early 2020.

Existing (2022) levels of $PM_{2.5}$ comply with the WHO daily guideline and are only just over the WHO annual guideline.

5. SULPHUR DIOXIDE

Tables A5 – A16 in Appendix A provide summary SO_2 statistics for all sites for 2019 through 2022.

5.1 MOUNT MAUNGANUI AIRSHED

Table 5 provides summary statistics for 1-hour SO_2 concentrations in the Mount Maunganui Airshed for comparison with national standards. Table 6 provides summary statistics for 10-minute and daily SO_2 concentrations in the Mount Maunganui Airshed for comparison with WHO guidelines.

Mount Maunganui Airshed values are calculated from all available monitoring sites (refer Figure 1). This includes six sites monitoring SO_2 (Sulphur Point, Tauranga Bridge Marina, Whareroa Marae, Rata Street, Rail Yard South and Totara Street).

Table 5 and Table 6 show that short-term levels of SO_2 have reduced significantly in the Mount Maunganui Airshed since 2019. There were no exceedances of the hourly national environmental standards for SO_2, or the 10-minute WHO guideline for SO_2, anywhere in the Mount Maunganui Airshed in 2022. This is a significant improvement from 2019.

There was one exceedance of the WHO daily air quality guideline for SO_2 in 2022. This was a daily concentration of 43 µg/m^3 measured at Whareroa Marae on 10 June 2022. The WHO guidelines permit 3-4 exceedances of the daily SO_2 guideline in any 12-month period. It should be noted that exceedance of a WHO (global) air quality guideline has no regulatory status in New Zealand (which is different to a 'breach' of a national environmental standard for SO_2).

TABLE 5: Mount Maunganui Airshed* 1-hr SO_2 summary statistics: 2019 – 2022

Year	Maximum 1-hour SO_2 (µg/m^3)	99th Percentile 1-hour SO_2 (µg/m^3)	Exceedances Lower NES per year (no.)	Exceedances Upper NES per year (no.)
	[NES = 350 / 570]	[NES = 350 / 570]	[9 permitted]	[0 permitted]
2019	**575**	118	4	**1**
2020	251	35	0	0
2021	312	35	0	0
2022	204	33	0	0

*Calculated from data at six sites: Sulphur Point, Tauranga Bridge Marina, Whareroa Marae, Rata Street, Rail Yard South and Totara Street.

TABLE 6: Mount Maunganui Airshed* 10-minute and daily SO_2 summary statistics: 2019 – 2022

Year	10-minute SO_2 (µg/m^3)		Daily SO_2 (µg/m^3)		Exceedances per year (no.)	
	Maximum	99th Percentile	Maximum	99th Percentile	10-minute	Daily
	[WHO AQG = 500]		[WHO AQG = 40]		[0 permitted]	[3-4permitted]
2019	**775**	136	**140**	**71**	**10**	**113**
2020	432	39	54	20	0	4
2021	**1,247**	37	42	19	**1**	1
2022	396	35	43	18	0	1

* Calculated from data at six sites: Sulphur Point, Tauranga Bridge Marina, Whareroa Marae, Rata Street, Rail Yard South and Totara Street.

5.2 WHAREROA MARAE AND TAURANGA BRIDGE MARINA

Figure 28 presents a time series plot of 1-hour concentrations of SO_2 measured at Whareroa Marae and Tauranga Bridge Marina between 2019 and 2022 for comparison with national environmental standards. There were no exceedances of national standards for SO_2 during this monitoring period.

Figure 29 presents a time series plot of 10-minute concentrations of SO_2 measured at Whareroa Marae and Tauranga Bridge Marina between 2019 and 2022 for comparison with the WHO guideline. This shows one exceedance of the WHO 10-minute guideline (500 µg/m^3) on 27 August 2021 at 10:40 pm with a measured concentration of 1,247 µg/m^3 at Tauranga Bridge Marina. This corresponds with winds directed from the adjacent fertiliser works towards the marina.[16]

Previous briefings have consistently aligned elevated short-term (10-minute and hourly) SO_2 concentrations measured at Whareroa Marae and Tauranga Bridge Marina with winds coming from the fertiliser manufacturer towards these monitoring locations.[17]

Figure 30 presents a time series plot of daily concentrations of SO_2 measured at Whareroa Marae and Tauranga Bridge Marina between 2019 and 2022 for comparison with the New Zealand and WHO daily guidelines for SO_2. This shows occasional exceedances of the WHO daily guideline at both locations (but not more than the three permitted each year).

[16] Whareroa Marae recorded a (ten minute) wind direction of 41° at 10:40 pm on 27 August 2021.

[17] For example, Memo from L. Wickham (EIL) to S. Halligan (MoH) dated 7 April 2022 Re: *Three-year review (2019-2021) of air quality monitoring at Mount Maunganui*.

Memo from L. Wickham (EIL) to C. Lochore (Toi Te Ora) dated 12 March 2021 Re: *Two-year review (2019/2020) of air quality monitoring at Mount Maunganui.*

Memo from L. Wickham (EIL) to S. Layne & J. Miller (Toi Te Ora) dated 7 February 2020. Re: *Annual review: 2019 air quality monitoring at Mount Maunganui*.

FIGURE 28: Time series plot of 1-hour SO_2 concentrations (µg/m^3) measured at Tauranga Bridge Marina and Whareroa Marae: 2019 – 2022

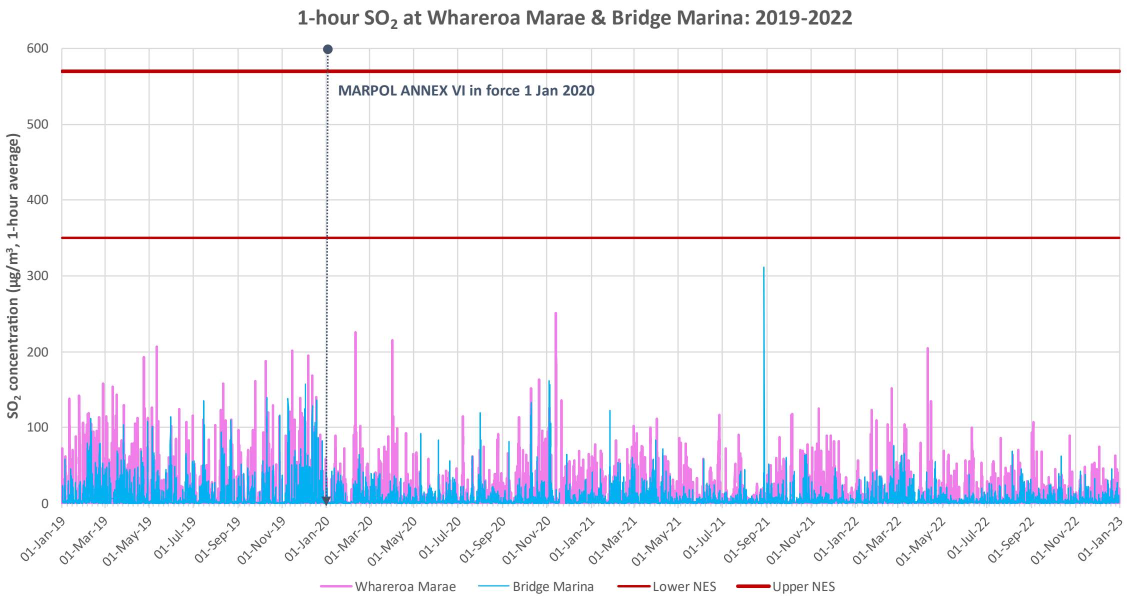


FIGURE 29: Time series plot of 10-minute SO_2 concentrations (µg/m^3) measured at Tauranga Bridge Marina and Whareroa Marae: 2019 – 2022

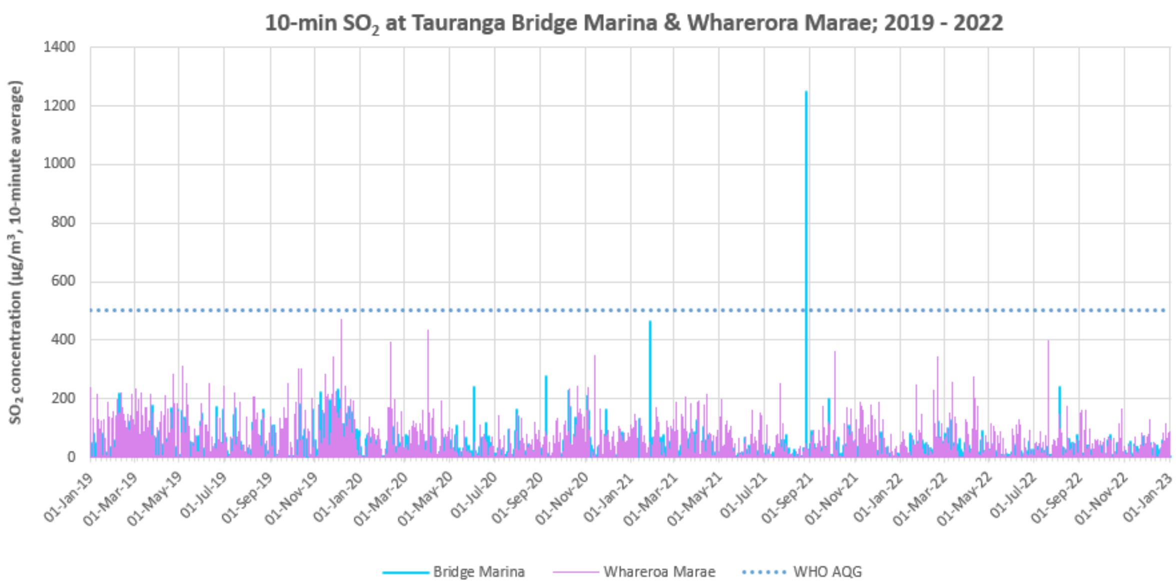
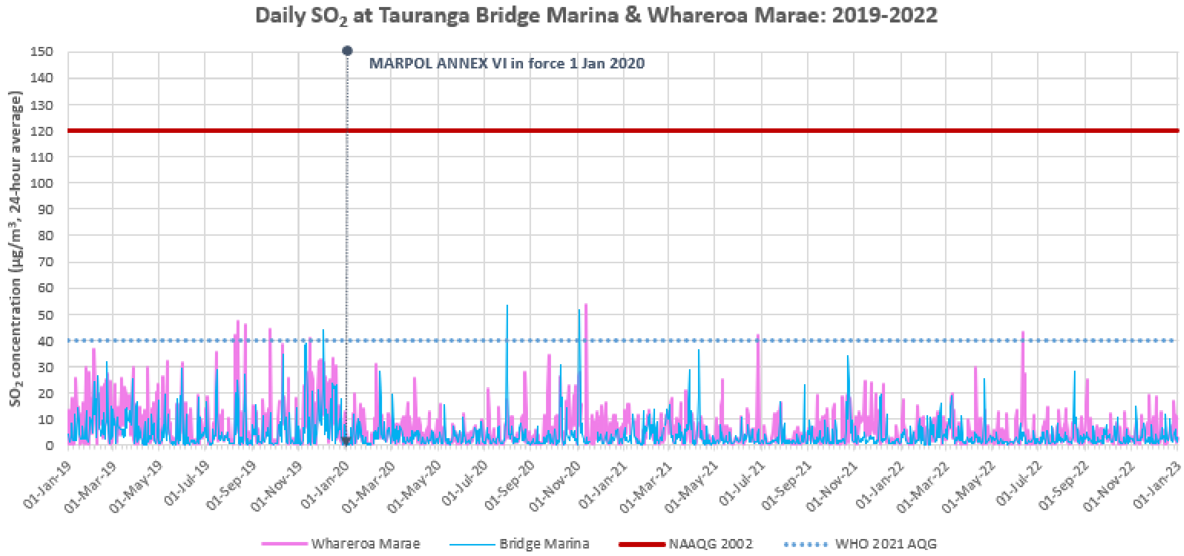


FIGURE 30: Time series plot of daily SO_2 concentrations (µg/m^3) measured at Tauranga Bridge Marina and Whareroa Marae: 2019 – 2022



5.2.1 Key Source Determination

Figure 31 presents mean SO_2 concentrations with 95% confidence intervals measured at Whareroa Marae for the years 2019 – 2022 by hour of day and day of the week (top), by hour of day (bottom left), month of the year (bottom middle) and day of the week (bottom right). Figure 32 presents the same data for Tauranga Bridge Marina.

Hourly concentrations of SO_2 measured at these two monitoring locations are broadly similar, being highest during the day, from lunchtime through early evening, every day of the week. Overall, levels are slightly higher at Whareroa Marae compared with Tauranga Bridge Marina, however there is more variation (i.e., larger 95% confidence intervals) in daily concentrations at Tauranga Bridge Marina. The monthly averages suggest levels are generally highest in October through to March.

Figure 33 presents polar plots of 10-minute SO_2 concentrations measured at Whareroa Marae for the years 2019 – 2022.[18] Figure 33 shows a clear alignment of short-term concentrations of SO_2 with winds directed from the adjacent fertiliser manufacturer to the northwest (refer Figure 2) over all wind speeds. However, the signature in 2019 is stronger (i.e., higher concentrations) than in 2020 through 2022.

Figure 34 presents polar plots of 10-minute SO_2 concentrations measured at Tauranga Bridge Marina for the years 2019 – 2022. This shows short-term concentrations of SO_2 occur with winds from the northwest, north *and* northeast in 2019, but only with winds from the northeast in 2020 through 2022. Figure 2 shows that the POTL container terminal is located to the northwest, the POTL berths are located to the north, and the fertiliser works is located to the northeast of Tauranga Bridge Marina.

Taken together, the polar plots for Whareroa Marae and Tauranga Bridge Marina indicate that there has been a reduction in ambient SO_2 at these locations due to shipping, but emissions from the fertiliser works remain significant. Historical analyses have consistently linked elevated short-term concentrations (i.e., > 200 µg/m^3) with contemporaneous winds directed from the fertiliser works towards these monitoring locations.

[18] A polar plot presents concentrations overlaid with wind speed (in metres per second) and wind direction (degrees from) information.

FIGURE 31: Time variation plot of hourly SO_2 (µg/m^3) with 95% confidence intervals measured at Whareroa Marae: 2019 – 2022

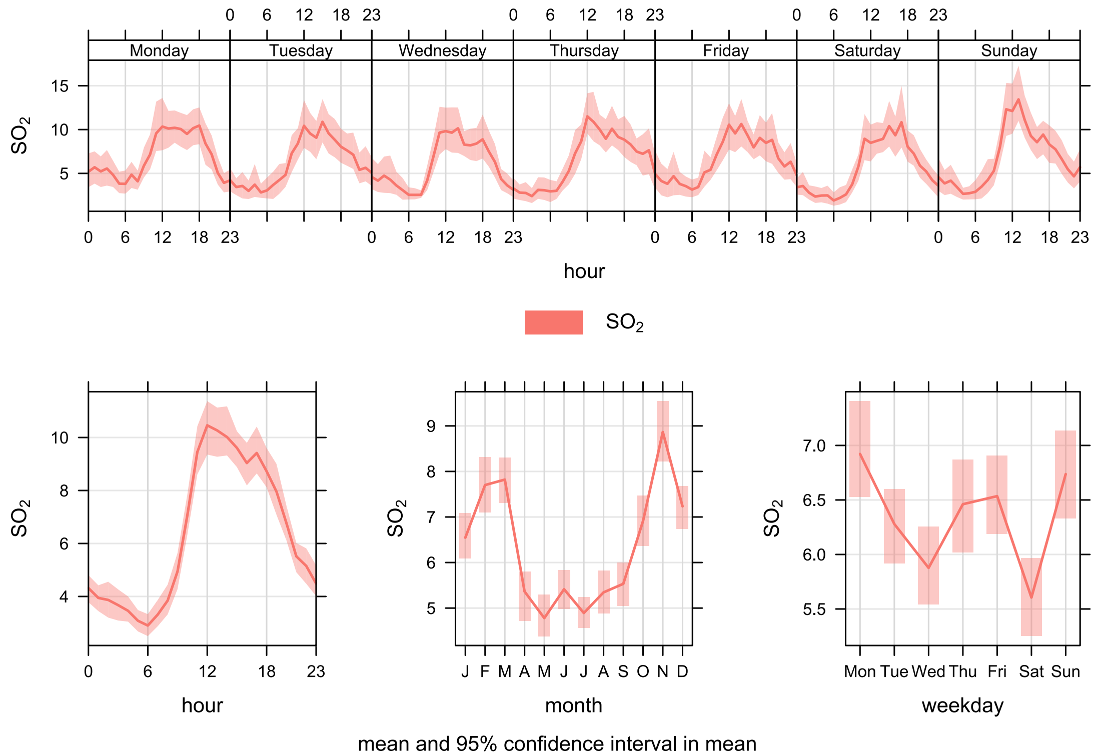


FIGURE 32: Time variation plot of hourly SO_2 (µg/m^3) with 95% confidence intervals measured at Tauranga Bridge Marina: 2019 – 2022

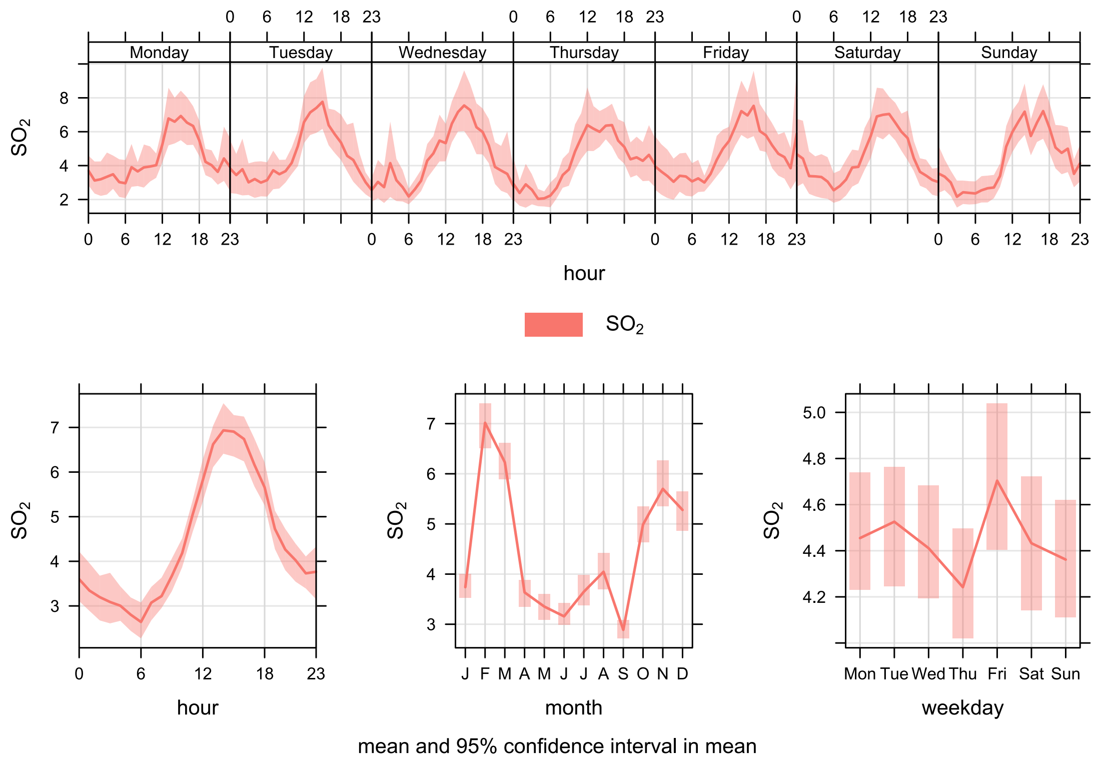


FIGURE 33: Polar plot of 10-minute concentrations of SO_2 (µg/m^3) measured at Whareroa Marae: 2019 – 2022

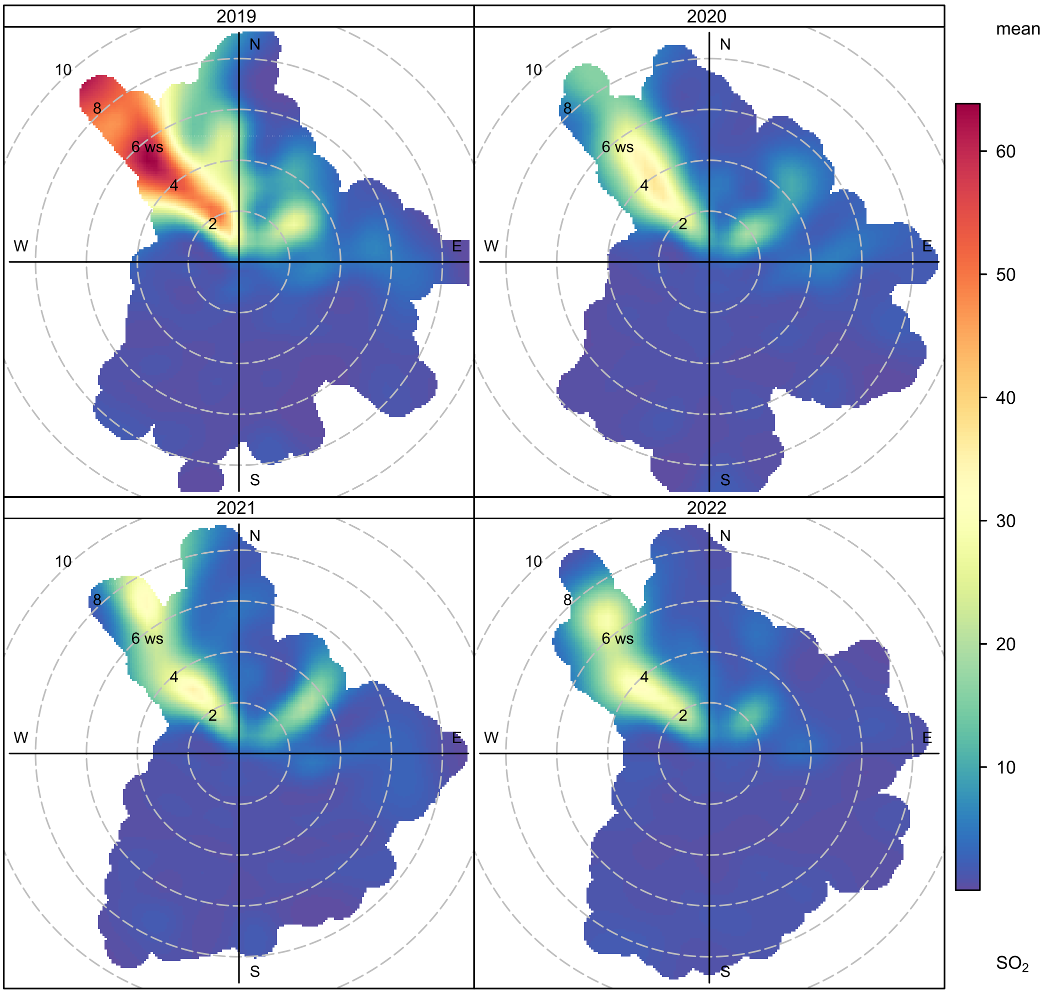
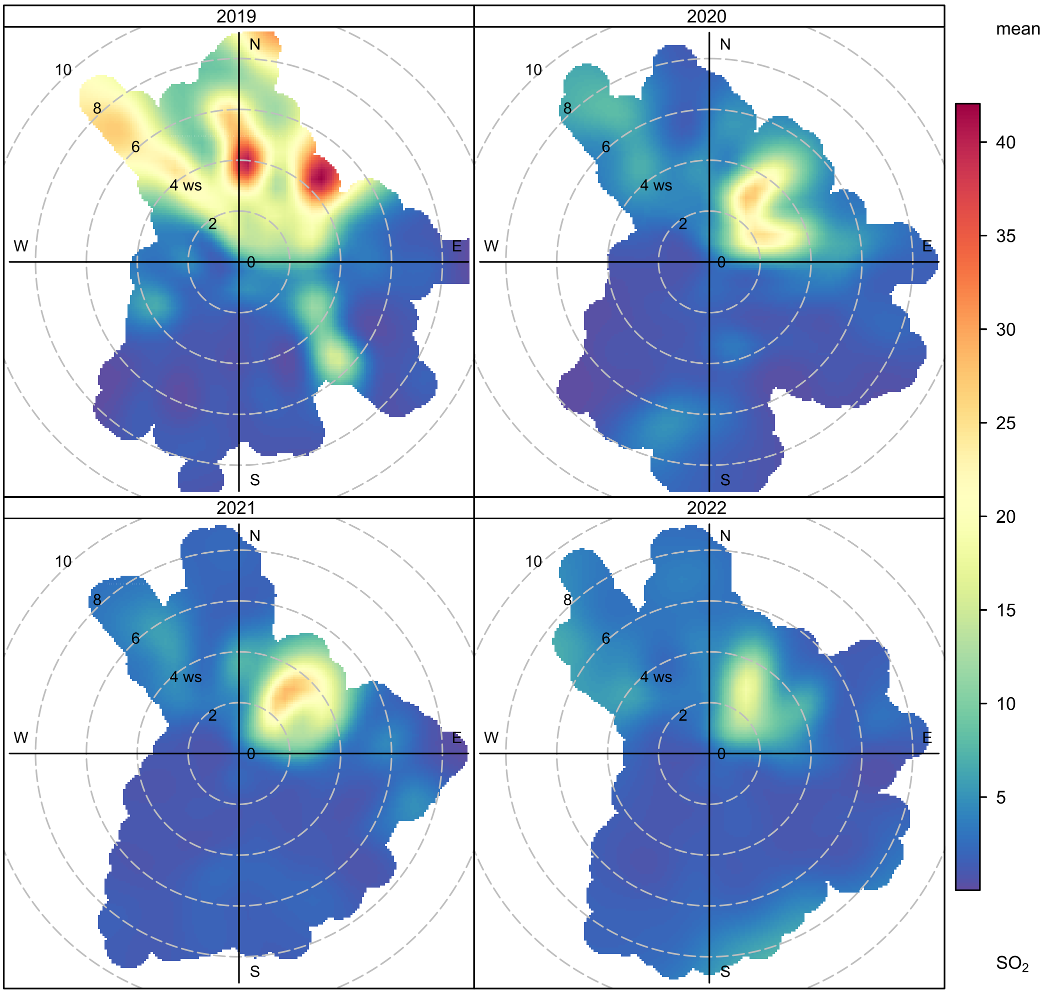


FIGURE 34: Polar plot of 10-minute concentrations of SO_2 (μg/m³) measured at Tauranga Bridge Marina: 2019 – 2022



5.3 SULPHUR POINT AND RATA STREET

Figure 35 presents a time series plot of 1-hour concentrations of SO_2 measured at Sulphur Point and Rata Street between 2019 and 2022 for comparison with the national environmental standards for SO_2. There have been no exceedances of national standards for SO_2 at either location since early 2019.

Figure 36 presents a time series plot of 10-minute concentrations of SO_2 measured at Sulphur Point and Rata Street between 2019 and 2022 for comparison with the WHO guideline for SO_2. There have been no exceedances of the WHO 10-minute guideline for SO_2 at either location since late 2019.

Figure 37 presents a time series plot of daily concentrations of SO_2 measured at Sulphur Point and Rata Street between 2019 and 2022 for comparison with the New Zealand and WHO daily guidelines for SO_2. There have been no exceedances of either daily guideline for SO_2 since late 2019.

The time series plots show a significant step change reduction in ambient levels of short-term SO_2 at Sulphur Point and Rata Street that appears to coincide with ships implementing Annex VI of MARPOL on 1 January 2020.

FIGURE 35: Time series plot of 1-hour SO_2 concentrations (µg/m^3) measured at Sulphur Point and Rata Street: 2019 – 2022

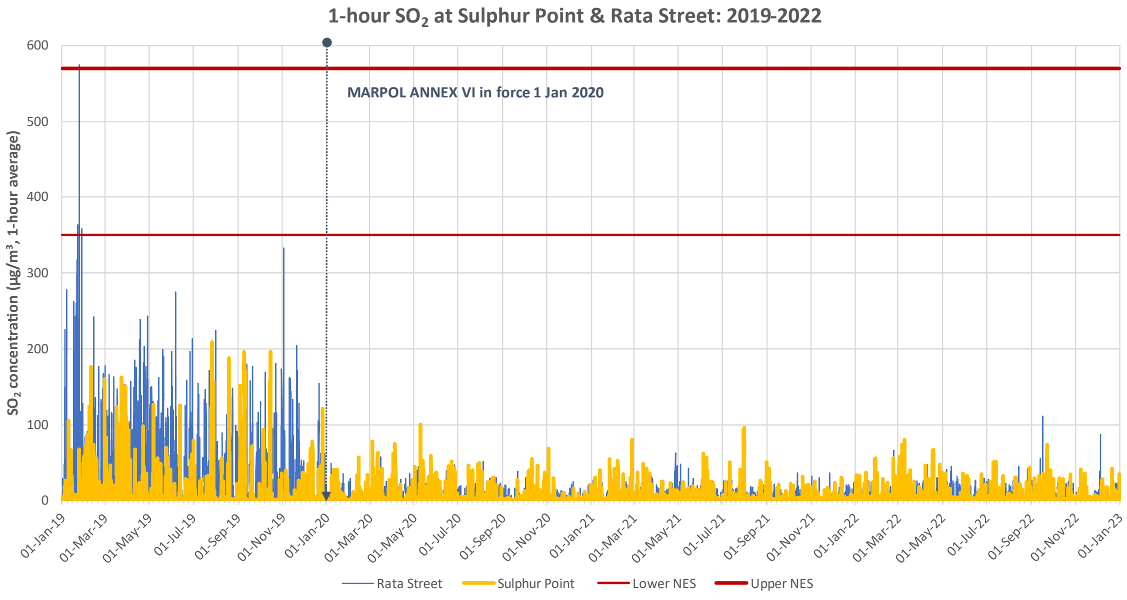


FIGURE 36: Time series plot of 10-minute SO_2 concentrations (µg/m^3) measured at Sulphur Point and Rata Street: 2019 – 2022

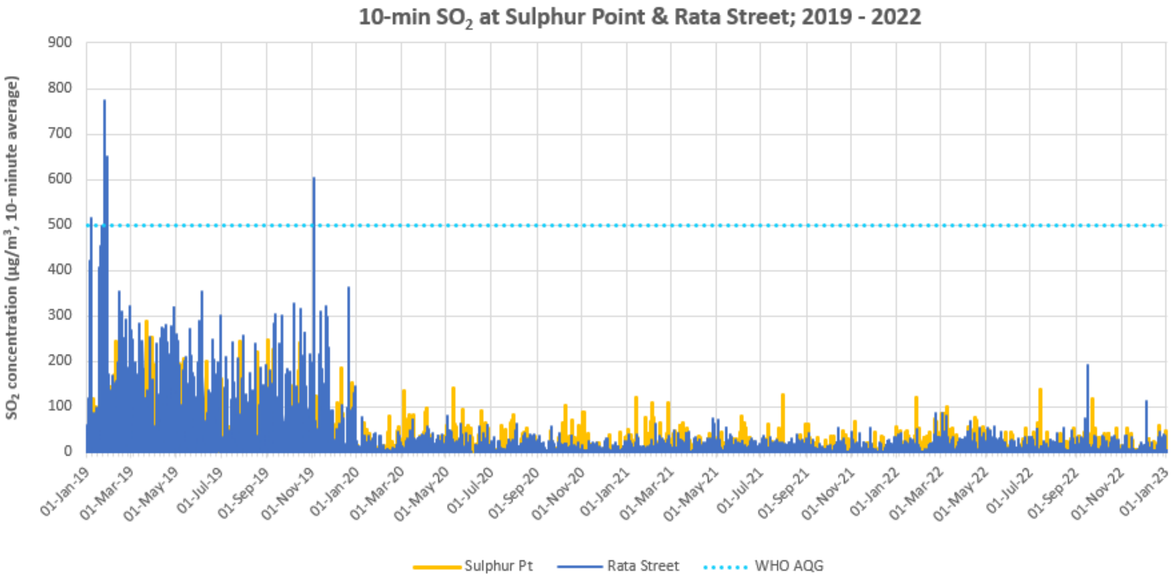
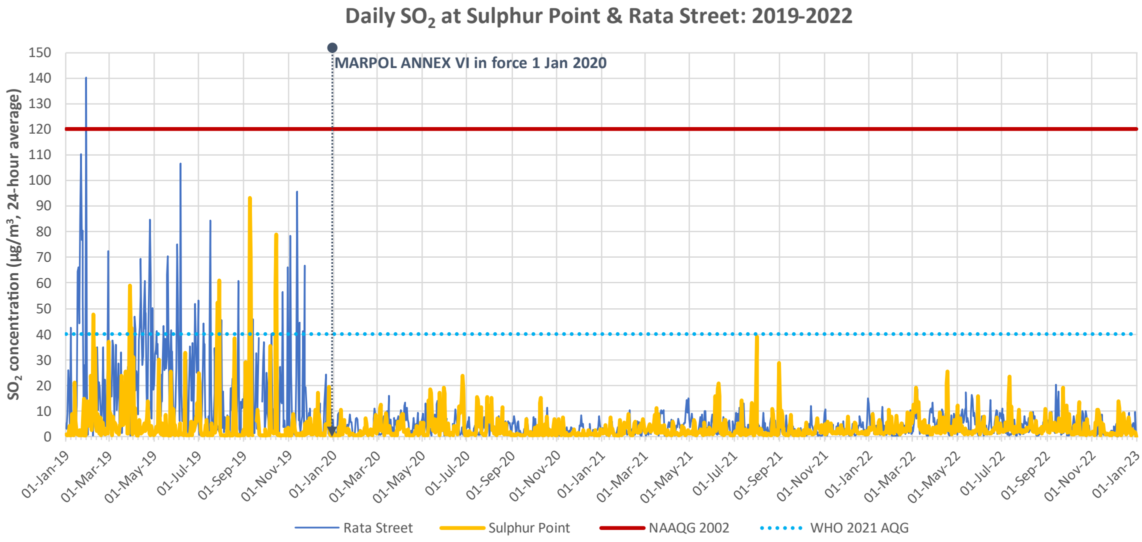


FIGURE 37: Time series plot of daily SO_2 concentrations (µg/m^3) measured at Sulphur Point and Rata Street: 2019 – 2022



5.4 RAIL YARD SOUTH AND TOTARA STREET

Figure 38 presents a time series plot of 1-hour concentrations of SO_2 measured at Rail Yard South and Totara Street between 2019 and 2022 for comparison with the national environmental standards for SO_2. There have been no exceedances of national standards for SO_2 at either location over this monitoring period.

Figure 39 presents a time series plot of 10-minute concentrations of SO_2 measured at Rail Yard South and Totara Street between 2019 and 2022 for comparison with the WHO guideline for SO_2. There have been no exceedances of the WHO guideline for SO_2 at either location.

Figure 40 presents a time series plot of daily concentrations of SO_2 measured at Rail Yard South and Totara Street between 2019 and 2022 for comparison with the New Zealand and WHO daily guidelines for SO_2. There have been no exceedances of either daily guideline for SO_2 since late 2019.

The time series plots show a significant step change reduction in ambient levels of short-term SO_2 at Rail Yard South and Totara Street that appears to coincide with ships implementing Annex VI of MARPOL on 1 January 2020.

FIGURE 38: Time series plot of 1-hour SO_2 concentrations (µg/m^3) measured at Rail Yard South and Totara Street: 2019 – 2022

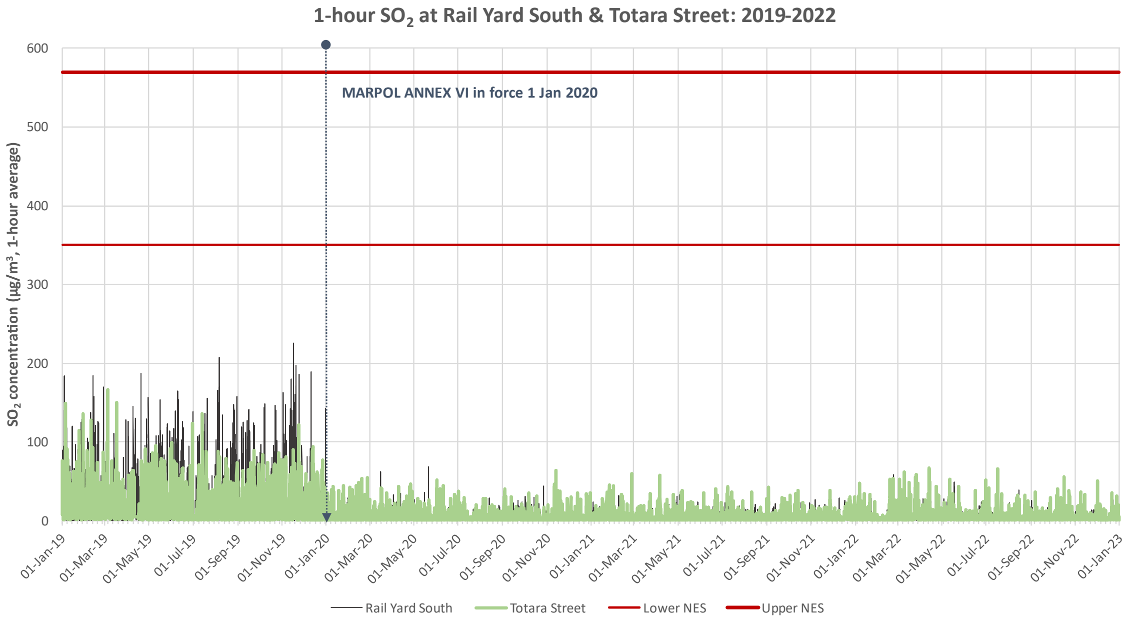


FIGURE 39: Time series plot of 10-minute SO_2 concentrations (µg/m3) measured at Rail Yard South and Totara Street: 2019 – 2022

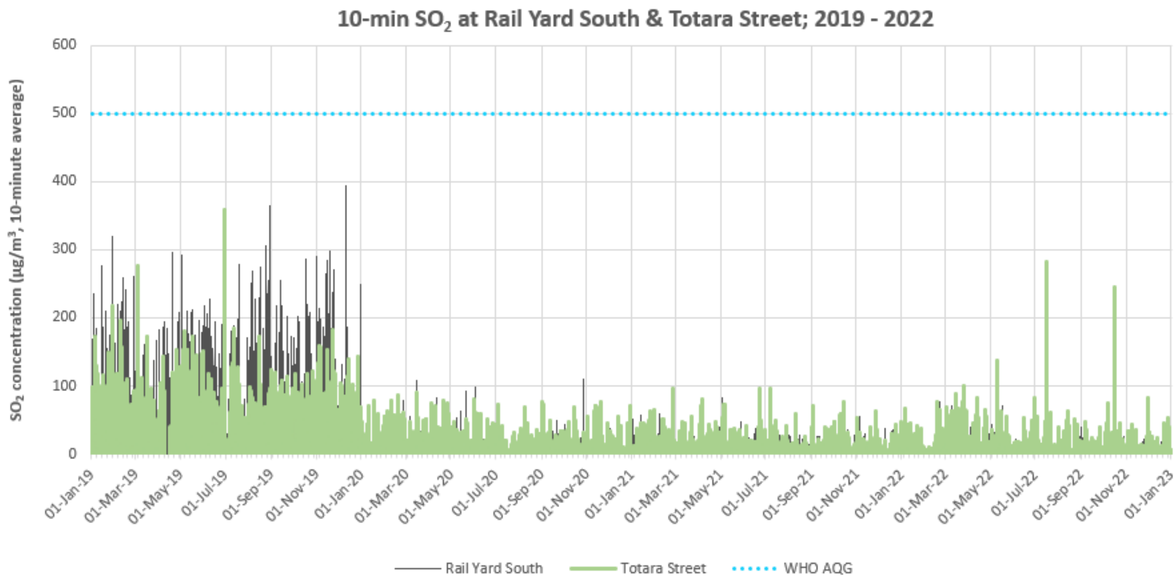
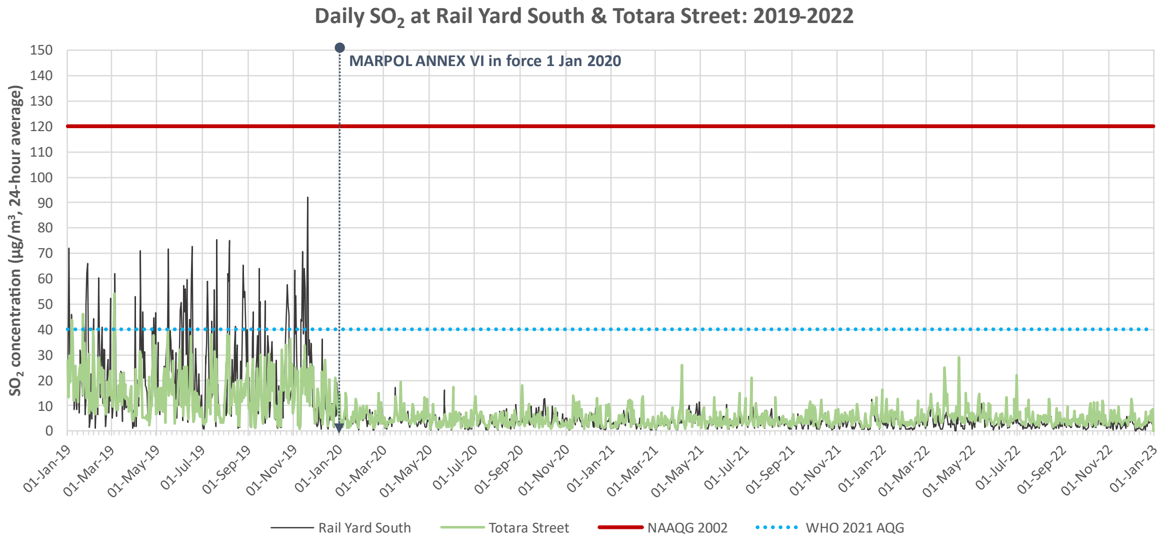


FIGURE 40: Time series plot of daily SO_2 concentrations (µg/m³) measured at Rail Yard South and Totara Street: 2019 – 2022



5.5 DISCUSSION

Short-term levels of SO_2 have significantly reduced in the Mount Maunganui Airshed since 2019. This reduction appears to correlate with the introduction of MARPOL Annex VI in early January 2020.

There is a clear difference in the time-series records of short-term levels of SO_2 measured at Whareroa Marae and Tauranga Bridge Marina between 2019 and 2022 and those measured at other monitoring locations in the Mount Maunganui Airshed. Specifically, all monitoring locations in the Mount Maunganui Airshed except Whareroa Marae and Tauranga Bridge Marina show a step change reduction in short-term SO_2 concentrations in early January 2020. This reduction coincides with the introduction of MARPOL Annex VI which mandated reductions in emissions of SO_2 from ships. This reduction is not as evident in the time series record for Whareroa Marae and Tauranga Bridge Marina.

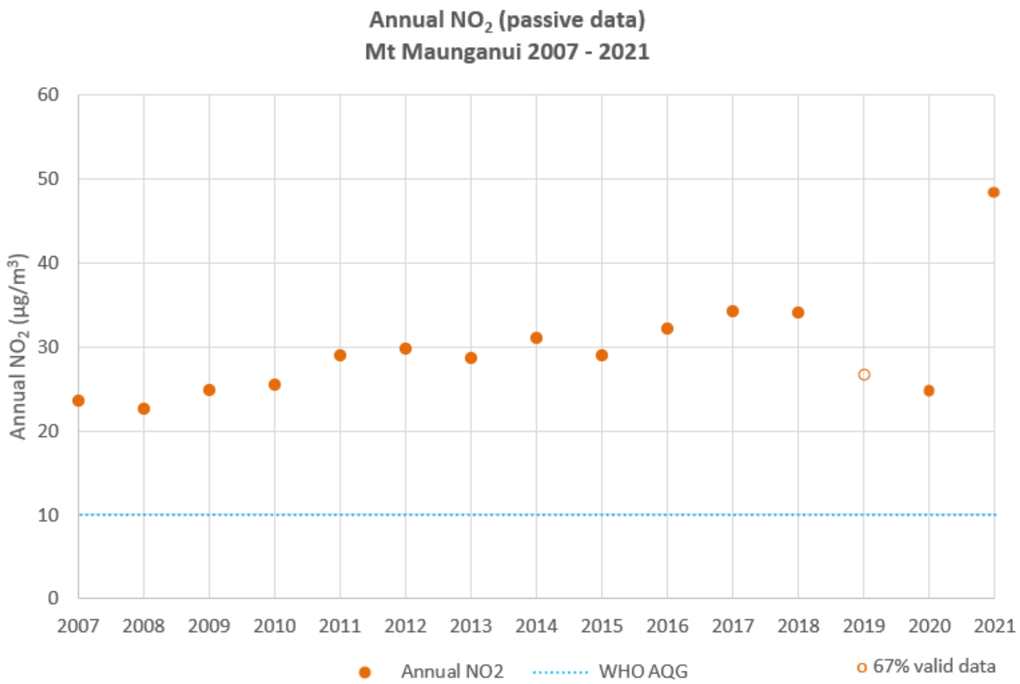
Closer investigation of directional data at Whareroa Marae and Tauranga Bridge Marina indicates that short-term levels of SO_2 at these two locations have also reduced, likely due to reductions in shipping emissions. However, the data indicate that short-term levels of SO_2 at Whareroa Marae and Tauranga Bridge Marina remain significantly influenced by emissions from the neighbouring fertiliser manufacturer.

6. NITROGEN DIOXIDE

Waka Kotahi NZ Transport Agency has been monitoring NO_2 at the intersection of Golf Road and Maunganui Road on the eastern boundary of the Mount Maunganui Airshed (refer Figure 1) since 2007. Typically, people do not spend long periods of time at the roadside, so this location is *not* representative of wider population exposure. The monitoring is also undertaken using passive samplers which do not meet the regulatory requirements to assess compliance with air quality standards and guidelines (Waka Kotahi 2023).[19] However, long-term passive data can help identify where concentrations are higher relative to other locations and be used to look at trends.

Figure 41 presents annual concentrations of NO_2 measured at the Golf Road / Maunganui Road intersection using passive samplers for the period 2007 – 2021.

FIGURE 41: Long-term monitoring of annual NO_2 concentrations (µg/m^3) measured at Golf Road and Maunganui Road: 2007 – 2022 [Source: NZTA][20]



In reviewing Figure 41 it is important to note:

- Construction of the Baypark to Bayfair link, with significant traffic route changes and congestion at this monitoring location, commenced in May 2017 and is still underway.[21]
- 2019 has only 67% valid data (good practice requires 75% valid data for calculation of an annual average); and

[19] Passive samplers rely on the pollutant diffusing into a tube where it is captured on a medium and then later analysed at a laboratory. Tubes are typically exposed for one month. Passive monitoring data are, on average, 33% higher than the continuous data collected using approved regulatory methods.

[20] https://www.nzta.govt.nz/assets/resources/air-quality-monitoring/docs/Ambient-air-quality-nitrogen-dioxide-monitoring-data-summary-2007-2021.xlsx [Accessed 13 June 2023]

[21] https://nzta.govt.nz/assets/projects/baypark-to-bayfair-link-upgrade/project-update-july-2017.pdf

- 2020 and 2021 were subject to measures introduced to combat COVID-19 which may have impacted on traffic at this location.

Figure 41 appears to show a long-term *increase* in annual roadside NO_2 concentrations over the period 2007 – 2018, with no clear trend since then. Bearing in mind the limitations of monitoring at a roadside location with a screening (non-regulatory) methodology, the data suggest annual levels of NO_2 are elevated in comparison with the WHO guideline.

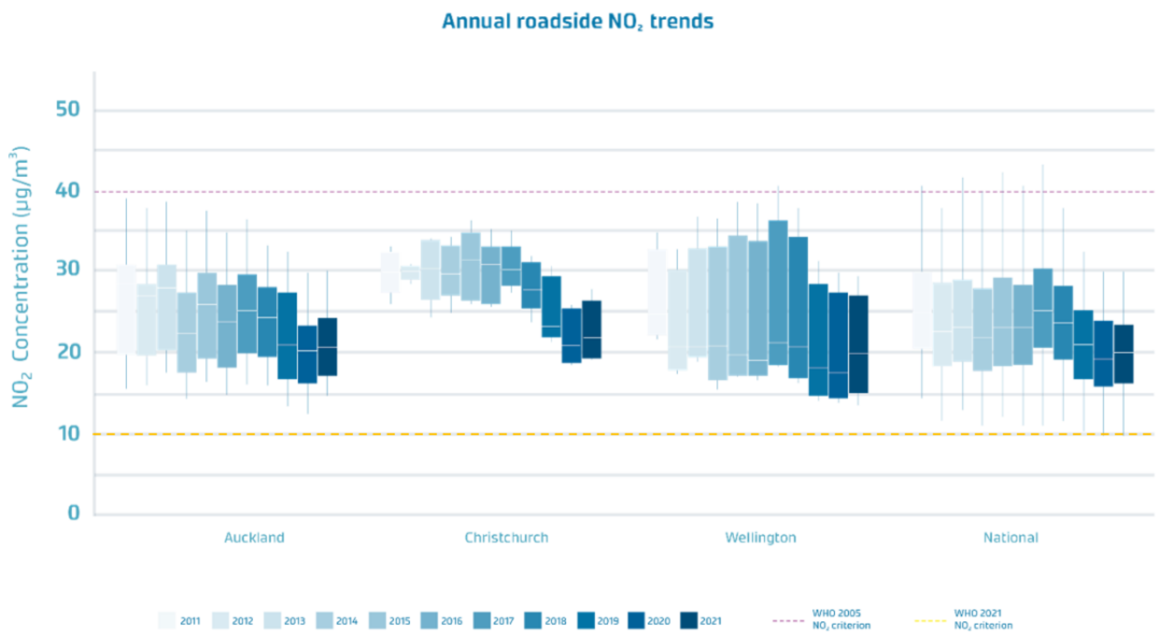
6.1 DISCUSSION

Figure 42 presents annual average NO_2 concentrations measured at state highway monitoring sites in New Zealand's three largest cities and the aggregated national results for the ten years 2011 to 2021. This shows a gradual decline in median values (represented by the inner white line within the boxes) that has been attributed to, at least in part, increasingly stringent vehicle emissions regulations (Waka Kotahi 2023).

The long-term data record of NO_2 monitoring at Mount Maunganui is significantly different to data gathered at most other monitoring locations in New Zealand. NZTA data suggests traffic volumes have increased by around 20% over the last ten years at State Highway 2 near the Golf Road monitoring location in Mount Maunganui.[22] However, similar increases in traffic volumes at other monitoring locations have still been associated with long-term declines in annual NO_2 (Waka Kotahi 2023).

NO_2 is a precursor pollutant that contributes to the formation of $PM_{2.5}$. The elevated levels, and potential long-term increase in annual NO_2 measured at the Golf Road intersection, warrants additional monitoring and investigation.

FIGURE 42: Annual roadside trends of NO_2 in New Zealand [Source: NZTA 2022]



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[22] Site reference 220158

https://opendata-nzta.opendata.arcgis.com/datasets/NZTA::state-highway-traffic-monitoring-sites/explore?location=-37.668843%2C176.200214%2C15.88

https://nzta.govt.nz/assets/resources/state-highway-traffic-volumes/docs/SHTV-2016-2020-all-regions.xlsx

https://nzta.govt.nz/assets/resources/state-highway-traffic-volumes/docs/SHTV-2011-2015.pdf

REFERENCES

Chappell, P 2013. *The Climate and Weather of Bay of Plenty*. 3rd Edition. NIWA Science & Technology Series.

Emission: Impossible Ltd. (2020). *National air quality (NO_2) monitoring network: Correlations between passive and continuous results 2010 to 2019*. Prepared for Waka Kotahi NZ Transport Agency. Auckland. Available on request.

International Agency for Research on Cancer (IARC), 2013. IARC: Outdoor air pollution a leading *environmental cause of cancer deaths*. [Online: www.iarc.who.int]

Ministry for the Environment (MfE), 2002. Ambient Air Quality Guidelines 2002 Update. Wellington. [Online: www.environment.govt.nz]

MfE, 2014. *2011 users' guide to the revised National Environmental Standards for Air Quality*. Updated 2014. Ministry for the Environment. Wellington. September.

Orellano *et al.,* 2021. Short-term exposure to sulphur dioxide (SO_2) and all-cause and respiratory mortality: A systematic review and meta-analysis. *Env Int*. Vol 150. May. 2021. 106434. https://doi.org/10.1016/j.envint.2021.106434

Pacific Air & Environment (PAE), 2009. *National Assessment of Industrial Sulphur Dioxide Emission in NZ*. Report for Ministry for the Environment. 25 March 2009.

United States Environmental Protection Agency (US EPA), 2016. *Integrated Science Assessment for Oxides of Nitrogen—Health Criteria*. EPA/600/R-15/068. [Online: www.federalregister.gov]

USEPA, 2020. *Integrated Science Assessment for Particulate Matter*. [Online: www.epa.gov]

Waka Kotahi NZ Transport Agency, 2022. *Ambient Air Quality (Nitrogen Dioxide) Monitoring Programme.* Annual Report 2007-2021. Prepared by Tonkin + Taylor Limited. December. Version 1.0. [Online: www.nzta.govt.nz]

World Health Organisation (WHO), 2000. *Air Quality Guidelines for Europe*. WHO Regional Office for Europe. Copenhagen. Denmark. [Online: https://www.who.int/]

WHO, 2006. *Air Quality Guidelines Global Update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide*. WHO Regional Office for Europe. Copenhagen. Denmark. [Online: https://www.who.int/]

WHO, 2013. *Review of evidence on health aspects of air pollution – REVIHAAP Project -Technical Report*. WHO Regional Office for Europe. Copenhagen. Denmark. [Online: www.euro.who.int]

WHO, 2016. *WHO Expert Consultation: Available evidence for the future update of the WHO Global Air Quality Guidelines (AQGs*). Meeting Report. Bonn. Germany. 29 Sep – 10 Oct 2015. WHO Regional Office for Europe. Copenhagen. Denmark. [Online: www.euro.who.int]

WHO, 2021. WHO global air quality guidelines. Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva. Switzerland. [Online: www.who.int]

Zheng et al., 2021. Short-term exposure to ozone, nitrogen dioxide, and sulphur dioxide and emergency department visits and hospital admissions due to asthma. A systematic review and meta-analysis. *Env Int*. Vol 150. February 2021. 106435. https://doi.org/10.1016/j.envint.2021.106435

APPENDIX A: TABULATED SUMMARY MONITORING RESULTS

Tables of summary air quality data are presented:

- for PM_{10} followed by SO_2; and
- west (predominantly upwind of the Mount Maunganui Airshed) to east (predominantly downwind), and then north to south (generally least to most industrial parts of the airshed).

Exceedance of standards and guidelines are summed for each site in these tables. NB: Total count of exceedances for the Mount Maunganui Airshed presented elsewhere in this report do not include events that occur on the same day. This avoids double counting when comparing with standards and guidelines that permit a number of exceedances in a 12-month period.

All data presented exclude exceptional events. Exceptional events are unusual or naturally occurring events that can affect air quality but are not reasonably controllable using techniques that regional councils may implement in order to attain and maintain the NES for PM_{10}.

It should be noted that Rail yard South and Totara Street are entirely industrial locations. All other monitoring locations are a mix of residential, commercial and industrial activities.

Table A-1: Summary PM_{10} concentrations in Mount Maunganui for 2022*

Monitoring Location	Maximum daily PM_{10} (µg/m³)	99th percentile daily PM_{10} (µg/m³)	Exceedances per year (no.)		Annual mean PM_{10} (µg/m³)
	[NES = 50] [WHO AQG = 45]		NES [1 permitted]	WHO AQG [3-4 permitted]	[WHO AQG = 15]
Sulphur Point	37	31	0	0	13
Bridge Marina	62	39	1	2	14
Whareroa Marae	29	24	0	0	10
De Havilland Way	45	41	0	0	**18**
Rata Street	53	41	1	3	**21**
Rail Yard South	50	42	0	3	**23**
Totara Street	50	45	0	3	**22**

*Excludes two exceptional events approved by the Minister for the Environment (18 Aug 2022 at Rata St, Rail Yard South, Bridge Marina and De Havilland Way and 19 Aug 2022 at the same sites and also at Totara St due to wave action).

Table A-2: Summary PM_{10} concentrations in Mount Maunganui for 2021*

Monitoring Location	Maximum daily PM_{10} (µg/m³)	99th percentile daily PM_{10} (µg/m³)	Exceedances per year (no.)		Annual mean PM_{10} (µg/m³)
	[NES = 50] [WHO AQG = 45]		NES [1 permitted]	WHO AQG [3-4 permitted]	[WHO AQG = 15]
Sulphur Point	32	27	0	0	13
Bridge Marina	43	38	0	0	14
Whareroa Marae	34	26	0	0	11
De Havilland Way	49	43	0	1	**19**
Rata Street	50	38	0	2	**19**
Rail Yard South	52	44	1	2	**24**
Totara Street	51	40	1	1	**21**

*Excludes five exceptional events approved by the Minister for the Environment (2-4 Feb 2021 at De Havilland Way due to asphalting adjacent to the monitor, and 9-10 Jun 2021 at Rata St due to wave action). One exceedance permitted in any 12-month period.

Table A-3: Summary PM_{10} concentrations in Mount Maunganui for 2020

Monitoring Location	Maximum daily PM_{10} (µg/m³)	99th percentile daily PM_{10} (µg/m³)	Exceedances per year (no.)		Annual mean PM_{10} (µg/m³)
	[NES = 50] [WHO AQG = 45]		NES [1 permitted]	WHO AQG [3-4 permitted]	[WHO AQG = 15]
Sulphur Point	28	25	0	0	13
Bridge Marina	35	32	0	0	14
Whareroa Marae	65	34	1	1	14
De Havilland Way	45	40	0	0	**18**
Rata Street	**87**	41	**2**	4	**18**
Rail Yard South	**115**	**52**	**5**	**9**	**23**
Totara Street	47	39	0	1	**21**

Table A-4: Summary PM_{10} concentrations in Mount Maunganui for 2019

Monitoring Location	Maximum daily PM_{10} (µg/m³)	99th percentile daily PM_{10} (µg/m³)	Exceedances per year (no.)		Annual mean PM_{10} (µg/m³)
	[NES = 50] [WHO AQG = 45]		NES [1 permitted]	WHO AQG [3-4 permitted]	[WHO AQG = 15]
Sulphur Point	31	27	0	0	14
Bridge Marina	39	31	0	0	**16**
Whareroa Marae	50	45	0	3	**17**
De Havilland Way	**63**	47	**3**	4	**19**
Rata Street	44	41	0	0	**20**
Rail Yard South	**70**	**63**	**16**	**32**	**30**
Totara Street	57	43	1	1	**25**

*Excludes 1 exceptional event approved by the Minister for the Environment (6 Dec 2019 at all sites due to Australian bush fires). One exceedance permitted in any 12-month period.

Table A-5: Summary SO_2 10-minute concentrations in Mount Maunganui for 2022

Monitoring location	Maximum 10-minute SO_2 (μg/m³)	99th percentile 10-minute SO_2 (μg/m³)	Exceedances per year WHO AQG (no.)
	[WHO AQG = 500]		[0 permitted]
Sulphur Point	137	34	0
Bridge Marina	239	33	0
Whareroa Marae	396	59	0
Rata Street	192	29	0
Rail Yard South	76	21	0
Totara Street	282	34	0

Table A-6: Summary SO_2 10-minute concentrations in Mount Maunganui for 2021

Monitoring location	Maximum 10-minute SO_2 (μg/m³)	99th percentile 10-minute SO_2 (μg/m³)	Exceedances per year WHO AQG (no.)
	[WHO AQG = 500]		[0 permitted]
Sulphur Point	127	31	0
Bridge Marina	**1,247**	45	**1**
Whareroa Marae	361	70	0
Rata Street	75	24	0
Rail Yard South	82	21	0
Totara Street	96	29	0

Table A-7: Summary SO_2 10-minute concentrations in Mount Maunganui for 2020

Monitoring location	Maximum 10-minute SO_2 (μg/m³)	99th percentile 10-minute SO_2 (μg/m³)	Exceedances per year WHO AQG (no.)
	[WHO AQG = 500]		[0 permitted]
Sulphur Point	142	35	0
Bridge Marina	275	44	0
Whareroa Marae	432	72	0
Rata Street	80	27	0
Rail Yard South	109	22	0
Totara Street	90	34	0

Table A-8: Summary SO_2 10-minute concentrations in Mount Maunganui for 2019

Monitoring location	Maximum 10-minute SO_2 (µg/m³)	99th percentile 10-minute SO_2 (µg/m³)	Exceedances per year WHO AQG (no.)
	[WHO AQG = 500]		[0 permitted]
Sulphur Point	287	106	0
Bridge Marina	232	76	0
Whareroa Marae	472	113	0
Rata Street	**775**	197	**10**
Rail Yard South	393	154	0
Totara Street	359	85	0

Table A-9: Summary SO_2 1-hour concentrations in Mount Maunganui for 2022

Monitoring Location	Maximum 1-hour SO_2 (µg/m³)	99th percentile 1-hour SO_2 (µg/m³)	Exceedances per year (no.)	
	[Lower NES = 350 / Upper NES = 570]		Lower NES [9 permitted]	Upper NES [0 permitted]
Sulphur Point	80	33	0	0
Bridge Marina	76	30	0	0
Whareroa Marae	204	53	0	0
Rata Street	111	27	0	0
Rail Yard South	58	19	0	0
Totara Street	67	32	0	0

Table A-10: Summary SO_2 1-hour concentrations in Mount Maunganui for 2021

Monitoring Location	Maximum 1-hour SO_2 (µg/m³)	99th percentile 1-hour SO_2 (µg/m³)	Exceedances per year (no.)	
	[Lower NES = 350 / Upper NES = 570]		Lower NES [9 permitted]	Upper NES [0 permitted]
Sulphur Point	96	28	0	0
Bridge Marina	312	39	0	0
Whareroa Marae	125	59	0	0
Rata Street	63	22	0	0
Rail Yard South	38	18	0	0
Totara Street	60	27	0	0

Table A-11: Summary SO_2 1-hour concentrations in Mount Maunganui for 2020

Monitoring Location	Maximum 1-hour SO_2 (µg/m³)	99th percentile 1-hour SO_2 (µg/m³)	Exceedances per year (no.)	
	[Lower NES = 350 / Upper NES = 570]		Lower NES [9 permitted]	Upper NES [0 permitted]
Sulphur Point	100	33	0	0
Bridge Marina	161	40	0	0
Whareroa Marae	251	60	0	0
Rata Street	57	25	0	0
Rail Yard South	68	20	0	0
Totara Street	64	29	0	0

Table A-12: Summary SO_2 1-hour concentrations in Mount Maunganui for 2019

Monitoring Location	Maximum 1-hour SO_2 ($\mu g/m^3$)	99th percentile 1-hour SO_2 ($\mu g/m^3$)	Exceedances per year (no.)	
	[Lower NES = 350 / Upper NES = 570]		Lower NES [9 permitted]	Upper NES [0 permitted]
Sulphur Point	208	96	0	0
Bridge Marina	157	65	0	0
Whareroa Marae	206	97	0	0
Rata Street	**575**	173	4	**1**
Rail Yard South	226	126	0	0
Totara Street	167	72	0	0

Table A-13: Summary SO_2 daily concentrations in Mount Maunganui for 2022

Monitoring Location	Maximum daily SO_2 ($\mu g/m^3$)	99th percentile daily SO_2 ($\mu g/m^3$)	Exceedances per year (no.)	
	[NAAQG = 120] [WHO AQG = 40]		NAAQG [0 permitted]	WHO AQG [3-4 permitted]
Sulphur Point	26	19	0	0
Bridge Marina	28	17	0	0
Whareroa Marae	43	24	0	1
Rata Street	20	17	0	0
Rail Yard South	13	10	0	0
Totara Street	29	17	0	0

Table A-14: Summary SO_2 daily concentrations in Mount Maunganui for 2021

Monitoring Location	Maximum daily SO_2 ($\mu g/m^3$)	99th percentile daily SO_2 ($\mu g/m^3$)	Exceedances per year (no.)	
	[NAAQG = 120] [WHO AQG = 40]		NAAQG [0 permitted]	WHO AQG [3-4 permitted]
Sulphur Point	39	19	0	0
Bridge Marina	36	24	0	0
Whareroa Marae	42	24	0	1
Rata Street	15	13	0	0
Rail Yard South	12	11	0	0
Totara Street	26	14	0	0

Table A-15: Summary SO_2 daily concentrations in Mount Maunganui for 2020

Monitoring Location	Maximum daily SO_2 ($\mu g/m^3$)	99th percentile daily SO_2 ($\mu g/m^3$)	Exceedances per year (no.)	
	[NAAQG = 120] [WHO AQG = 40]		NAAQG [0 permitted]	WHO AQG [3-4 permitted]
Sulphur Point	24	18	0	0
Bridge Marina	54	29	0	3
Whareroa Marae	54	28	0	1
Rata Street	16	13	0	0
Rail Yard South	17	12	0	0
Totara Street	19	15	0	0

Table 16: Summary SO_2 daily concentrations in Mount Maunganui for 2019

Monitoring Location	Maximum daily SO_2 ($\mu g/m^3$)	99th percentile daily SO_2 ($\mu g/m^3$)	Exceedances per year (no.)	
	[NAAQG = 120] [WHO AQG = 40]		NAAQG [0 permitted]	WHO AQG [3-4 permitted]
Sulphur Point	**93**	**60**	0	**11**
Bridge Marina	44	33	0	1
Whareroa Marae	**48**	**42**	0	**5**
Rata Street	**140**	**90**	**1**	**50**
Rail Yard South	**92**	**72**	0	**62**
Totara Street	54	40	0	4

APPENDIX B: TIME VARIATION SUMMARY PLOTS

The following are time variation summary plots (pollutant by hour of day, day of week and month of year) over the four-year period 2019 – 2022 with 95% confidence intervals.

Time variation plots discussed in the body of the report (e.g., Figure 15 Monthly and daily time variation of PM_{10} concentrations for 2019 – 2022 for Whareroa Marae) are not repeated here.

Summary plots are presented:

- for PM_{10} followed by SO_2; and
- west (predominantly upwind of the Mount Maunganui Airshed) to east (predominantly downwind), and then north to south (generally least to most industrial parts of the airshed).

It should be noted that Rail Yard South and Totara Street are entirely industrial locations. All other monitoring locations are a mix of residential, commercial and industrial activities.

Figure B-1: Monthly (left hand side) and daily (right hand side) PM_{10} concentrations (µg/m^3) measured at Sulphur Point with 95% confidence intervals: 2019 – 2022

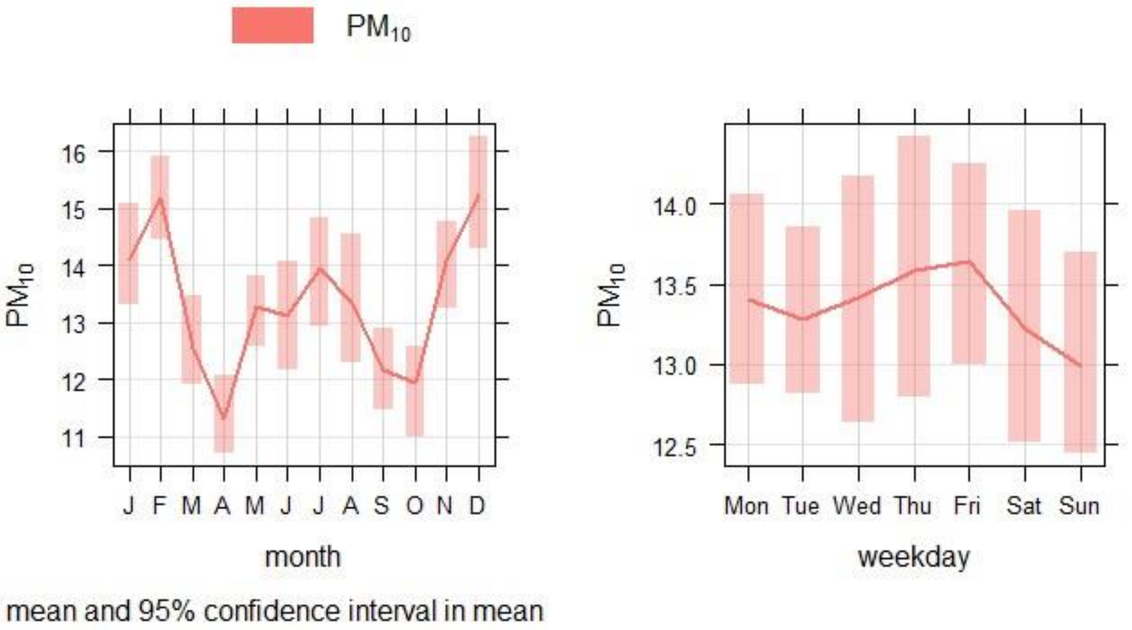


Figure B-2: Monthly (left hand side) and daily (right hand side) PM_{10} concentrations (µg/m^3) measured at Tauranga Bridge Marina with 95% confidence intervals: 2019 – 2022

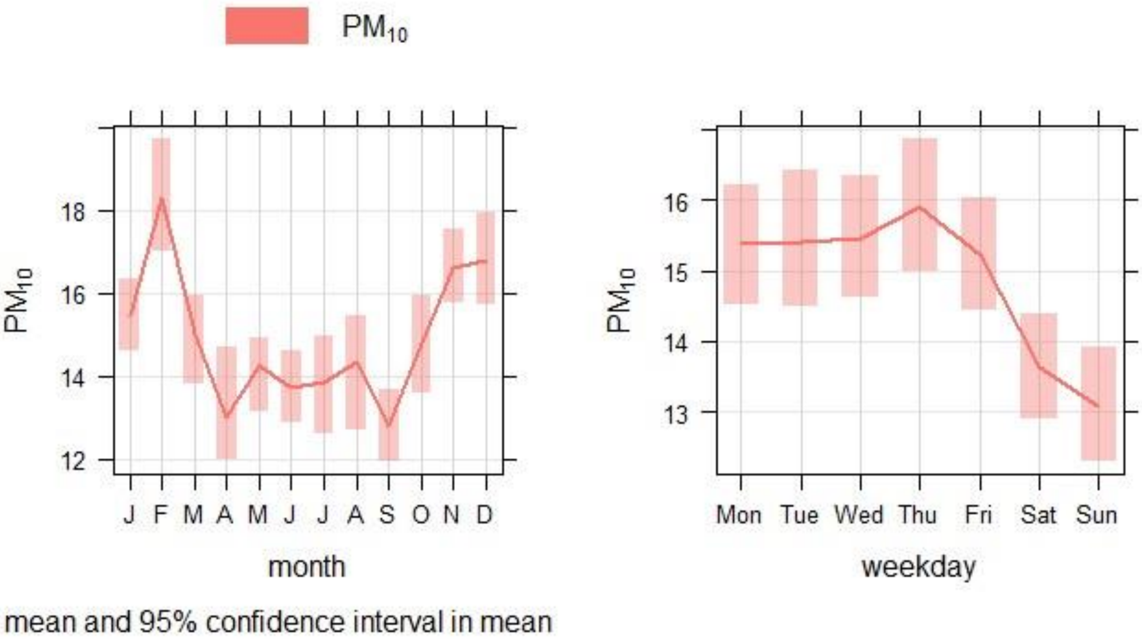


Figure B-3: Monthly (left hand side) and daily (right hand side) PM_{10} concentrations (μg/m^3) measured at Rata Street with 95% confidence intervals: 2019 – 2022

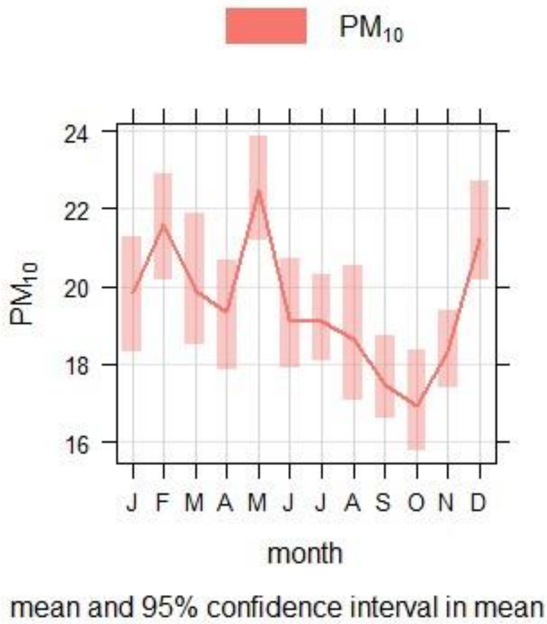


Figure B-4: Monthly (left hand side) and daily (right hand side) PM_{10} concentrations (μg/m^3) measured at Rail Yard South with 95% confidence intervals: 2019 – 2022

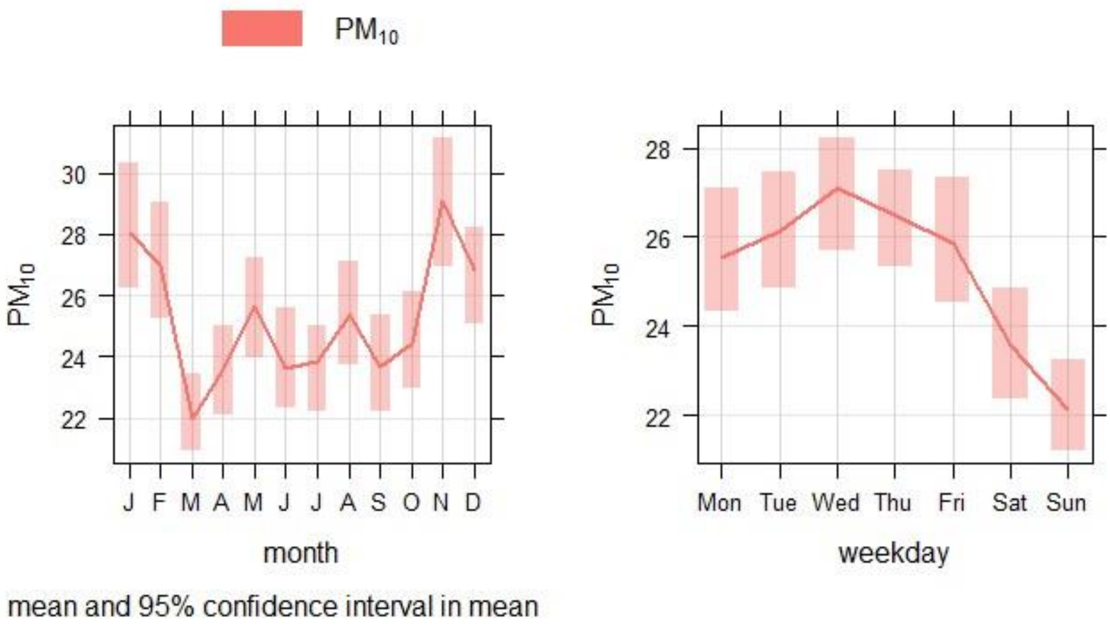


Figure B-5: Monthly (left hand side) and daily (right hand side) PM_{10} concentrations (µg/m^3) measured at Totara Street with 95% confidence intervals: 2019 – 2022

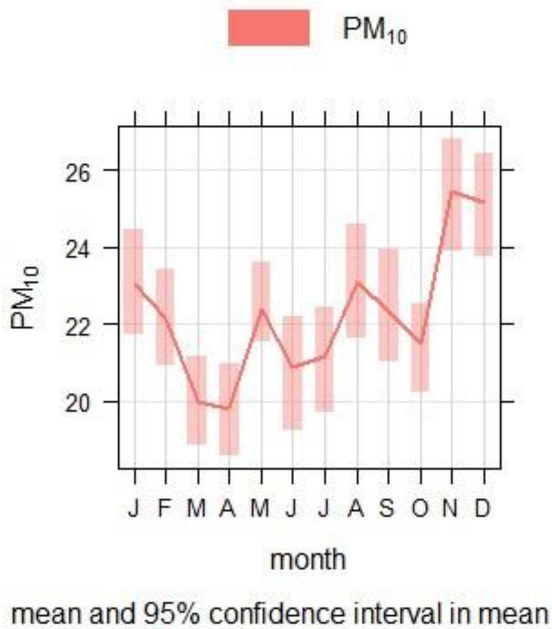


Figure B-6: Mean concentrations of SO_2 (µg/m^3) with 95% confidence intervals measured at Sulphur Point by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): 2019 – 2022

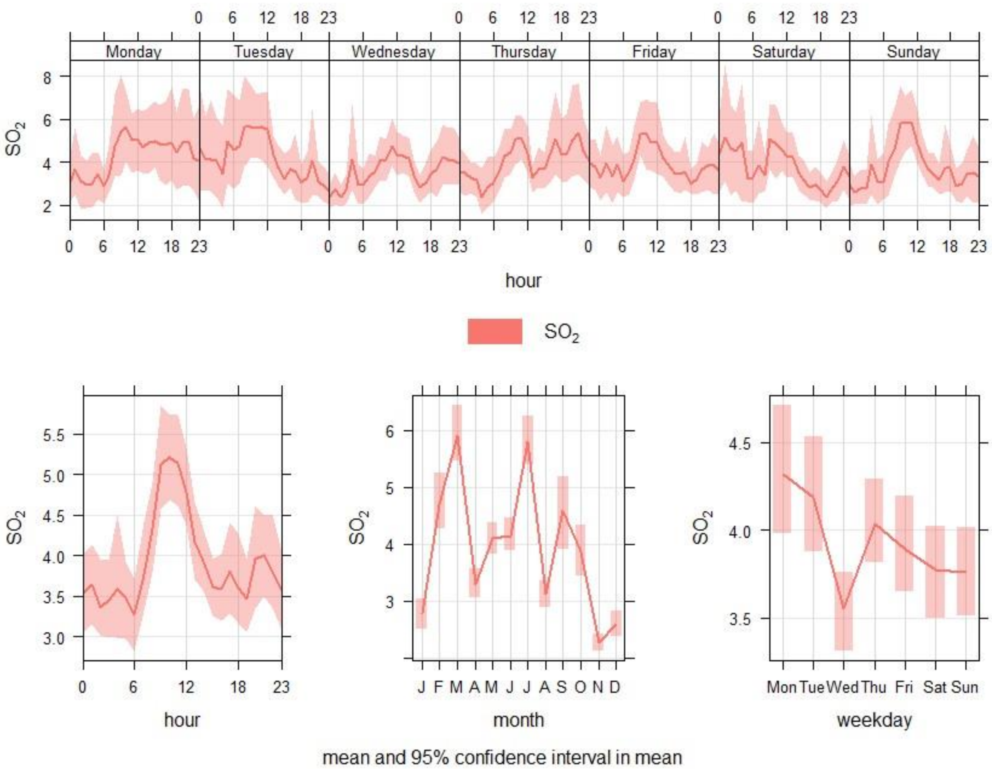


Figure B-7: Mean concentrations of SO_2 (µg/m³) with 95% confidence intervals measured at Tauranga Bridge Marina by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): 2019 – 2022

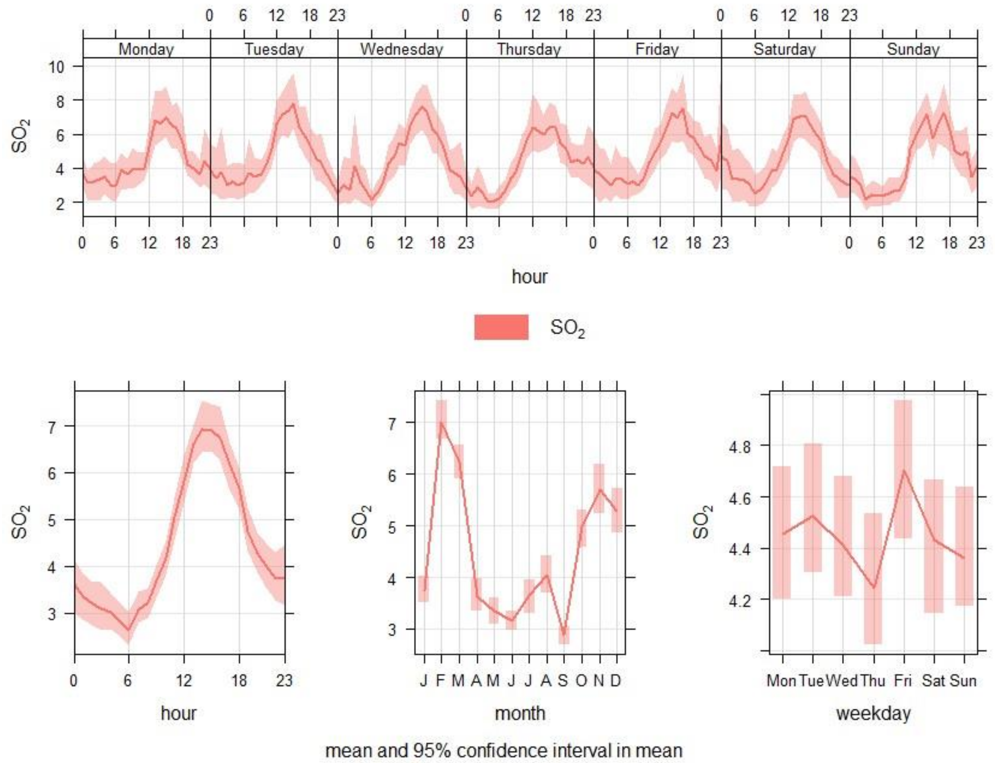


Figure B-8: Mean concentrations of SO_2 (µg/m³) with 95% confidence intervals measured at Rata Street by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): 2019 – 2022

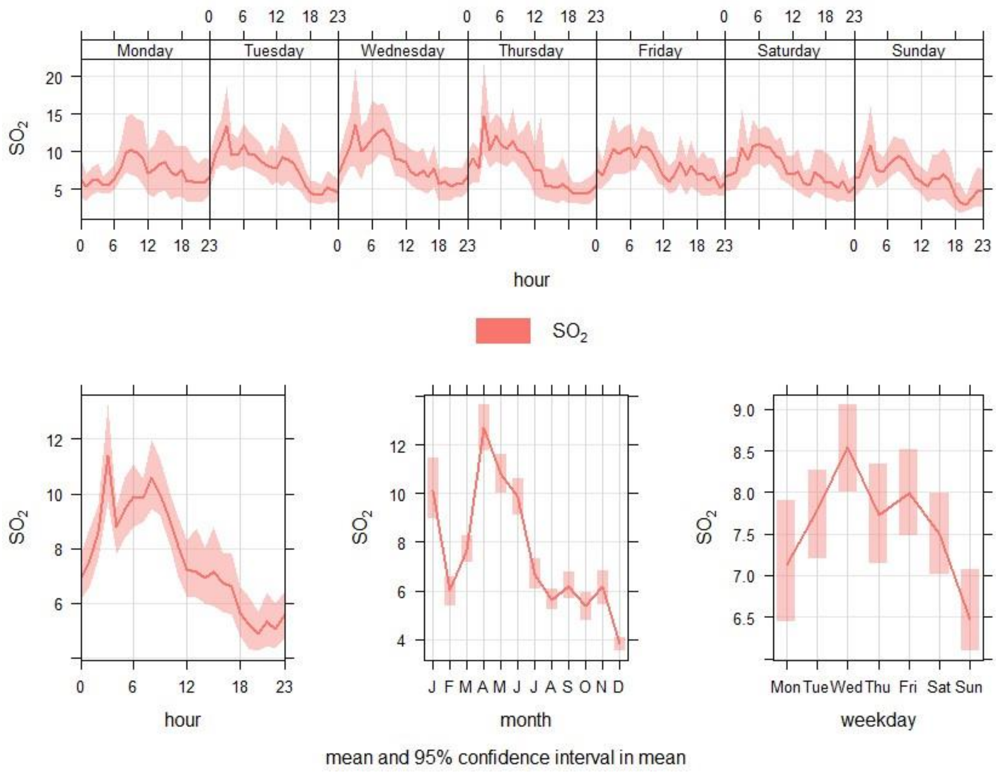


Figure B-9: Mean concentrations of SO_2 (µg/m^3) with 95% confidence intervals measured at Rail Yard South by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): 2019 – 2022

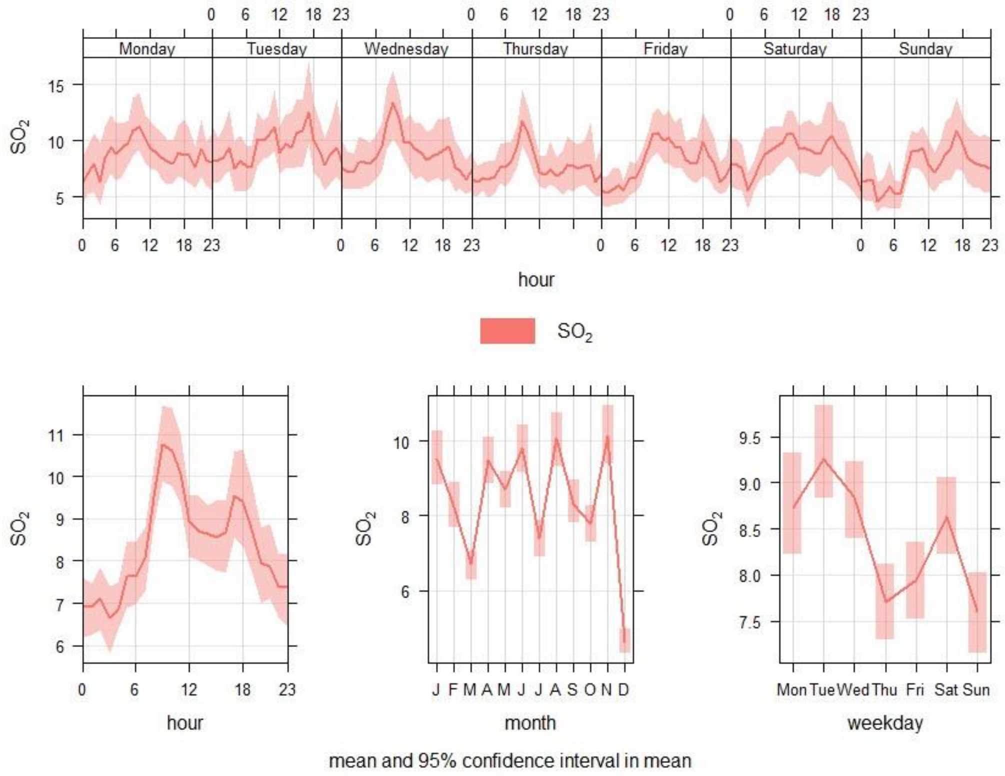
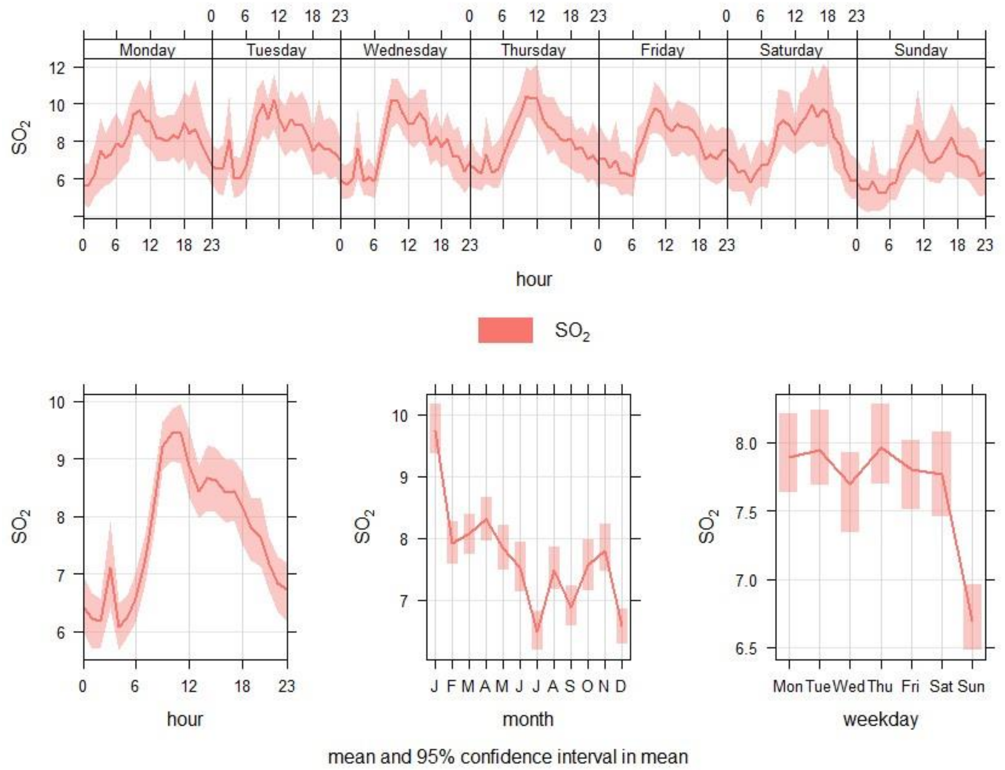


Figure B-10: Mean concentrations of SO_2 (µg/m^3) with 95% confidence intervals measured at Totara Street by hour of day and day of week (top), hour of day (bottom left), month of year (bottom middle) and day of week (bottom right): 2019 – 2022



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