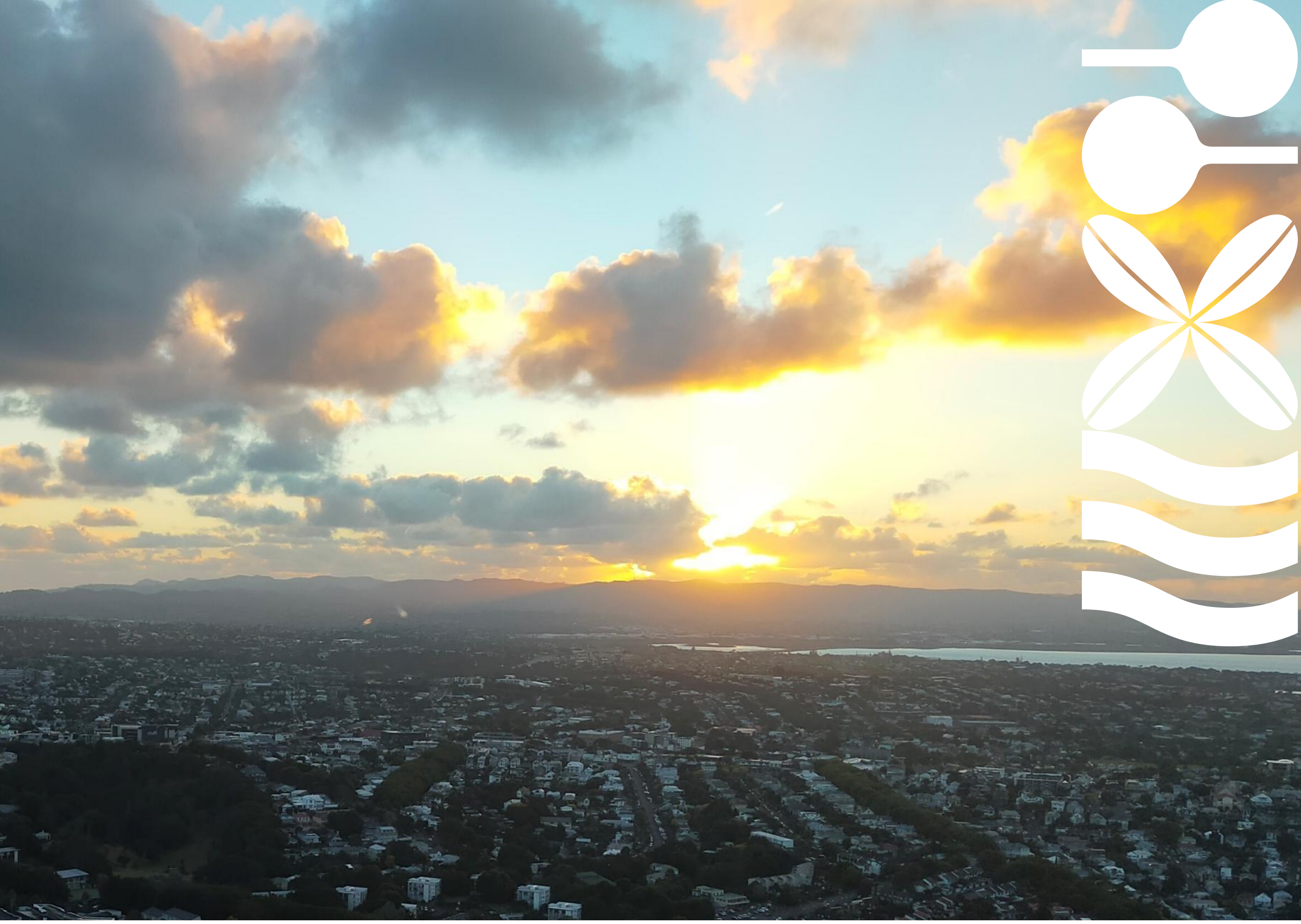


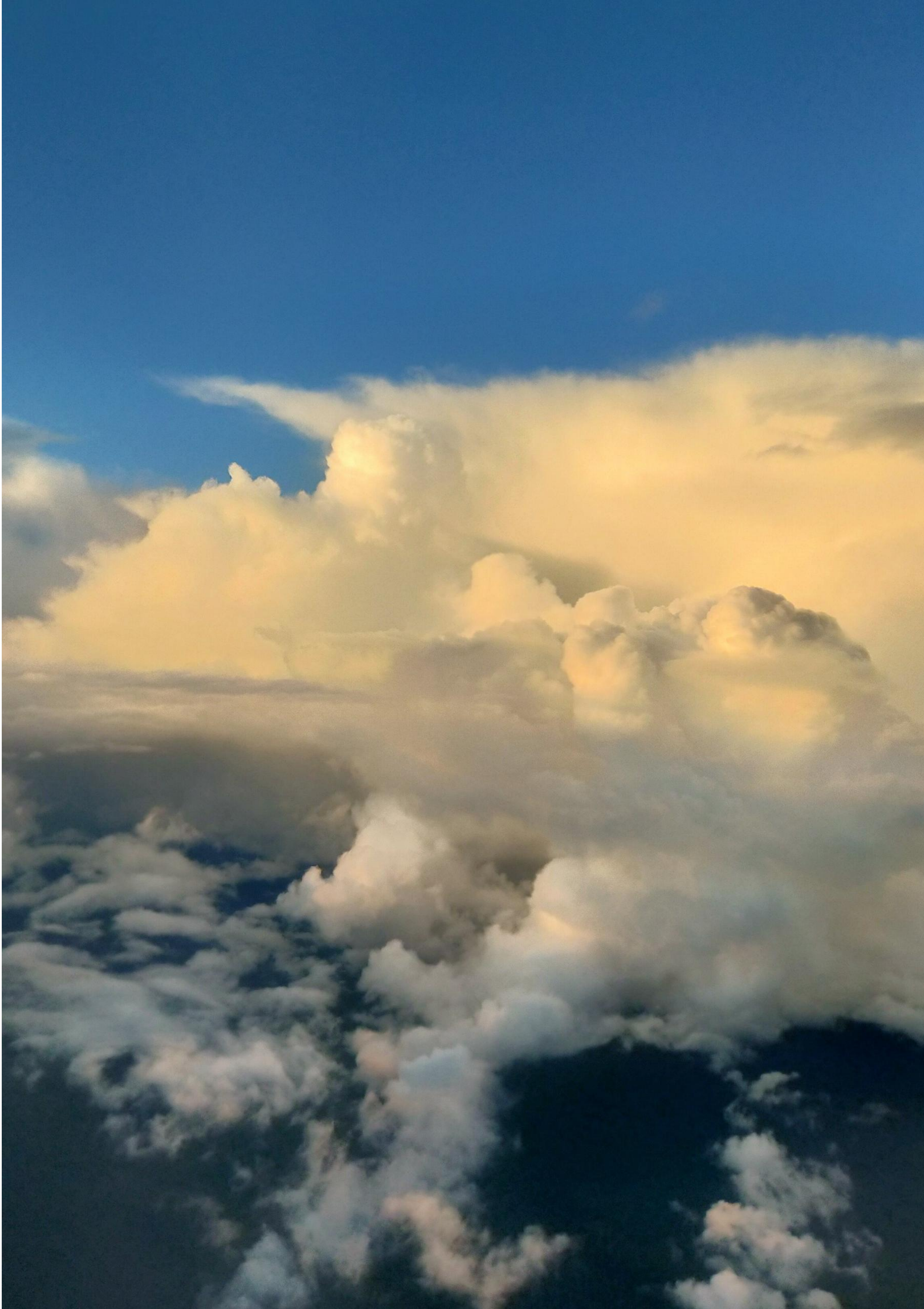
Ambient Air Quality in Auckland – Trend Analysis 2015 to 2024

State of the Environment Reporting

Gustavo Olivares Pino

August 2025

Technical Report 2025/26



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Environmental Evaluation and Monitoring Unit, EEMU

Auckland Council
Technical Report 2025/26

ISSN 2230-4525 (Print)
ISSN 2230-4533 (Online)

ISBN 978-1-991377-86-9 (PDF)

The Peer Review Panel reviewed this report
Review completed on 21 August 2025 Reviewed by two reviewers
Approved for Auckland Council publication by: Name: Paul Klinac Position: General Manager, Engineering, Assets and Technical Advisory
Recommended for approval/publication by:
Name: Dr Jonathan Benge Position: Head of Environmental Evaluation and Monitoring
Name: Jacqueline Lawrence-Sansbury Position: Team Manager, Air, Land and Biodiversity. Environmental Evaluation and Monitoring Unit, EEMU
Date: 21 August 2025

Recommended citation
Olivares Pino, G. (2025). Ambient air quality in Auckland – trend analysis 2015 to 2024. State of the environment reporting. Auckland Council technical report, TR2025/26

Cover images credit:
Panoramic sunset view of Auckland, New Zealand. January 2022. Photograph by Gustavo Olivares Pino. Clouds over Auckland. Photograph by Gustavo Olivares Pino.

Executive summary

Air quality refers to the condition of the air we breathe, shaped by the presence of pollutants that can harm human health and the environment. Good air quality is essential for the well-being of individuals and the health of ecosystems. Poor air quality is linked to respiratory and cardiovascular diseases and can even lead to premature death. Auckland's air quality is generally good compared to many cities worldwide, thanks in part to its geography and climate. However, local activities – including transport, domestic heating, and industry – continue to influence pollutant levels. Auckland Council has monitored ambient air quality for over four decades using high-accuracy equipment and nationally recognised standards. This long-term monitoring supports a robust scientific understanding of pollutant levels, trends, and sources, enabling the Council to manage air quality effectively under the Resource Management Act 1991.

This report presents an analysis of air quality trends in Auckland over the past decade, with a particular focus on the last five years. It includes long-term and seasonal statistics for key pollutants and incorporates source apportionment data for particulate matter (PM_{10} and $PM_{2.5}$) to identify contributing emission sources.

Encouragingly, Auckland has not exceeded national air quality standards or regional targets since 2022. Concentrations of nitrogen dioxide (NO_2), a key traffic-related pollutant, have decreased across the region at a rate of around 5% each year, with particularly strong improvements in the Central Business District (CBD) that have seen improvements of nearly 20% over the last five years. These reductions have occurred despite population and vehicle growth, highlighting the benefits of low-emission vehicles, increased public transport use and improved traffic flow for heavy vehicles.

In contrast, PM_{10} and $PM_{2.5}$ concentrations have remained relatively stable over the past three years, with some areas showing signs of worsening. The source mix for PM pollution has remained consistent, with marine aerosol (sea spray) contributing approximately 45% of PM_{10}, motor vehicles around 30%, and biomass (wood) burning about 10%. For $PM_{2.5}$, motor vehicles are the dominant source, contributing over 40%, followed by sea spray and wood burning. While the impact of most sources has decreased, the relative contribution of non-tailpipe emissions (e.g., brake and tyre wear) has increased, reflecting the changing nature of urban pollution.

One of the most significant events to impact air quality over the past few years was the COVID-19 pandemic. New Zealand's response to the pandemic, which included the use of lockdowns, had a notable impact on air quality. During Level 4 restrictions, NO_2 concentrations dropped by more than 70% across Auckland, and PM levels also declined, though less dramatically. These changes highlight the influence of mobile combustion sources on urban air quality. More subtly, the experience of the COVID-19 pandemic response changed some habits. Notably, the increased prevalence of working from home arrangements. These changes had an impact on the number of people and vehicles travelling to destinations like the CBD and are likely to have impacted the changes in the trends observed since 2020.

Significant spatial variation in traffic pollution remains, and many fast-growing areas lack sufficient monitoring data. Not all Aucklanders are exposed to the same air, and for some communities – particularly in the north-west and south of the region – pollution levels are still unknown. Ensuring clean air for all will require continued investment in clean transport, expanded monitoring in underserved areas, and targeted action on particulate pollution. These efforts are essential to protect public health and support sustainable urban growth.

Together, these findings highlight both the progress made and the challenges that remain in ensuring clean, healthy air for all Aucklanders.

Acknowledgements

The air quality monitoring data for this report was collected on contract to Auckland Council by Watercare Laboratory Services Ltd with thanks from the author for its accuracy and completeness.

Thank you to the peer reviewers of this report Dr Louis Boamponsem and Dr Gerda Kuschel for the thoughtful and useful comments and recommendations that greatly improved this document.

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Glossary of terms, acronyms, and abbreviations

Term	Meaning
Aerodynamic diameter	Used to describe the behaviour of a particle as it moves around in the air; it compares the behaviour with that of a spherical particle of unit density
Aerosol	A mixture of particles suspended in the atmosphere
Air pollutant/contaminant	Any substance in the air that could harm humans, animals, vegetation, or other parts of the environment when present in high enough concentrations
Air pollution	The presence of one or more air pollutants in high enough concentrations to cause harm
Air quality	Air quality is the degree to which air is suitable or clean enough for humans, animals, or plants to remain healthy
Airshed	A geographic area established to manage air pollution within the area as defined by the national environmental standard for air quality (NESAQ).
Ambient air	The external air environment (does not include the air environment inside buildings or structures)
Anthropogenic sources	Sources resulting from human activity (not natural sources) such as combustion of fuels
BAM	Beta attenuation monitor
Benzene	Benzene is an aromatic organic compound which is a minor constituent of petrol (about 2% by volume)
Black carbon	Is an air pollutant made up of tiny soot-like particles discharged into the atmosphere from combustion processes
BTEX	Benzene, toluene, ethylbenzene and xylenes. A group of volatile organic compounds
CO	Carbon monoxide, a type of air pollutant
Exceedance	An exceedance defines a period of time during which the concentration of a pollutant is greater than the appropriate air quality criteria
Ground-level ozone	At ground level, ozone is considered an air pollutant that can seriously affect the human respiratory system. It is a major component of photochemical smog
HAPINZ	Health and Air Pollution in New Zealand. The HAPINZ 3.0 study investigated the impact of air pollution on New Zealanders' health
MfE	Ministry for the Environment
MoH	Ministry of Health
Monitoring site	A facility for measuring the concentration of one or more pollutants in the ambient air; also referred to as ‘monitoring station’
NESAQ	National Environmental Standard for Air Quality
NO_2	Nitrogen dioxide, a type of air pollutant

Term	Meaning
NO_X	Oxides of nitrogen (NO_2 + NO). NO_X is principally formed by the oxidation of nitrogen contained in air at high combustion temperatures. It is a significant tracer for the impact of traffic pollution
NZTA	New Zealand Transport Agency
Pb	Lead
PM	Particulate matter. It is made up of a mixture of various sizes of solid and liquid particles suspended in air; a type of air pollutant
PM_{10}	Particulate matter with an aerodynamic diameter of 10 micrometres or less; a type of air pollutant
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of 2.5 micrometres or less; a type of air pollutant
Relative humidity	Is a ratio, expressed in per cent, of the amount of atmospheric moisture present relative to the amount that would be present if the air were saturated.
SO_2	Sulphur dioxide, a type of air pollutant
TSP	Total suspended particulates; a type of air pollutant
VOCs	Volatile organic compounds – chemical compounds that have high enough vapour pressure to exist at least partially as a gas at standard atmospheric temperature and pressure
Wind rose	A graphic tool used to get a view of how wind speed and direction are typically distributed at a particular site
$\mu g/m^3$	Microgram of pollutant (1 millionth of a gram) per cubic metre of air, referenced to temperature of 0°C (273.15 K) and absolute pressure of 101.325 kilopascals (kPa)

1 Introduction

Auckland is a vibrant city, home to more than 1.7 million people. Situated between the Tasman Sea and the South Pacific Ocean, it benefits from an airflow that helps disperse air pollutants away from our city and region. However, the city's urban environment, where transport and industrial activities combine with domestic heating practices, pose a challenge to our air quality, particularly in winter.

The World Health Organization (WHO) has identified outdoor air pollution as a leading cause of global mortality and morbidity with seven million premature deaths estimated to be due to air pollution. In 2021, the WHO updated their health-based guidelines for air pollutants, highlighting that the research points to the absence of a "safe limit" for these contaminants (World Health Organization 2021).

In New Zealand, the most recent update to the Health and Air Pollution in New Zealand (HAPINZ 3.0) estimates the social costs of the health impacts from air pollution for 2016 to be more than $15 billion with more than 3000 premature deaths and more than 13,000 hospital admissions (Kuschel et al. 2022)[1]. The same report calculates that the social costs for Auckland are over $4 billion, or more than 3% of Auckland's GDP for 2016[2].

The regional air quality monitoring programme, in line with the Resource Management Act 1991 and the National Environmental Standards for Air Quality, aims to provide a comprehensive understanding of air quality in Auckland. This programme is crucial for identifying pollution sources, assessing the effectiveness of regulatory measures, and guiding policy decisions to protect public health. By continuously monitoring key pollutants such as particulate matter, black carbon, nitrogen dioxide (NO_2), carbon monoxide (CO) and ozone (O_3), Auckland Council can implement targeted interventions to mitigate the health impacts of air pollution and improve the quality of life for its residents.

Since the 1990s, Auckland Council has intensified its efforts to monitor and manage air quality, ensuring a robust scientific understanding of pollutant levels, trends, and sources. This report aims to present a summary of the air quality in Auckland for the last decade, with a focus on the last five years and it is an update to the previous State of the Environment report (Talbot and Crimmins 2020).

The report is structured first giving a general overview of air quality, followed by a description of the analysis methods and data availability. The results section then presents the trends observed in air quality, highlighting significant findings for key pollutants with more detailed information presented in the appendix section of this report. There is also a *case studies* section that highlights three key topics: the impact of the COVID-19 lockdowns on air quality; a summary of the breakdown of the

[1] Note that the value of a statistical life has increased significantly since the HAPINZ report was released.
[2] Regional GDP information can be found here:
https://qem.infometrics.co.nz/auckland/economic/gdp

emission sources of particulate matter in Auckland; and the changes in air quality in the city centre. The final section discusses the results in the wider context of Auckland's environmental management efforts, compares them to the previous state of the environment report and identifies key research and monitoring gaps for the future.

Supporting information

This report is one of a series of technical publications prepared in support of *Te oranga o te taiao o Tāmaki Makaurau – The health of Tāmaki Makaurau Auckland's Natural Environment in 2025: a synthesis of Auckland Council State of the Environment reporting*.

All related reports (past and present) are published on the Knowledge Auckland website.

All data supporting this report can be requested through our Environment Auckland Data Portal. Here you can also view live rainfall, river flow and air quality data and use several data explorer tools.

2 What is air quality?

2.1 Overview

Air quality refers to the condition of the air we breathe, and it is influenced by the presence of pollutants (both natural and human-generated) which can be harmful to human health and the environment. Good air quality is essential for maintaining the health and well-being of individuals, as well as the overall ecosystem. Poor air quality can lead to various health issues, including respiratory problems, cardiovascular diseases, and premature death (World Health Organization 2021; Brauer et al. 2012; Hasenkopf et al. 2016).

Auckland's unique geography and climate plays a key role in our air quality. The lack of significant mountain ranges means that the wind flows mostly unimpeded between the Tasman Sea and the Pacific Ocean, helping the ventilation of our city (Jiang et al. 2013). Other factors that determine the quality of our air are controlled by our activities, for example, emissions from transport, domestic fires, and industrial activities (Boamponsem et al. 2025; 2024).

Auckland's air quality is generally good compared to many other cities worldwide, but there are still areas where improvements are needed. The key pollutants affecting Auckland's air quality include particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2).

2.2 Pollutants

2.2.1 Particulate matter

Particulate matter (PM) is a term used to describe the mixture of solid particles and liquid droplets found in the air (Breysse et al. 2012). These particles come in various sizes and, when inhaled, they can be harmful. Because PM is a complex mixture, we use several different ways to describe it, each with its distinct history and purpose.

- Total Suspended Particulate (TSP) refers to the mass concentration of all particles suspended in the air, regardless of their size, and it is the oldest measure of PM still in use. In Auckland, we measure TSP only at Penrose, connected to our monitoring of lead in the particles.
- PM_X is another way of describing PM by separating the particles by size before measuring their mass density in the air. In general, PM_X refers to the concentration of particles whose size is less than X micrometres.
    - PM_{10} only includes particles with a diameter of 10 micrometres or less (smaller than about 1/10 of the width of a human hair).
    - $PM_{2.5}$ only includes particles with a diameter of 2.5 micrometres or less (less than half the size of a red blood cell).

- Black Carbon (BC) refers to the soot-like particles produced by the incomplete combustion of fossil fuels, biofuels, and biomass. It is a component of PM and is especially relevant because of its strong impact on both human health and climate. In Auckland, BC is mainly emitted by motor vehicles, especially diesel engines, and domestic heating. Although there is no environmental standard associated to BC, we monitor this pollutant to help us understand the sources of combustion-related air pollution. BC is monitored at two sites in the region, Henderson (Lincoln Rd) and the city centre (Customs Street).

While PM_{10} and $PM_{2.5}$ are often treated as distinct pollutants, it's essential to understand that they both describe the concentration of particles suspended in the air and refer to the same particulate matter. Figure 1 illustrates the relationship between PM_{10} and $PM_{2.5}$. All particles within the red circle (including those in the blue circle) contribute to PM_{10}, whereas only the particles within the blue circle are counted as $PM_{2.5}$.

The choice to focus on these specific particle sizes is based on the particles' ability to penetrate our respiratory system. As illustrated in Figure 2, particles larger than 10 micrometres tend to settle out of the air or are trapped by the nose hairs and do not penetrate our respiratory system, while those smaller than 2.5 micrometres can reach deeper into our lungs and can even pass into our bloodstream (Sagona et al. 2020). Therefore, historically, regulation has focused on PM_{10} and $PM_{2.5}$.

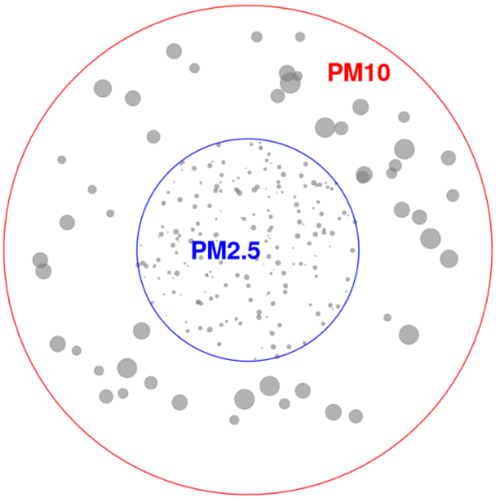


Figure 1. Diagram illustrating the relationship between PM_{10} and $PM_{2.5}$.

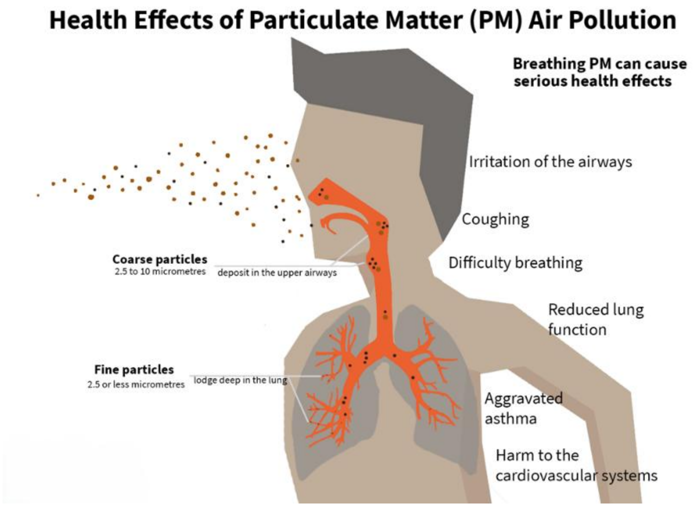


Figure 2. Schematic representation of the health effects from particulate matter, by the different fractions of PM. From LAWA[3]

2.2.2 Nitrogen oxides

Nitrogen oxides (NO_X) are a group of gases that include nitrogen oxide (NO) and nitrogen dioxide (NO_2). These gases are typically produced by the combustion, in the presence of air, of fossil fuels,

[3] Land, Air, Water Aotearoa (LAWA) – Air pollutants – particulate matter (https://www.lawa.org.nz/learn/factsheets/air-quality-topic/air-pollutants-particulate-matter)

such as coal, gas, and oil, especially in vehicles and industrial processes. Most of the NO_X emissions from combustion come in the form of NO (95%) with a smaller fraction emitted directly as NO_2 (5%). However, ambient concentrations of NO are typically much lower than those of NO_2. This is because, once in the air, NO reacts with chemicals in the atmosphere and transforms into NO_2 (World Health Organization 2021).

The main sources of NO_X in Auckland are motor vehicles, industrial activities, and domestic heating (Boamponsem et al. 2024). These gases can have significant health effects, particularly on the respiratory system. Short-term exposure to high concentrations of NO_2 can cause decreased lung function, increased airway responsiveness, and inflammation of the airways. Long-term exposure is associated with respiratory and cardiovascular diseases, aggravating asthma and causing premature death. In addition to health effects, NOx can also impact the environment by forming secondary particles called nitrates, which cause brown haze and reduce visibility (Salmond et al. 2016).

2.2.3 Sulphur dioxide

Sulphur dioxide (SO_2) is gas with a pungent odour that is primarily produced by the burning of fuels with high levels of sulphur such as used to be the case with diesel and petrol. According to the latest air pollutants emission inventory, the main sources of SO_2 in Auckland are marine transport and industrial activities (Xie et al. 2019).

At present there are two sites monitoring SO_2, namely Customs Street and Penrose. The former focuses on the impact of marine activities while the second one targets industrial processes.

2.2.4 Carbon monoxide

Carbon monoxide (CO) is a colourless, odourless, and tasteless gas that can be harmful when inhaled. It is produced by the incomplete combustion of fuels, such as petrol in cars, and wood in home heating. The primary sources of carbon monoxide in Auckland are motor vehicles, domestic heating, and industrial activities. For many years, CO was of concern for Auckland but with the improvements in vehicle emission control technologies (catalytic converters), concentrations have dropped significantly, so this pollutant is now only monitored in one site as an indicator for the city's traffic fleet.

2.2.5 Ozone

Ozone (O_3) is a gas, and it is found in two different areas of the atmosphere. In the upper layers of the atmosphere, known as the stratosphere, ozone forms the ozone layer, which protects the Earth from harmful ultraviolet (UV) rays. However, at ground level, ozone is a pollutant that can have adverse effects on health and the environment (World Health Organization 2021).

Ground-level ozone is not emitted directly into the air, but it is formed through chemical reactions between nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the presence of sunlight. These reactions often produce photochemical smog, which is common in urban areas with high traffic and industrial activities, as well as locations impacted by bushfires (Jaffe and Wigder 2012; McClure and Jaffe 2018).

The primary sources of ozone precursors in Auckland are motor vehicle emissions and industrial activities. In Auckland, ozone is monitored at one site and concentrations are at their highest during the summer months. Studies have identified an impact of Australian bushfires, that are also more frequent in summer, on ozone formation downwind of the events (Adeeb and Shooter 2004; Bègue et al. 2021; Zhang et al. 2021). Further research is required to quantify the impact of these sources in the ozone concentrations in Auckland, however, current monitoring shows no significantly high concentrations.

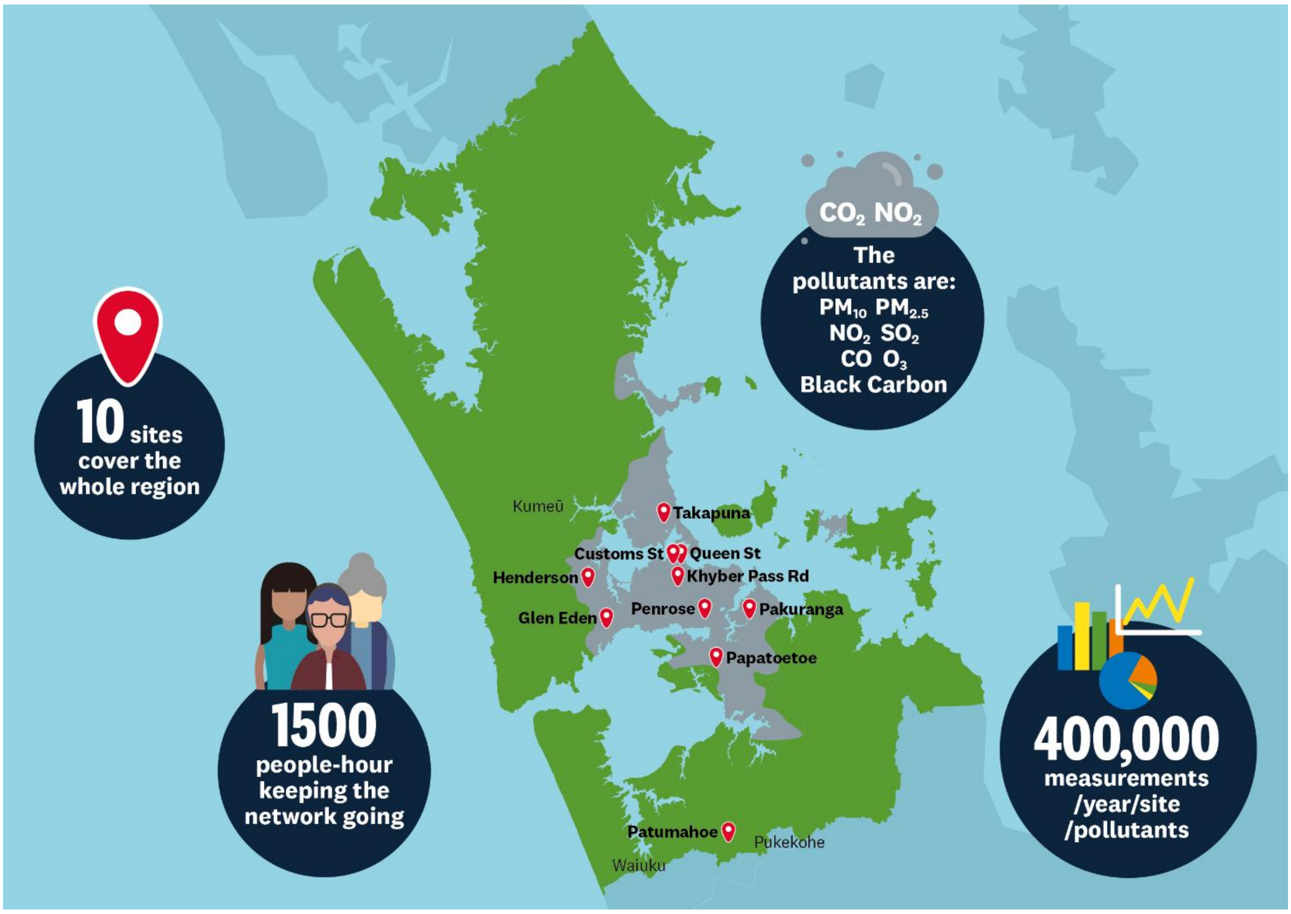
2.2.6 BTEX

BTEX refers to a group of volatile organic compounds (VOC) that includes **b**enzene, **t**oluene, **e**thylbenzene, and **x**ylenes. These compounds are commonly found in vehicle emissions and industrial processes. In Auckland, BTEX pollution is primarily associated with traffic emissions, particularly in areas with high traffic density. Benzene, one of the most harmful BTEX compounds, is a known human carcinogen and can cause serious health issues such as leukaemia and other blood disorders. Monitoring data from Auckland has shown that benzene concentrations are generally below levels of concern for human health, but there have been instances of elevated levels in areas with heavy traffic. BTEX and other VOC are monitored at Penrose as an indicator for the city by focusing on industrial and traffic sources.

2.2.7 Lead

Lead (Pb) is a highly toxic element that can have severe health effects, particularly on the neurological development of children (Pardo et al. 2015). Since the removal of lead from petrol in New Zealand in 1996, lead pollution is primarily associated with particulate matter in the air, often originating from the burning of lead-painted timber and other sources (Boamponsem et al. 2025). Monitoring data has shown that lead concentrations in Auckland's air are generally low, but there have been instances of higher concentrations during winter months due to increased burning of lead-painted timber. Lead is monitored in the TSP particulate fraction at Penrose.

2.3 Air quality management in Auckland



In New Zealand, outdoor air quality is monitored and managed by regional councils, within designated air quality management areas known as Airsheds. These Airsheds are formally identified by regional councils and publicly notified by the Ministry for the Environment (MfE). Under the Resource Management Act 1991 (RMA), regional councils are responsible for overseeing air quality within their jurisdictions.

The National Environmental Standards for Air Quality (NESAQ), established under the RMA, set mandatory requirements that include:

- Ambient air quality standards for PM_{10}, nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), and ozone (O_3) to safeguard human health (Table 1).
- Obligations for regional councils to monitor air quality where there is a risk of exceeding these standards within an Airshed.
- A classification of an Airshed as "polluted" if the PM_{10} standard is exceeded more than once in a 12-month period.
- A provision that an Airshed is no longer considered polluted if the PM_{10} standard has not been breached for five consecutive years.

Based on these criteria, the Auckland Urban Area is currently not classified as a polluted Airshed.

Table 1. National Environmental Standards for Air Quality

Pollutant	Standard Concentration	Standard Averaging Period	Allowable exceedances per year
Carbon monoxide (CO)	10 µg/m^3	8-hour	1
Particles smaller than 10 micrometres (PM_{10})	50 µg/m^3	24-hour	1
Nitrogen dioxide (NO_2)	200 µg/m^3	1-hour	9
Sulphur dioxide (SO_2)	350 µg/m^3	1-hour	9
Sulphur dioxide (SO_2)	570 µg/m^3	1-hour	0
Ozone (O_3)	150 µg/m^3	1-hour	0

Additional ambient air quality targets are outlined in the Auckland Unitary Plan Operative in Part[4] (Table 2). The Plan's objectives and policies require Auckland Council to consider these targets to reduce potential health risks. These targets generally align with the World Health Organization's 2013 guidelines and cover a wide range of hazardous air pollutants, including those regulated under the National Environmental Standards for Air Quality (NESAQ), but with varying averaging periods.

Table 2. Ambient air quality guidelines relevant to this report (Auckland Unitary Plan Operative in Part)[5]

Pollutant	Target	Averaging Time
Particles smaller than 10 micrometres (PM_{10})	20 µg/m^3	Annual
Particles smaller than 2.5 micrometres ($PM_{2.5}$)	25 µg/m^3	24-hour
Particles smaller than 2.5 micrometres ($PM_{2.5}$)	10 µg/m^3	Annual
Nitrogen dioxide (NO_2)	100 µg/m^3	24-hour
Nitrogen dioxide (NO_2)	40 µg/m^3	Annual
Carbon monoxide (CO)	30 µg/m^3	1-hour

[4] https://unitaryplan.aucklandcouncil.govt.nz/index.html
[5] https://unitaryplan.aucklandcouncil.govt.nz/index.html

3 Methods

3.1 Analysis period

The analysis period for this report spans from 2015 to 2024, with a particular focus on the years since 2019. The extended timeframe allows for the analysis of long-term changes in the quality of the air in Auckland, while the more recent period gives us insights into whether those long-term trends are continuing.

This timeframe includes two major events that significantly influenced how people move around the city. First, the City Rail Link (CRL) project has reshaped the Central Business District (CBD), especially in terms of traffic flow and pedestrian movement as construction limited access to parts of the CBD. Construction began in 2017, and tunnel testing started in mid-2025. Second, the COVID-19 pandemic, along with the public health measures introduced between 2020 and 2022, had a major impact on mobility. These changes led to a shift in commuting patterns, with more people working from home and fewer traveling into the city.

3.2 Data availability

Auckland's real-time air quality monitoring network is operated by Watercare Services Limited. Data are captured from the instruments by Kisters[6] dataloggers and sent to a Hydstra[7] database for real time access and an Aquisnet[8] database for quality control. Once data have been quality assured, they are transferred to our long-term storage database, another instance of Aquisnet. Figure 3 shows the location of the monitoring stations in Auckland.

[6] https://www.kisters.eu/
[7] https://www.kisters.com.au/product/hydstra/
[8] https://www.kisters.net/aquisnet/

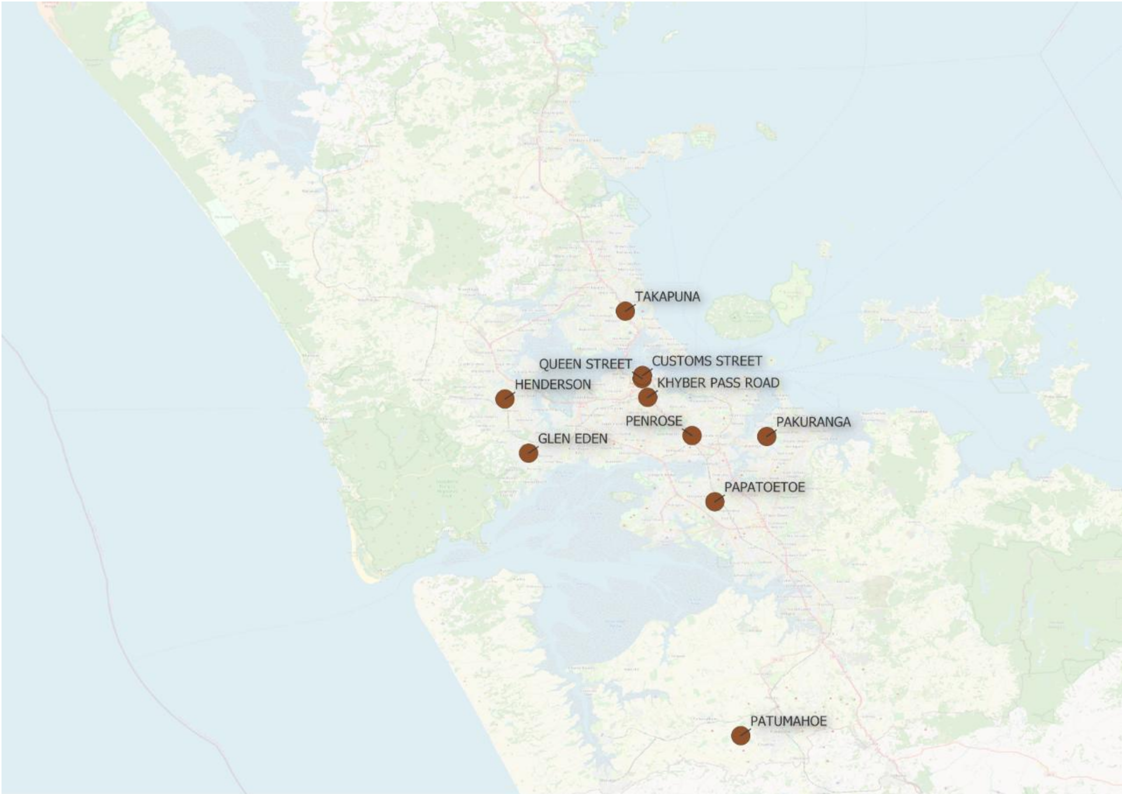


Figure 3. Map of the current permanent air quality monitoring network in Auckland.

Table 3 shows the coverage of hourly data for each site and parameter between January 2019 and December 2024. Most sites have data covering more than 90% of the period, except a few that correspond to specific issues:

- Customs Street: The site started its operations in January 2020, which explains the 80% data capture for most parameters, while for $PM_{2.5}$, the instrument was not available between August 2021 and February 2022.
- Pakuranga: The $PM_{2.5}$ monitor malfunctioned between August 2021 and January 2022, and again during April 2022.
- Khyber Pass: The site was not available between February 2015 and September 2019.
- Queen Street: The site was unavailable due to building works from August 2023.

All data used in this report are available through Auckland Council's environmental data portal[9].

[9] https://environmentauckland.org.nz/

Table 3. Data coverage for each parameter at all permanent monitoring sites. The percentages correspond to the fraction of hours with valid data, from the total hours for the period between January 1st, 2019, to December 31st, 2024. The values underlined correspond to parameters where the hourly data availability is below 90%. See the text for more information.

Site	Black Carbon	NO_2	PM_{10}	$PM_{2.5}$	SO_2	CO	O_3
Customs Street	**80 %**	**80 %**		**72 %**	**81 %**		
Glen Eden		95 %	98 %	**85 %**			
Henderson	98 %	98 %	97 %				
Khyber Pass		**87 %**	**86 %**			**87 %**	
Pakuranga			99 %	**72 %**			
Papatoetoe			98 %				
Patumahoe		94 %	95 %	90 %			93 %
Penrose		95 %	98 %	92 %	96 %		
Queen Street		**74 %**	**76 %**	**76 %**			
Takapuna		96 %	97 %	94 %			

3.3 Data analysis

Data analysis was conducted using the scientific software R (R Core Team 2024) for which a number of packages are available for specific analytical methods such as the Openair package (Carslaw and Ropkins 2012). The Openair package is specifically designed for ambient air quality data analysis and is freely available from the Comprehensive R Archive Network (CRAN) (http://www.cran.r-project.org). The scripts used to generate the statistics and graphs presented in this report are available on request from the Environmental Data Team[10].

To establish the long-term trend of air quality and identify what changes are occurring, the trends of the pollutant concentrations over time have been analysed to assess if changes in the observed concentrations are within the expected uncertainty or are the result of changes in air pollution across the region. The method used in this report follows the one used by Stats NZ and the Ministry for the Environment in their environmental reporting series (Ministry for the Environment and Stats NZ 2025). This method uses the Theil-Sen technique (Theil 1992; Sen 1968), which, in simple terms, tries to obtain an estimate of the long term trend, reducing the impact of outliers and seasonal variations. This technique allows us to robustly estimate the long-term trends in the quality of Auckland's air. See Appendix A for more details on this analytical technique.

PM_{10} and $PM_{2.5}$ source contributions are detailed in elemental analysis carried out since 2006 across the Auckland network (Boamponsem et al. 2025; 2024). The results of these analyses are referenced where relevant, to explore the causes of observed trends.

[10] environmentaldata@aklc.govt.nz

4 Results

4.1 Regional summary

The Auckland region spans nearly 4,400 km^2, yet only 10 monitoring sites are currently in operation. With more than 13% of the region classified as urban (about 500 km^2), the coverage of our network is limited, which makes it difficult to fully characterise air quality across the landscape – particularly in areas earmarked for future growth such as Dairy Flat, Westgate, New Lynn, Mangere or Drury (Auckland Council 2023; 2024) where monitoring is often sparse or absent (Figure 4). Despite these limitations, Auckland's air quality monitoring network has been shown to compare well with similar urban areas across the world (Petersen and Gillies 2014). Changes to the network in the past decade have reduced the number of sites but it still provides very useful information about the impact of the region's emissions, helping us formulate the right policies to reduce the population exposure to air pollutants.

Overall, air quality in Auckland is generally good in most places for most of the year. However, there are still locations and periods when air pollution becomes a significant concern for Aucklanders. These fluctuations reflect the complexity of Auckland's geography, the uneven spread of emission sources across the region and the varied weather patterns that we experience.

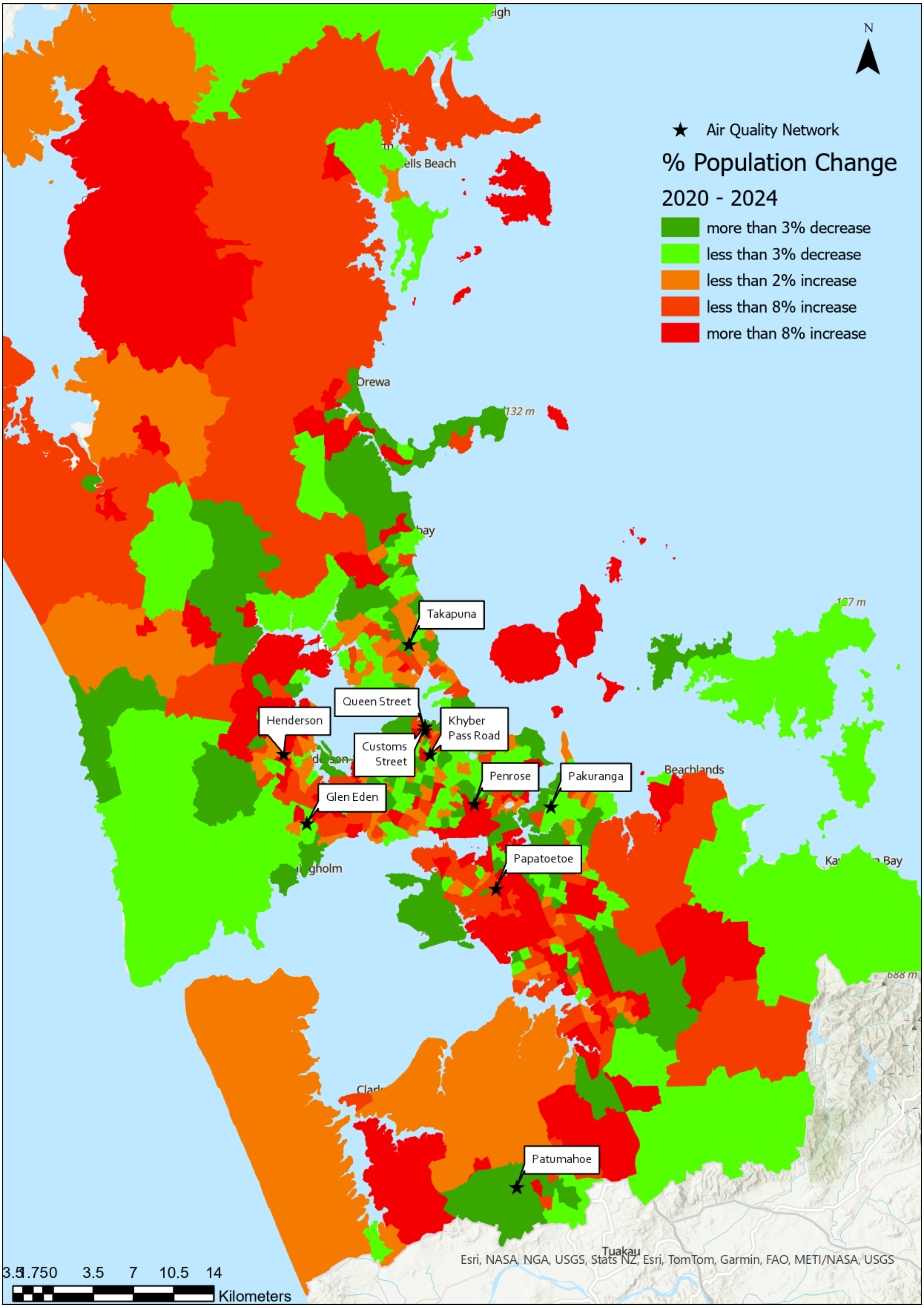


Figure 4. Location of the air quality monitoring stations in Auckland, overlaid with the population growth over the last five years, to highlight the growth areas where there is limited monitoring.

There has been notable progress though. The last recorded breach of any National Environmental Standards for air quality (NES-AQ) occurred in June 2022, when one of the central city monitors detected an exceedance of the NO_2 1-hour standard. This was likely caused by a large diesel generator operating near the site. In contrast, Auckland reported more than 10 days above the PM_{10} 24-hour standard in 2009 and more than 1000 hours above the NO_2 hourly standard in 2011.

In terms of Auckland air quality guidelines, the $PM_{2.5}$ 1-hour guideline hasn't been exceeded since 2022 and the $PM_{2.5}$ annual guideline hasn't been exceeded since records began in 2019. For NO_2, the only guideline that has been exceeded after 2022 is the 1-hour one, which is half the NES-AQ limit, with high concentrations observed once or twice during winter at Khyber Pass Rd and Customs Street sites.

More detailed description of the observations at each monitoring site can be found in the appendix section of this report but Table 4 shows the 5- and 10-year long-term trends for each site across the region for the main pollutants. For the main pollutants (PM_{10}, $PM_{2.5}$, NO_2), concentrations have generally declined over time, but the pace of improvement has slowed in recent years and even reversed in some sites. This suggests that while past interventions have been effective, we need to review and adapt our management strategies to the changes in the city.

Table 4. Long-term trends (10 and 5 years) for all pollutants across the monitoring network. The trends are obtained through a deseasonalised Theil-Sen trend analysis. Expressed as average year-on-year percentage change. Orange shaded cells indicate worsening of air quality, green shaded cells indicate improvement, and light blue shaded ones indicate no change. A dash indicates no data. More detailed information about each site can be found in the appendix section of this report.

Site	PM_{10}		$PM_{2.5}$		NO_2		BC		SO_2		CO		O_3	
	10 yr	5 yr	10 yr	5 yr	10 yr	5 yr	10 yr	5 yr	10 yr	5 yr	10 yr	5 yr	10 yr	5 yr
Auckland	0%	2%	0%	2%	-3%	-9%	2%	0%	6%	16%	-3%	-5%	0%	0%
Glen Eden	-1%	-1%	-4%	0%	-3%	3%	-	-	-	-	-	-	-	-
Henderson	-1%	0%	-	-	-3%	0%	-9%	-8%	-	-	-	-	-	-
Khyber Pass	2%	8%	-	-	0%	-5%	-	-	-	-	-3%	-5%	-	-
Pakuranga	-2%	5%	-	0%	-	-	-	-	-	-	-	-	-	-
Papatoetoe	0%	0%	-	-	-	-	-	-	-	-	-	-	-	-
Patumahoe	-1%	-4%	3%	6%	0%	5%	-	-	-	-	-	-	0%	0%
Penrose	0%	4%	-2%	0%	-4%	-5%	-	-	0%	31%	-	-	-	-
Queen Street	3%	7%	3%	9%	-5%	-20%	-	-	-	-	-	-	-	-
Takapuna	0%	6%	0%	1%	-4%	3%	-	-	-	-	-	-	-	-
Customs Street	-	-	-	-5%	-	-17%	-	0%	-	13%	-	-	-	-

As the trend summaries indicate, air quality is not uniform across the Auckland region. Areas with high traffic experience higher concentrations of traffic related air pollutants, residential areas are more impacted by domestic wood combustion, and industrial areas have more complex mixtures of pollutants.

Unfortunately, the sparseness of the data prevents us from generating spatial distribution maps based on these measurements, but **Figure 5**, **Figure 6** and **Figure 7** illustrate this variability for NO_2, PM_{10} and $PM_{2.5}$ respectively. In general, sites with significant traffic sources nearby (Customs St, Queen St and Khyber Pass) report higher concentrations of traffic pollutants (NO_2) but also stronger downward trends. In contrast, urban background sites like Glen Eden and Patumahoe report much lower concentrations but also a much weaker long-term trend.

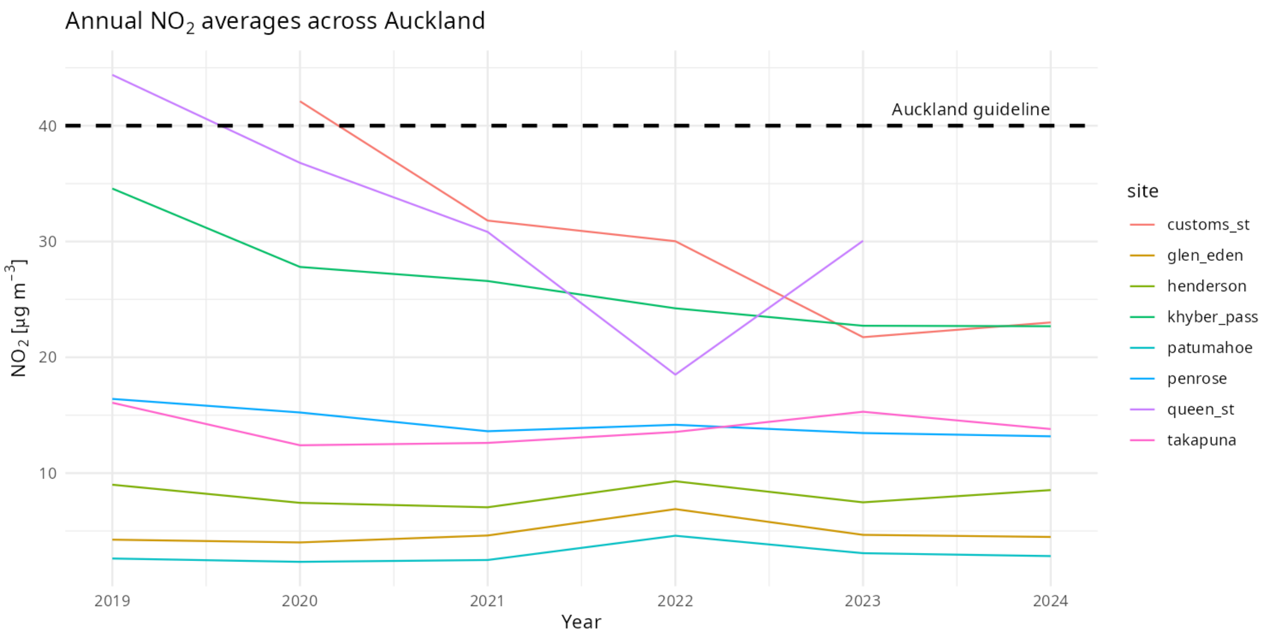


Figure 5. Timeseries of NO_2 annual averages at all monitoring sites in the region since Jan 2020. The Auckland annual air quality guideline is included for context (dashed).

Queen Street has recorded PM_{10} and $PM_{2.5}$ concentrations significantly higher than the rest of the sites, but unfortunately, it has a truncated record after 2023 (**Figure 6** and **Figure 7**). Data availability was compromised because the building where the site is located underwent significant renovation starting in August 2023 which meant that the site was inaccessible until early 2025. In terms of the high PM_{10} concentrations, these seem to be related to the significant construction activity in the city centre that has attracted an increased number of heavy vehicles to the area, as well as released coarse dust into the air. For a more detailed discussion, refer to the case study in Section 5 in this report – "City Centre: A mixed bag of news".

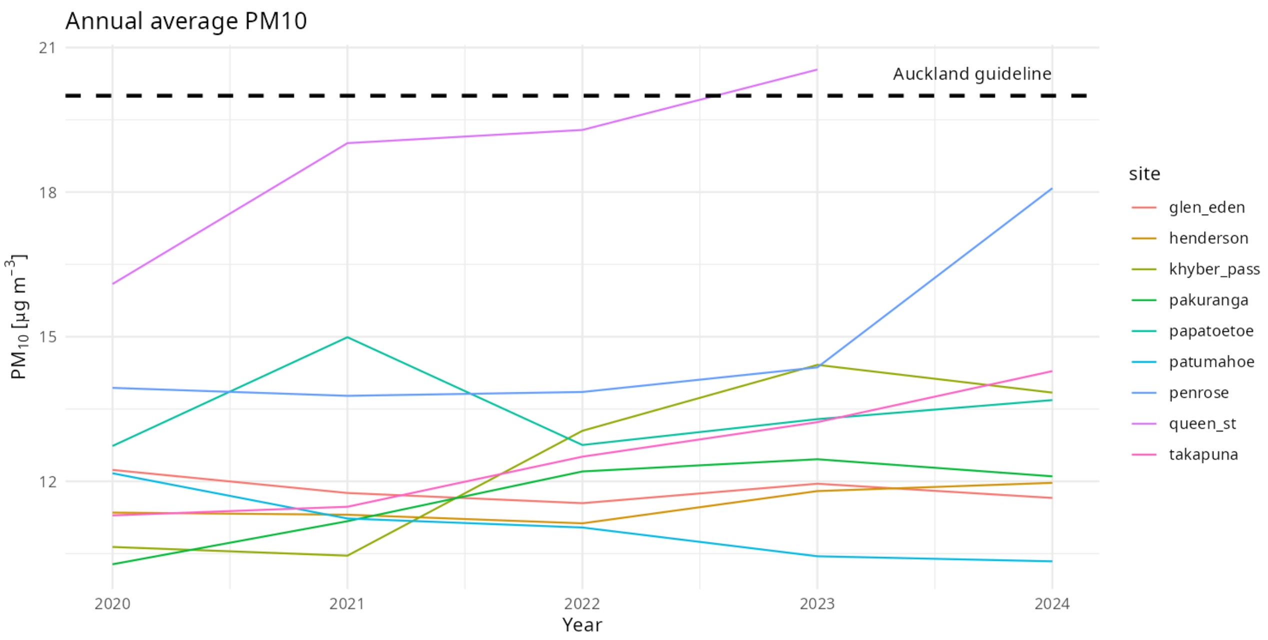


Figure 6. Timeseries of PM_{10} annual averages at all monitoring sites in the region since Jan 2020. The Auckland annual air quality guideline is included for context (dashed).

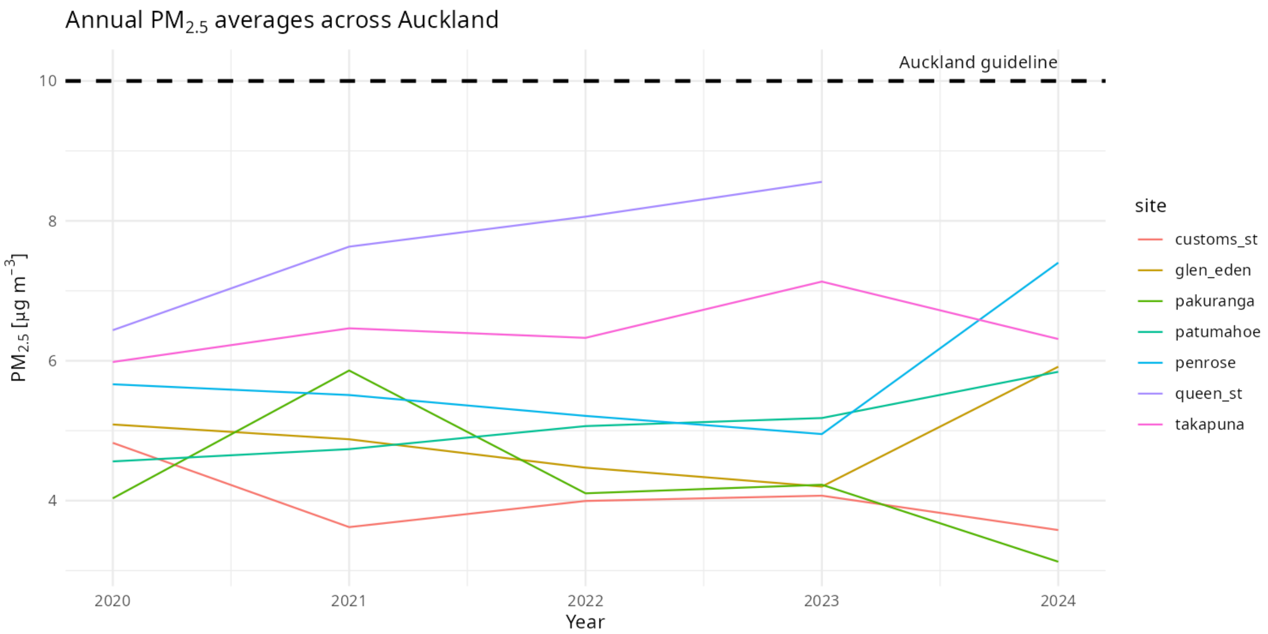


Figure 7. Timeseries of $PM_{2.5}$ annual averages at all monitoring sites in the region since Jan 2020. The Auckland annual air quality guideline is included for context (dashed).

4.2 Seasonal overview

The quality of our air changes throughout the year, shaped by both human activities – like driving and heating our homes – and by seasonal weather patterns. These patterns have remained relatively consistent over time, offering a predictable rhythm to air quality trends across the year.

Figure 8, Figure 9 Figure 9 and Figure 10 illustrate the seasonal patterns of NO_2, PM_{10} and $PM_{2.5}$ across the region. Note that there is very little seasonality in the PM_{10} concentrations averaged across the region which indicates that the main drivers of PM_{10} pollution are sources that don't show a strong seasonal pattern, like natural sources such as sea spray and resuspended dust. This has been confirmed by the source apportionment programme (Boamponsem et al. 2025; 2024) that indicates that sea spray and soil account for more than 50% of the PM_{10}.

For $PM_{2.5}$ and NO_2 the seasonal differences are more evident. During winter, air pollution levels tend to be higher. This is largely due to two factors: the atmosphere is often more stable and still, which limits the dispersion of pollutants, and there are additional combustion sources in use for heating, such as wood burners. Cold, calm nights can trap emissions close to the ground, leading to concentrations of pollutants building up to high levels.

In contrast, summer generally brings lower pollution levels. Warmer temperatures and more dynamic weather conditions – such as wind and atmospheric instability – help disperse pollutants more effectively. Also, there are generally fewer emissions from heating, contributing to cleaner air overall.

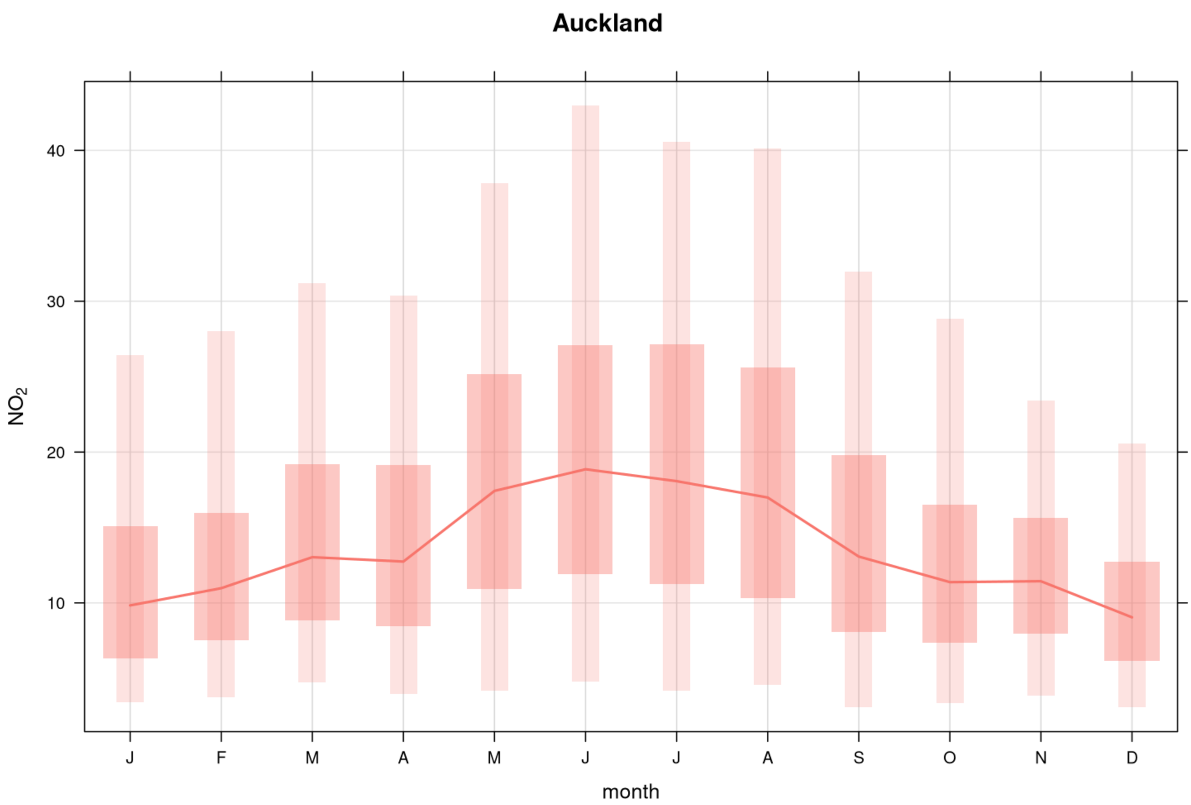


Figure 8. Seasonal variation of NO_2 ($\mu g\ m^{-3}$) across Auckland. The solid line corresponds to the median monthly value, across the network, for the period 2020-2024. The dark and light shading show the 25th – 75th and 5th – 95th percentile ranges, respectively.

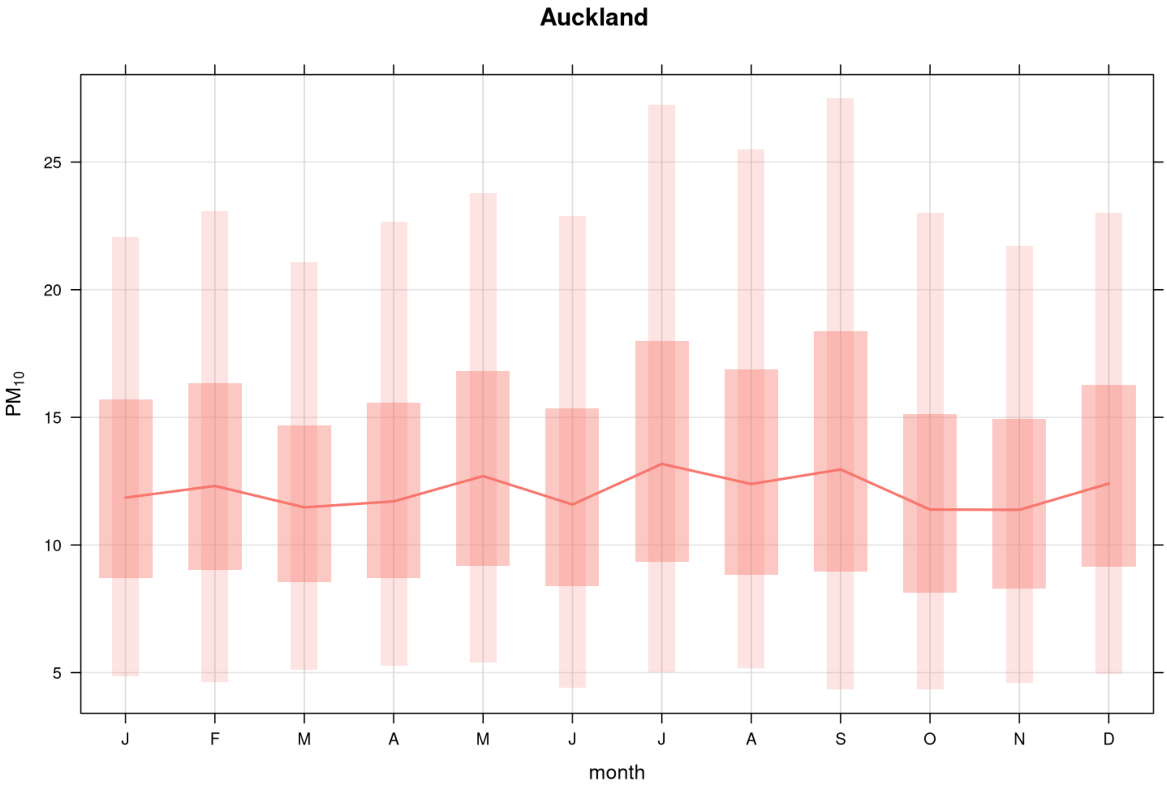


Figure 9. Seasonal variation of PM_{10} ($\mu g\ m^{-3}$) across Auckland. The solid line corresponds to the median monthly value, across the network, for the period 2020-2024. The dark and light shading show the 25th – 75th and 5th – 95th percentile ranges, respectively.

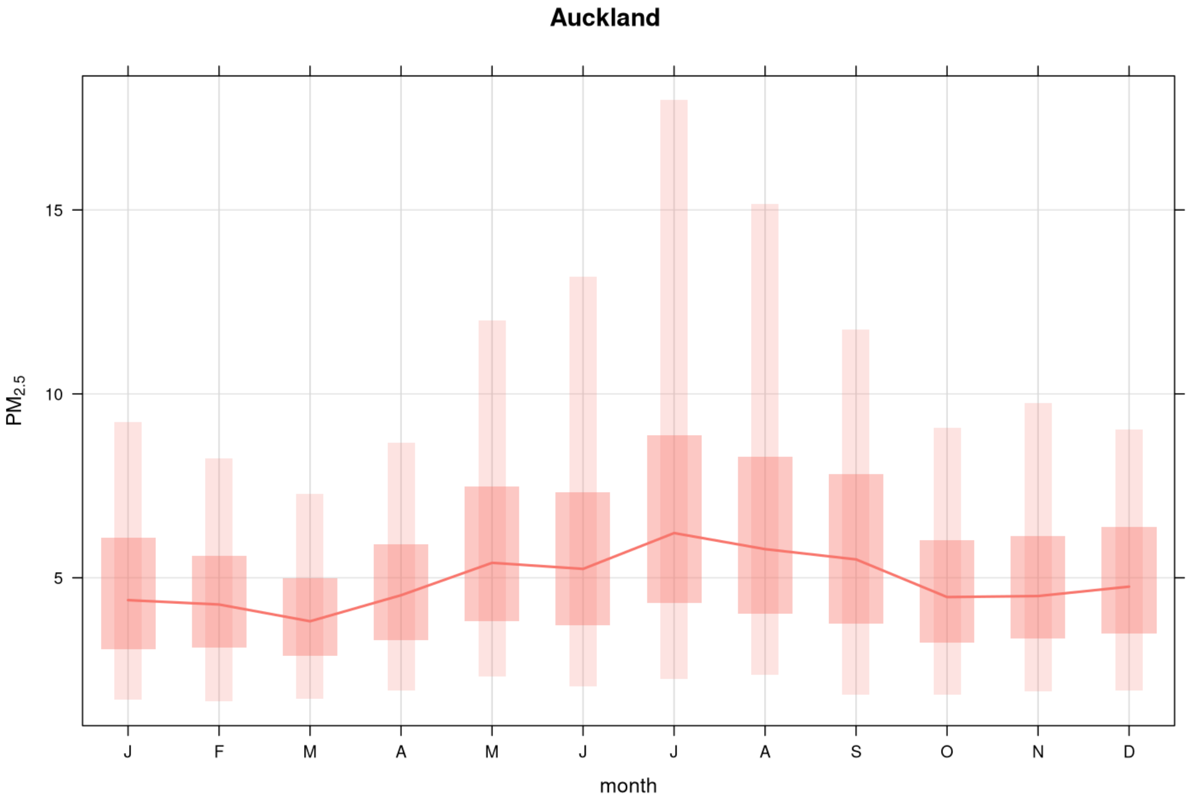


Figure 10. Seasonal variation of $PM_{2.5}$ ($\mu g\ m^{-3}$) across Auckland. The solid line corresponds to the median monthly value, across the network, for the period 2020-2024. The dark and light shading show the 25th – 75th and 5th – 95th percentile ranges, respectively.

4.3 Individual pollutants

4.3.1 PM_{10} and $PM_{2.5}$

Particulate matter (PM) is one of the most complex and variable pollutants in Auckland's air quality profile. While concentrations of PM_{10} and $PM_{2.5}$ were relatively stable between 2015 and 2020 (Talbot and Crimmins 2020), recent data shows a slow upward trend in both metrics.

The Khyber Pass and Queen Street sites have recorded the most significant long-term increases in PM_{10} concentrations (Figure 11). These increases are likely linked to extensive construction activities in the surrounding areas, which contribute coarse dust and increase the presence of heavy vehicles.

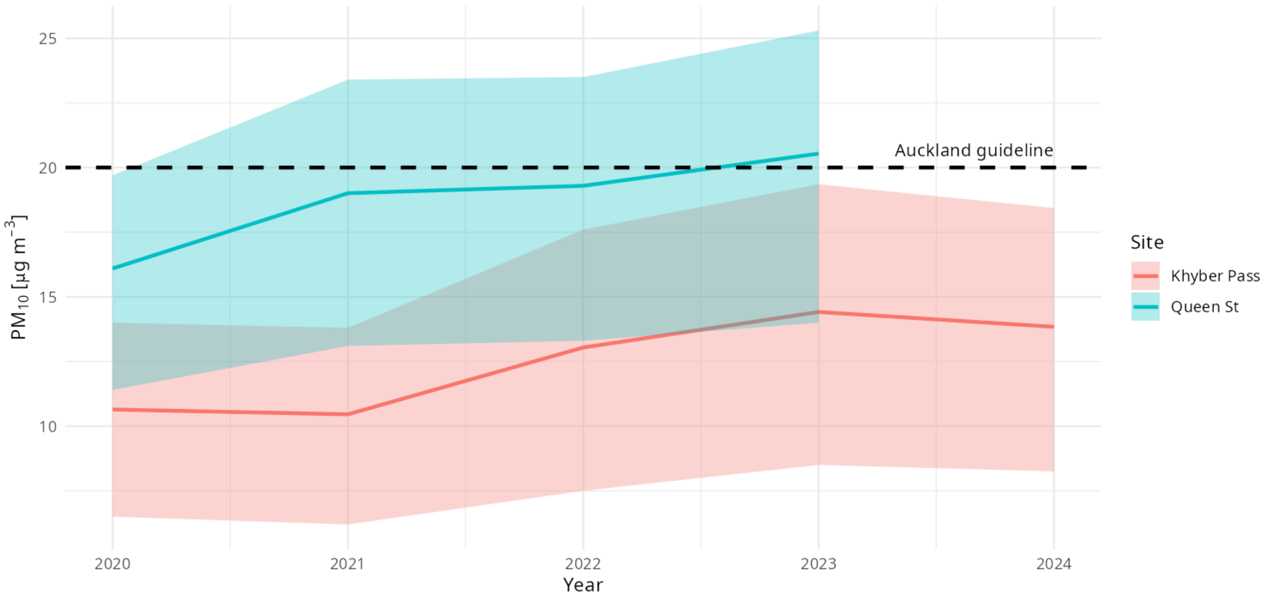


Figure 11. Annual PM_{10} time series for Khyber Pass and Queen Street sites. The solid line is the annual average and the shaded areas correspond to the 25th – 75th percentile range for each site. The Auckland annual air quality guideline is included for context (dashed).

For $PM_{2.5}$, the largest increases have been observed at Queen Street and Patumahoe (Figure 12). In the CBD, the rise is likely driven by construction-related emissions and ancillary heavy vehicle activity. In contrast, Patumahoe's increase could be associated with population growth in the area and the corresponding rise in domestic heating and vehicle use.

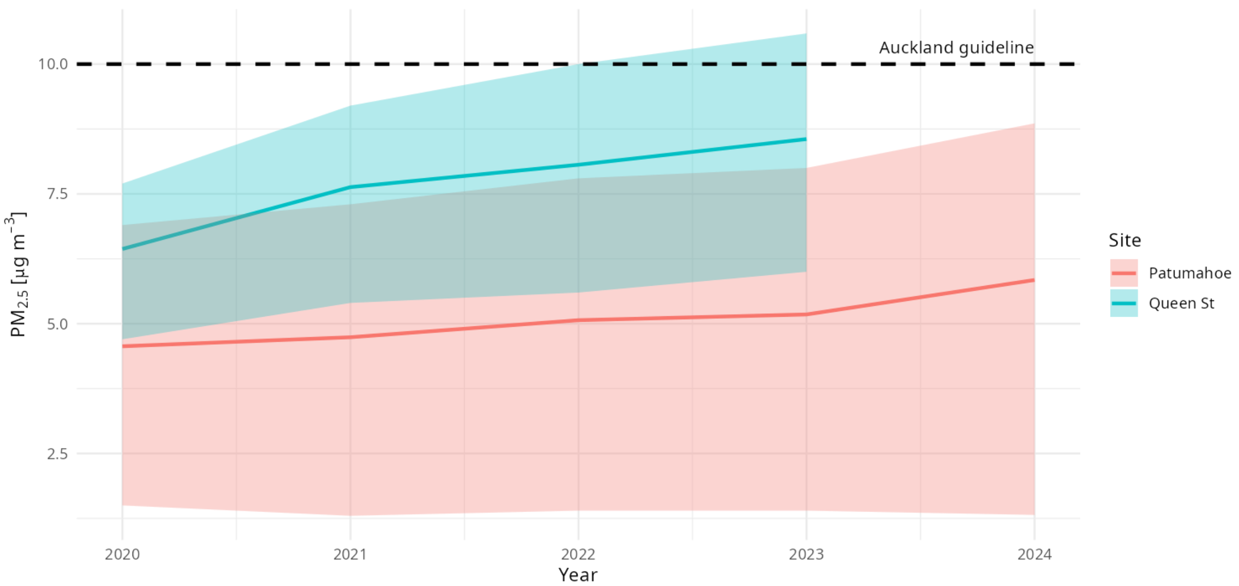


Figure 12. Annual $PM_{2.5}$ time series for Patumahoe and Queen Street sites. The solid line is the annual average and the shaded areas correspond to the 25-75 percentile range for each site. The Auckland annual air quality guideline is included for context (dashed).

Source apportionment studies (Boamponsem et al. 2024; 2025) indicate that sea salt and soil account for approximately 50% of PM_{10}, but only around 25% of $PM_{2.5}$. For $PM_{2.5}$, motor vehicles –

including non-tailpipe emissions such as brake and tyre wear – are the dominant contributors, followed by wood burning and sea spray.

4.3.2 NO_2

Nitrogen dioxide (NO_2) is a key traffic-related pollutant, and its trends across Auckland reflect the evolving nature of urban transport and population dynamics. Over the past decade, NO_2 concentrations have generally declined, driven by improvements in vehicle emission standards, increased uptake of low-emission vehicles, and a slow shift toward public and active transport modes. The most substantial reductions have occurred in the central business district (CBD), where Queen Street and Customs Street recorded decreases of approximately 20% over the past five years (Figure 13).

Penrose, an industrial and mixed-use area, has shown a consistent downward trend in NO_2 concentrations, with a 5% reduction over the past decade which is similar to other traffic impacted areas like Khyber Pass Road. In contrast, residential sites such as Glen Eden have experienced slight increases in NO_2 concentrations. These worsening trends may be linked to population growth and increased vehicle use in suburban areas and it is an issue that our monitoring programme will keep a watching brief.

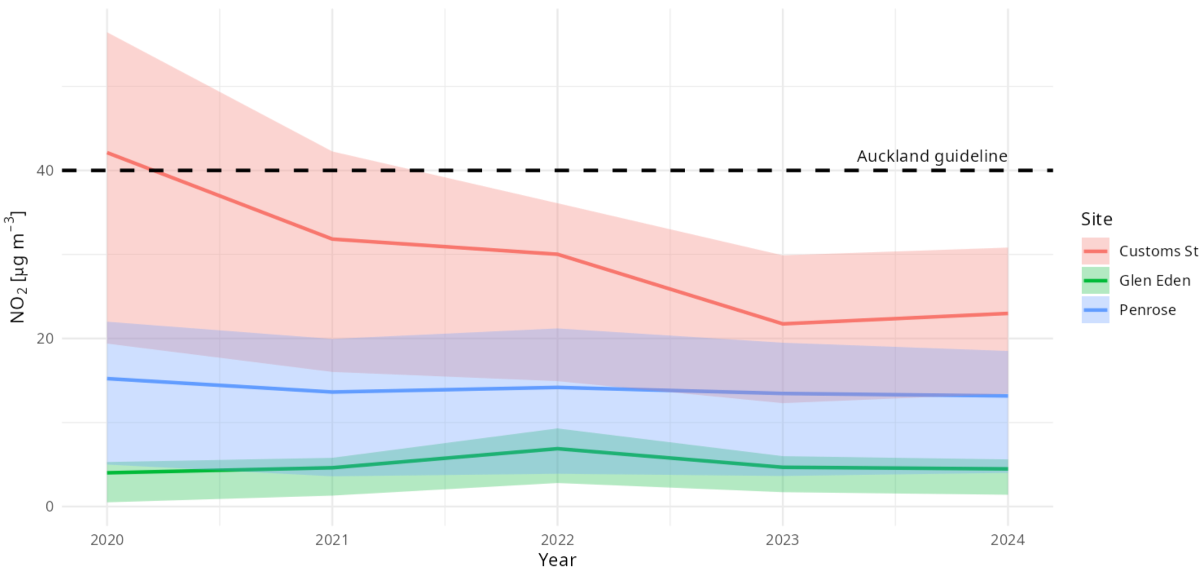


Figure 13. Annual NO_2 time series for Customs Street, Glen Eden and Penrose. The solid line is the annual average and the shaded areas correspond to the 25-75 percentile range for each site. The Auckland annual air quality guideline is included for context (dashed).

4.3.3 SO_2

Sulphur dioxide (SO_2) concentrations in Auckland have shown contrasting trends over the past five years, reflecting the influence of both regulatory changes and local industrial activity. Since early 2022, SO_2 levels at Customs Street have decreased significantly (Figure 14). This improvement is directly linked to the implementation of MARPOL Annex VI regulations, which limit the sulphur content in marine fuels used by ships in ports. As one of the purposes of the Customs Street site is to monitor the impact of port activities on the city, we expected this site to show the impact of changes in marine fuels. In contrast, SO_2 concentrations at Penrose have risen notably over the same period. This site, located in an industrial zone, is likely influenced by increased activity in manufacturing and energy production.

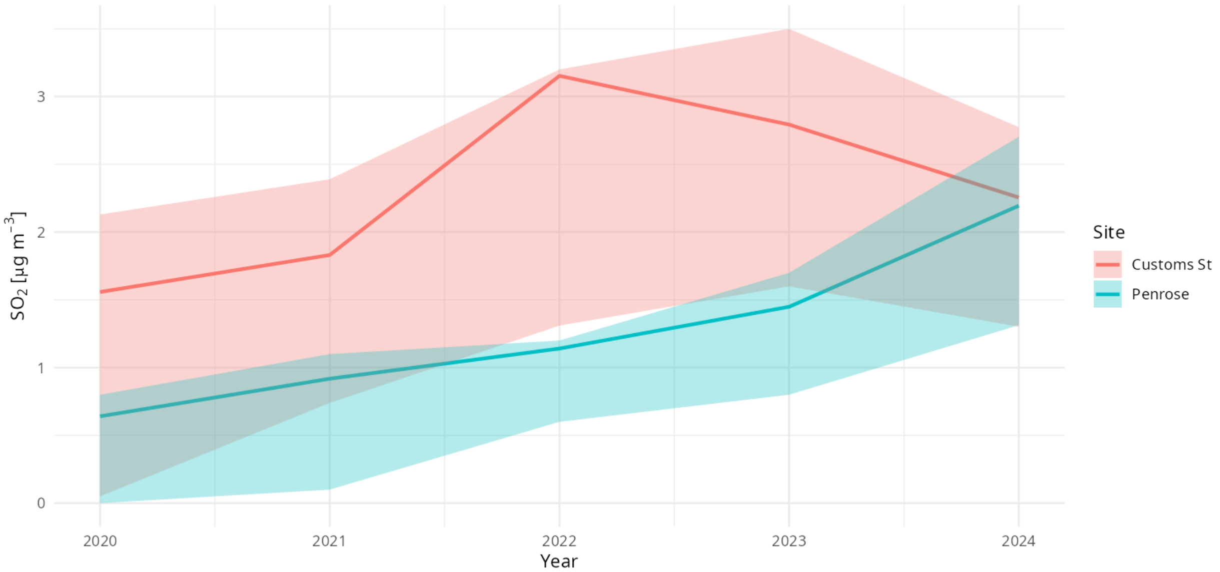


Figure 14. Annual SO_2 time series for Customs Street and Penrose sites. The solid line is the annual average and the shaded areas correspond to the 25-75 percentile range for each site.

5 Case studies

5.1 What the COVID-19 lockdowns taught us about air quality in Auckland

5.1.1 Introduction

The COVID-19 lockdowns in 2020 and 2021 were among the most significant events in Auckland in recent years. While the social and economic costs of the lockdowns were substantial, the period offered valuable insights into the impact of reduced traffic on air quality. It gave us a window into how good the air quality could be if the number of petrol and diesel vehicles was significantly reduced in the region.

It is not the purpose of this case study to evaluate the merits of the COVID-19 response but rather to highlight the significant changes in air quality during the lockdown periods and to offer insights into future air quality management.

5.1.2 Traffic reduction

The most immediate effect of the lockdown restrictions was a dramatic drop in the traffic flows observed across the region. During the Level 4 lockdowns in 2020, traffic across the Auckland harbour bridge dropped by nearly 85% (Figure 15) and throughout the region it dropped by nearly 70%, with bus trips down by almost 94%. This drastic reduction in vehicular movement led to a noticeable decrease in concentrations of traffic related air pollutants across Auckland.

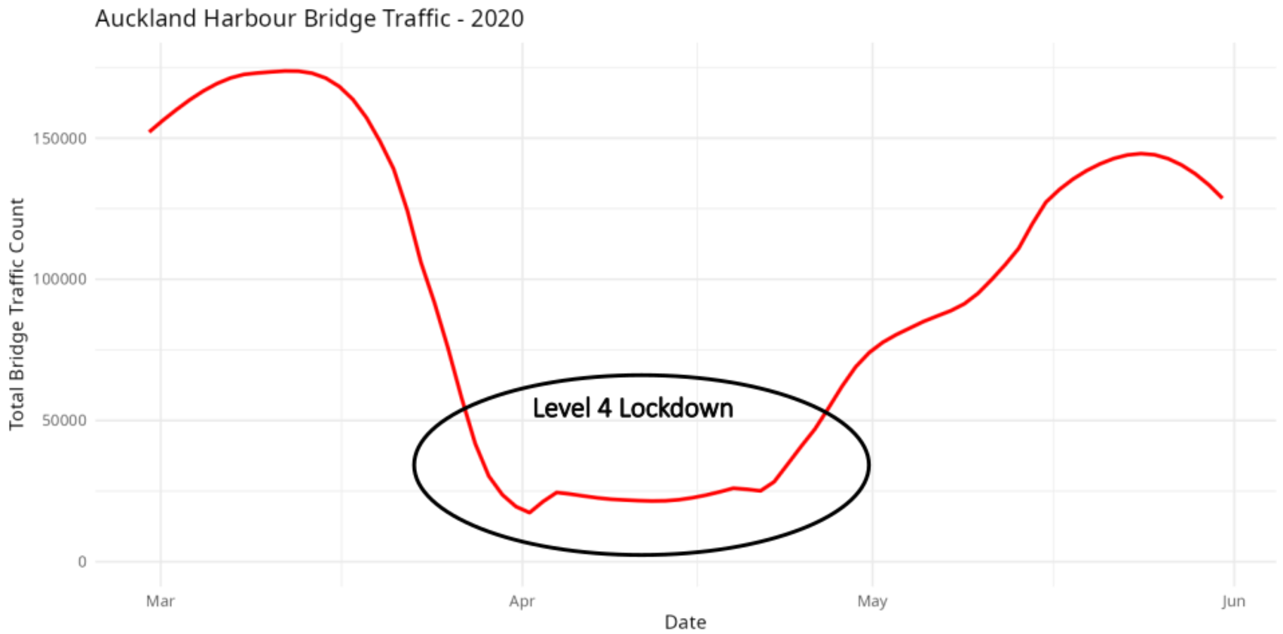


Figure 15. Daily traffic counts for the Auckland Harbour Bridge during and around the Level 4 lockdown in April 2020. Data from Waka Kotahi.

5.1.3 NO_2 concentrations

One of the most significant changes observed, as a direct result of the reduction in traffic volume, was in the levels of nitrogen dioxide (NO_2). This pollutant results from emissions released by petrol and diesel engines. Figure 16 shows that across the region, NO_2 concentrations dropped by nearly 50% but at traffic-dominated sites, such as Takapuna and Henderson, the reduction was even more pronounced, with NO_2 levels falling nearly 60%. In the city centre, NO_2 concentrations decreased by more than 30% (Patel et al. 2020; Auckland Council 2020).

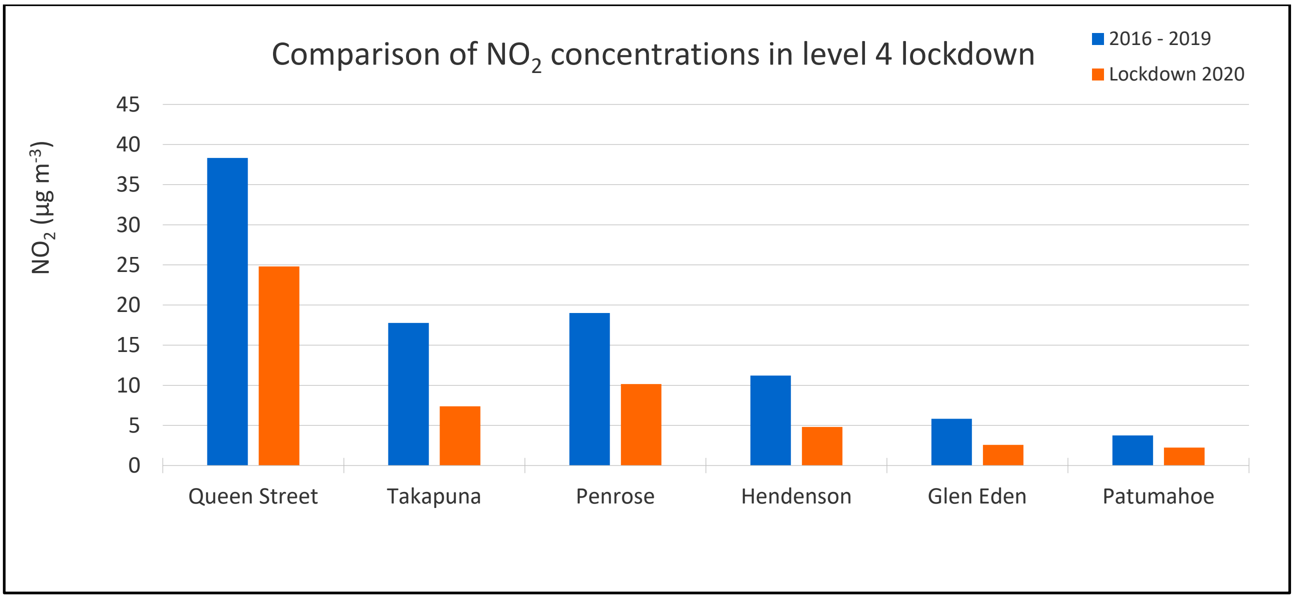


Figure 16. NO_2 concentrations averaged over the level 4 lockdown period in 2020 (26-March to 27 April), compared to the same period for the four previous years (Auckland Council 2020).

5.1.4 PM concentrations

Particulate matter (PM) also showed reductions, though less dramatic than NO_2 (Figure 17). PM_{10} concentrations saw a marginal reduction of less than 10% across the region with the largest reduction (30%) observed at the residential site of Pakuranga. $PM_{2.5}$ data was only available for Queen Street, where a decrease of only 10% was observed (Auckland Council 2020).

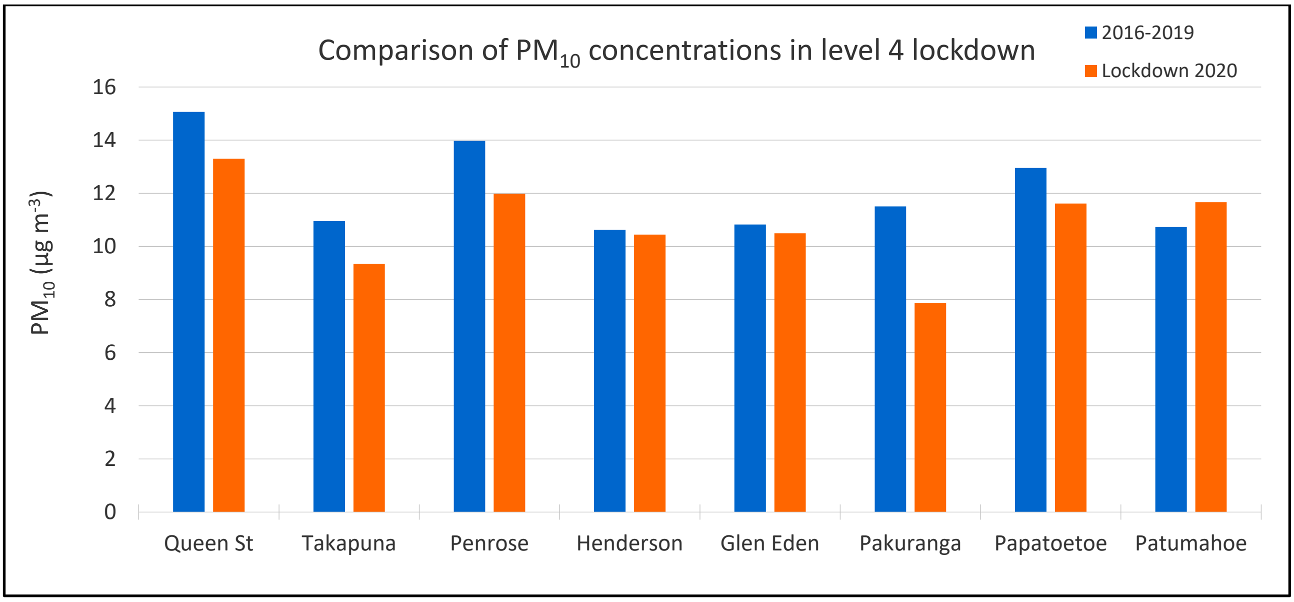
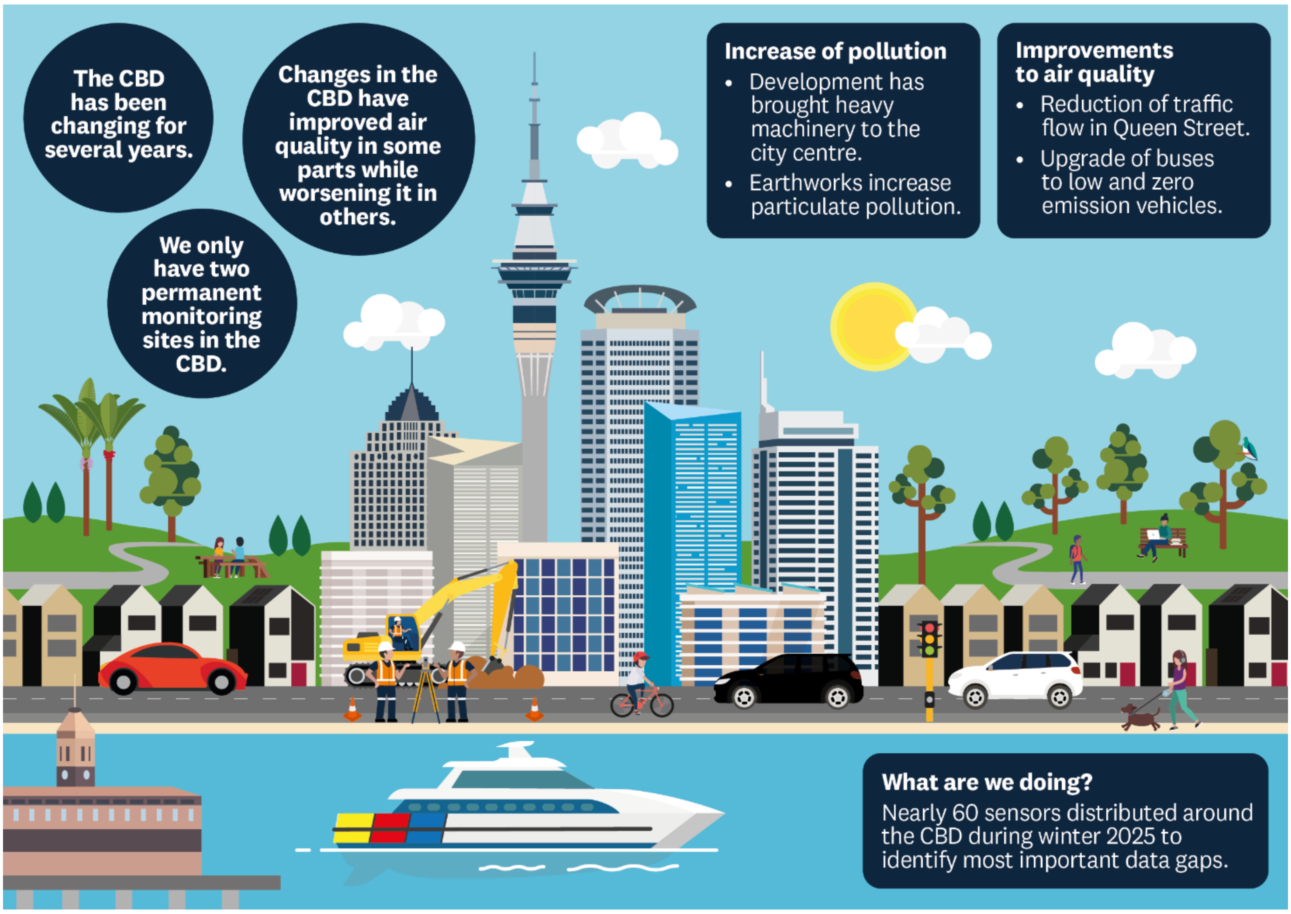


Figure 17. PM_{10} concentrations averaged over the level 4 lockdown period in 2020 (26-March to 27 April), compared to the same period for the previous four years (Auckland Council 2020).

5.1.5 Conclusion

The Level 4 lockdown demonstrated the potential for improved air quality in Auckland if traffic is significantly reduced. According to NIWA (NIWA 2020), if the current trend in NO_2 levels continues, we may only see these reduced levels again after 2030. These findings underscore the importance of sustainable traffic management and pollution control measures to achieve long-term air quality improvements.

5.2 City Centre: A mixed bag of news



5.2.1 Introduction

Auckland's city centre has evolved in the past decade, with change accelerating in the past five years; Queen Street is now a vibrant urban core with increased pedestrian activity, community events around Britomart, and Aotea Square regularly hosts events and exhibitions whilst serving as a central meeting point. The City Rail Link (CRL) development is also becoming more tangible, with Te Waihorotiu Station taking shape alongside supporting infrastructure that will enable future growth.

However, these positive changes come with environmental challenges – particularly in terms of air quality. Over the past five years, our monitoring data paints a complex picture of pollution trends in the CBD.

5.2.2 NO_2 concentrations keep dropping

Since 2020, traffic patterns along Queen Street have shifted dramatically. Lanes have been re-purposed to enable increased access for public transport and active modes, which has seen private vehicle use be significantly discouraged. Vehicle counts have halved, and the reduction in has contributed to a more breathable environment. This transformation is reflected in a nearly 50% drop in NO_2 concentrations, as recorded by our monitors on Queen Street and Customs Street (Figure 18).

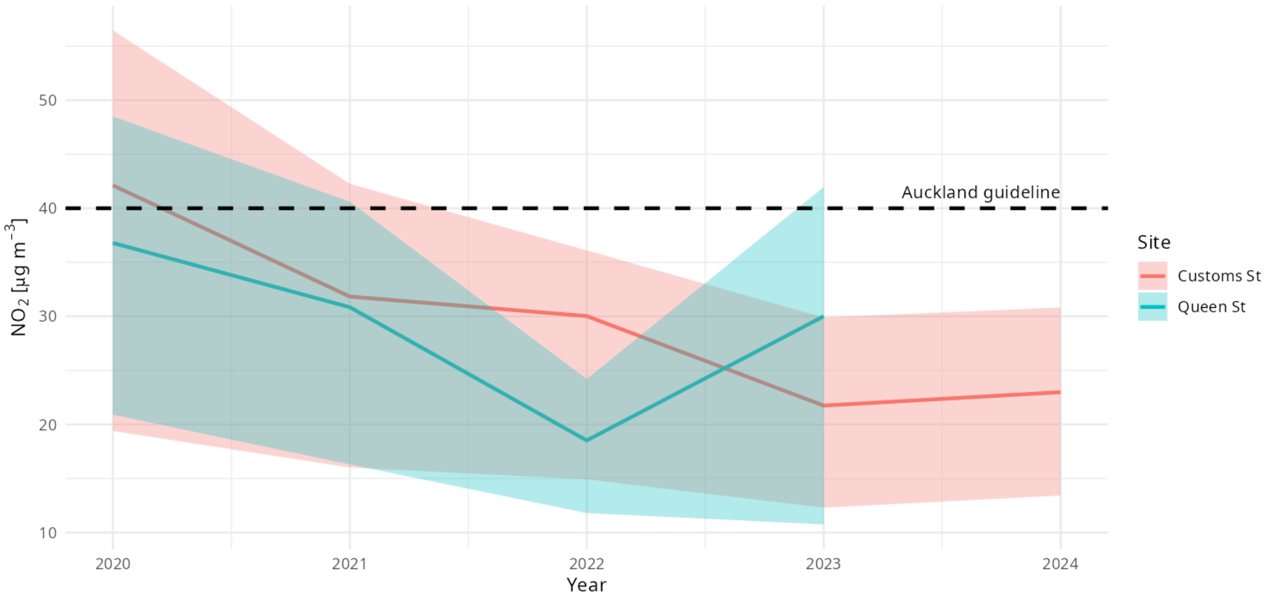


Figure 18. Annual NO_2 time series for Customs Street and Queen Street sites. The solid line is the annual average and the shaded areas correspond to the 25-75 percentile range for each site. Note that the Queen Street site was not available from August 2023, hence the last valid annual average is for 2022. The Auckland annual air quality guideline is included for context (dashed).

5.2.3 Temporary challenges

While urban development brings long-term benefits, it also introduces short-term air quality issues. Construction projects – essential for Auckland's growth – generate emissions from diesel machinery and earthworks. These activities have led to increased particulate matter (PM) levels at the Queen Street monitoring site over the past two years (Figure 19).

Fortunately, this impact appears to be highly localised. Customs Street, only a couple hundred metres from the Queen Street site, and less affected by construction, has shown a consistent decline in PM concentrations (Figure 19). This contrast gives us confidence that the elevated PM levels at Queen Street are temporary and site-specific.

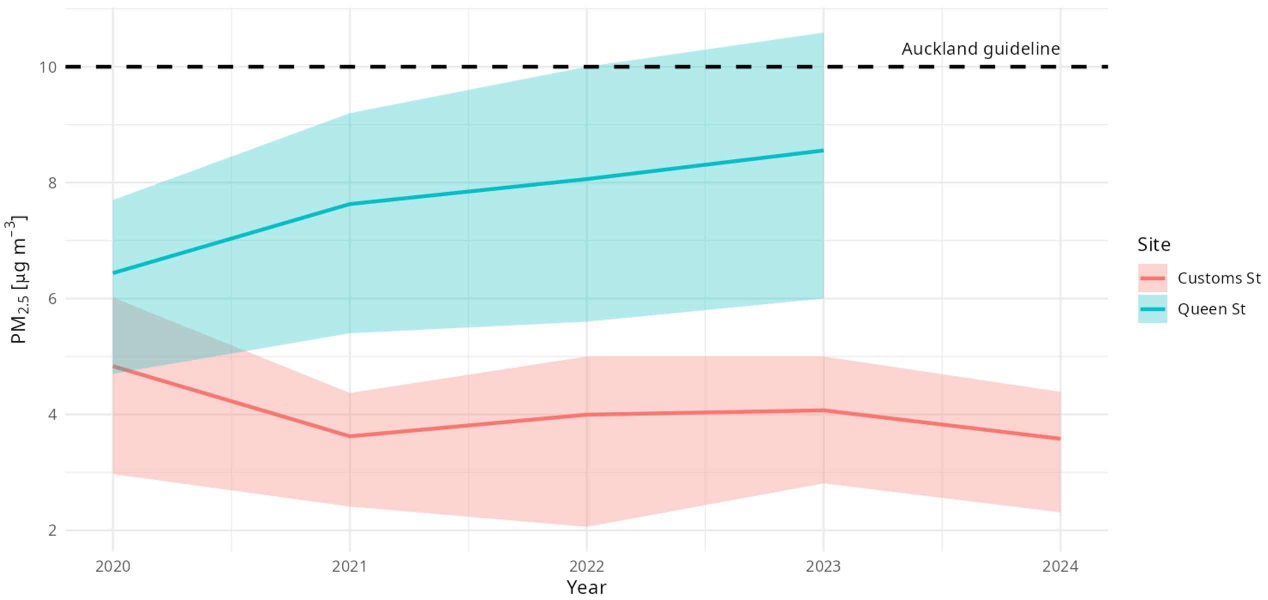


Figure 19. Annual $PM_{2.5}$ time series for Customs Street and Queen Street sites. The solid line is the annual average and the shaded areas correspond to the 25-75 percentile range for each site. The Auckland annual air quality guideline is included for context (dashed).

5.2.4 A success story in SO_2 reduction

On a more positive note, the implementation of MARPOL Annex VI regulations in mid-2022 – which limit the sulphur content of marine fuels used by ships in ports – has resulted in significant reductions in SO_2 levels across all port areas, including Auckland (Figure 20).

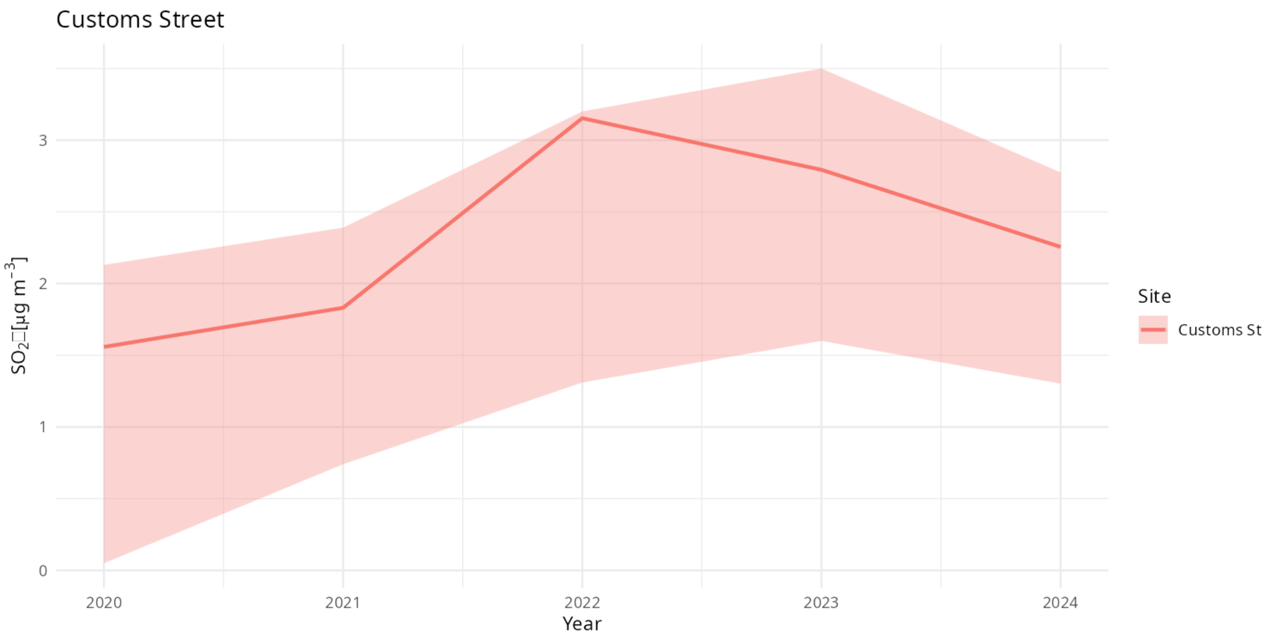


Figure 20. Annual SO_2 time series for Customs Street. The solid line is the annual average and the shaded areas correspond to the 25-75 percentile range for each site.

5.2.5 Conclusion

Overall, air quality in Auckland's CBD is improving, though the spatial variability remains complex. While $PM_{2.5}$ concentrations have risen at Queen Street, they've declined at Customs Street. On the other hand, NO_2 levels have dropped at both locations.

This variability highlights a gap in our understanding of air quality dynamics in the city centre. Addressing this gap will help us better assess the benefits and trade-offs of urban projects. To that end, we're leveraging the development of lower cost sensing technology to expand our monitoring network (Figure 21). These new sensors include solar powered devices that can be installed on lamp posts and can complement our long-term monitoring sites. We plan to start these monitoring activities in winter 2025, and we expect to expand their use to other parts of the region.

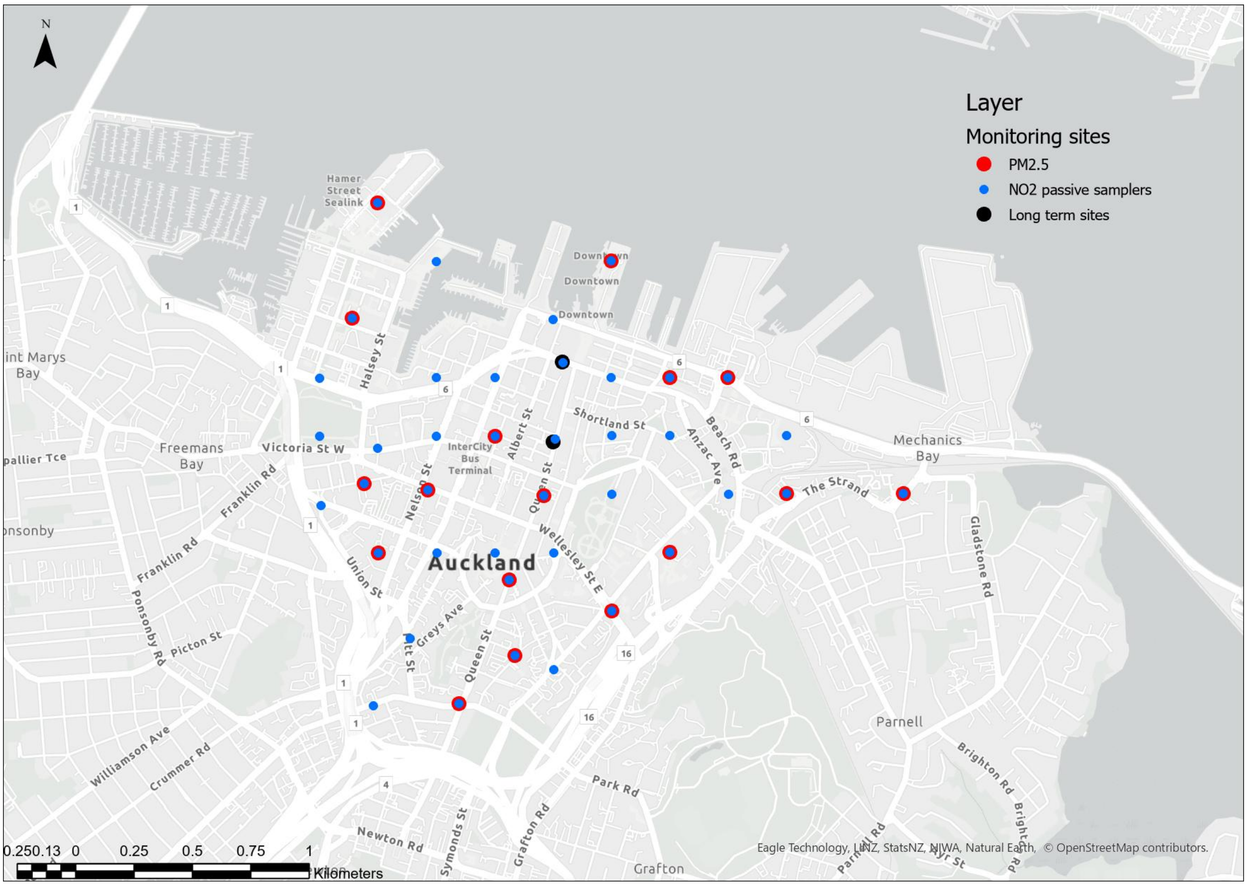
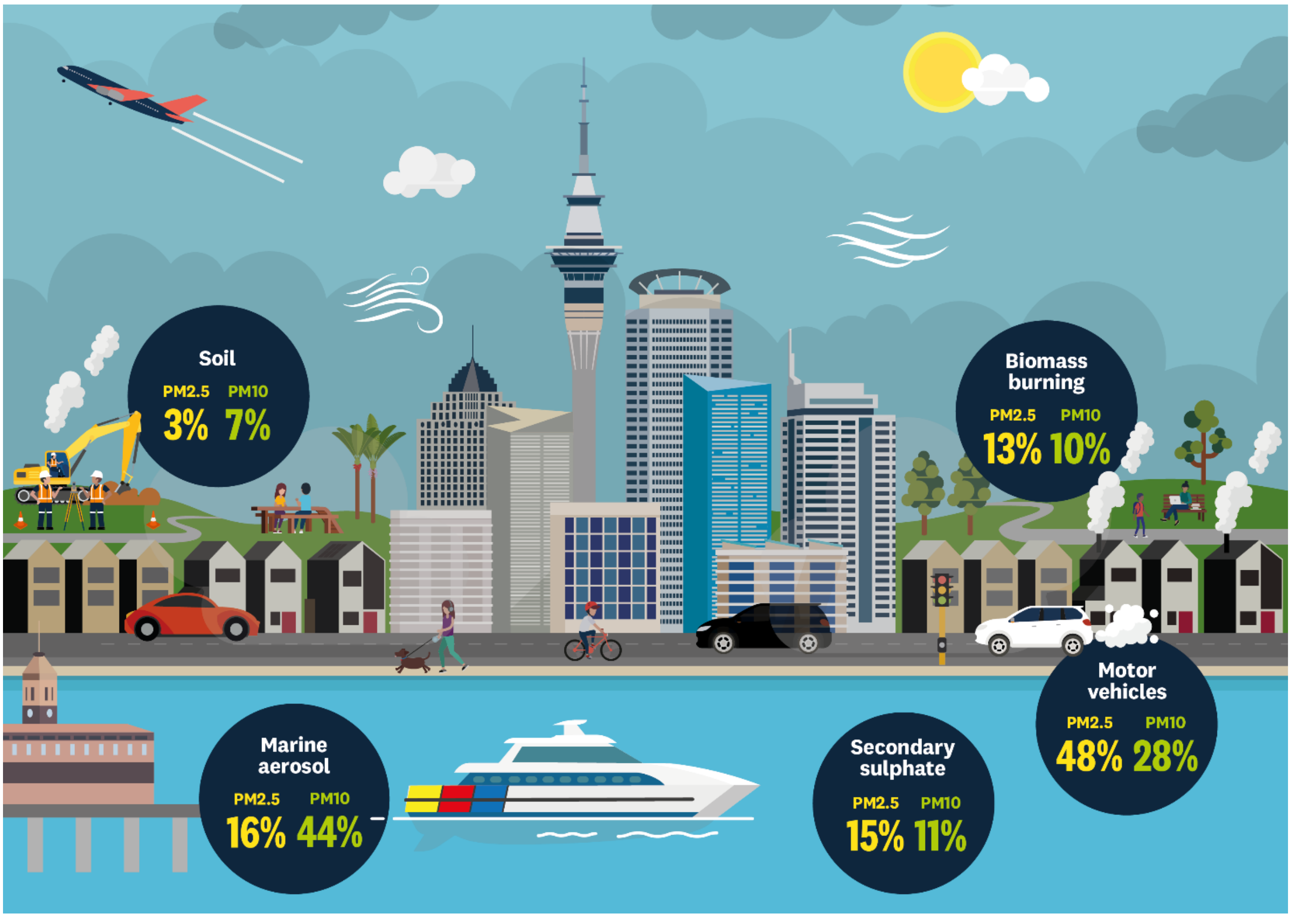


Figure 21. Planned dense network of air quality monitors in the CBD. The blue dots correspond to passive NO_2 sites, the red circles indicate the sites that also include $PM_{2.5}$ measurements, and the black circles represent the two long-term monitoring sites in the area.

5.3 Source apportionment: Where does our PM come from?



5.3.1 Introduction

Particulate matter (PM) in Auckland's air comes from a wide range of sources – sea spray from the surf, dust lifted by the wind, smoke from wood burning, and emissions from vehicles. Since 2003, we've been analysing the elemental composition of PM in Auckland, building one of the longest continuous records of its kind in New Zealand (Boamponsem et al. 2025; 2024; P. K. Davy et al. 2007; 2011). This long-term dataset allows us to understand not just what's in our air, but where it comes from – and how those sources have changed over time.

5.3.2 PM_{10}

The composition of PM_{10} in Auckland reveals a mix of natural and human-made sources. The largest contributor is sea spray, which accounts for nearly half of the coarse particles in the air. This is not surprising, given Auckland's coastal geography, where ocean winds frequently carry salt particles inland. Motor vehicles are the second-largest source, contributing over a quarter of PM_{10}. This includes both exhaust emissions and particles generated from road wear and vehicle movement.

Long-range transport – pollution carried from other regions – makes up a smaller but still notable portion, while soil and dust contribute around 10%, originating from earthworks and windblown particles. Wood burning, primarily for home heating, also accounts for about 10%, with its influence more pronounced during colder months.

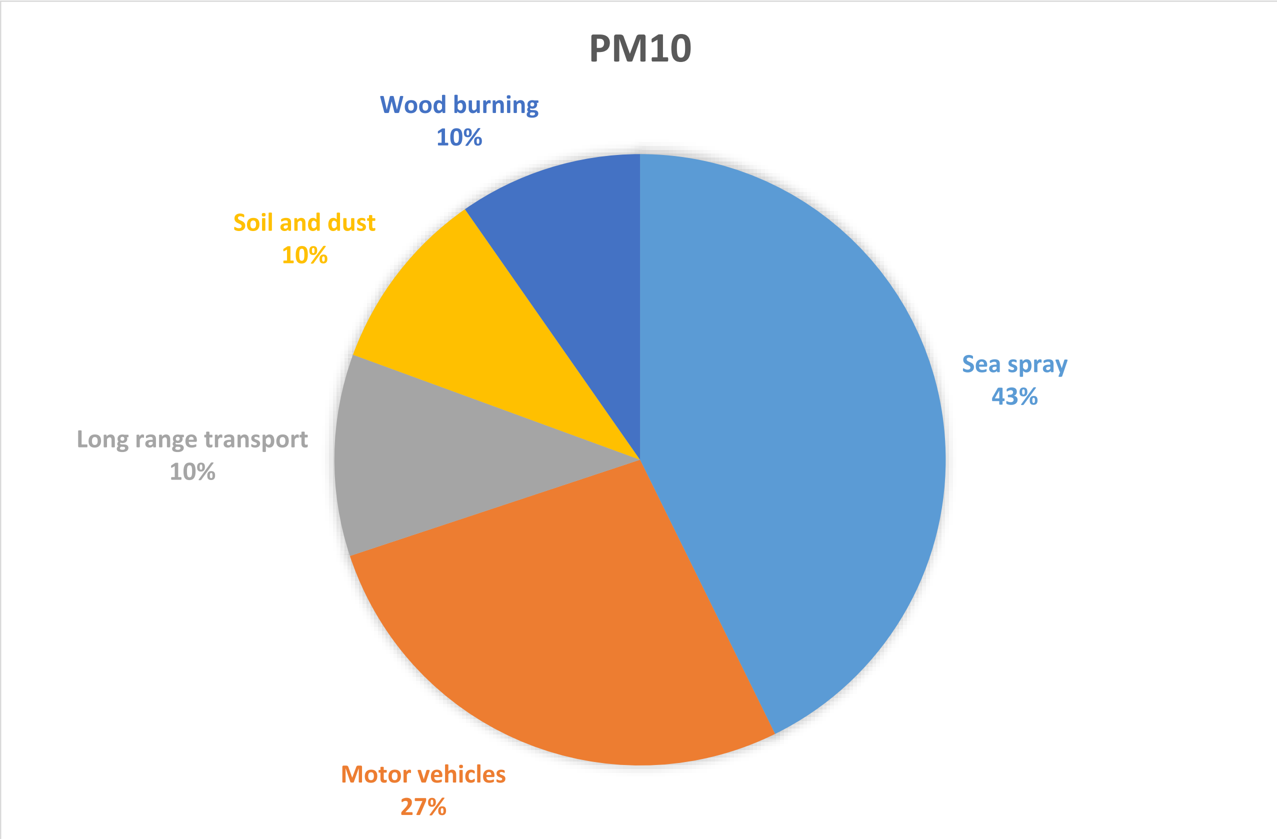


Figure 22. Relative source contribution to PM_{10} in Auckland.

5.3.3 $PM_{2.5}$

When we look at $PM_{2.5}$, the influence of human activity becomes even more apparent. Motor vehicles dominate the source profile, contributing nearly half of all fine particles. These emissions are particularly concerning due to their ability to penetrate deep into the lungs and bloodstream, posing significant health risks. Unlike PM_{10}, the contribution from sea spray is much lower, reflecting the larger size of particles generated by the wind over the sea.

Long-range transport remains a substantial contributor, bringing in fine particles from outside the region. Wood burning also plays a significant role, especially in winter, when domestic heating increases. Interestingly, soil and dust make up only a small fraction of $PM_{2.5}$, highlighting how finer particles are more closely tied to combustion and industrial processes than to natural resuspension.

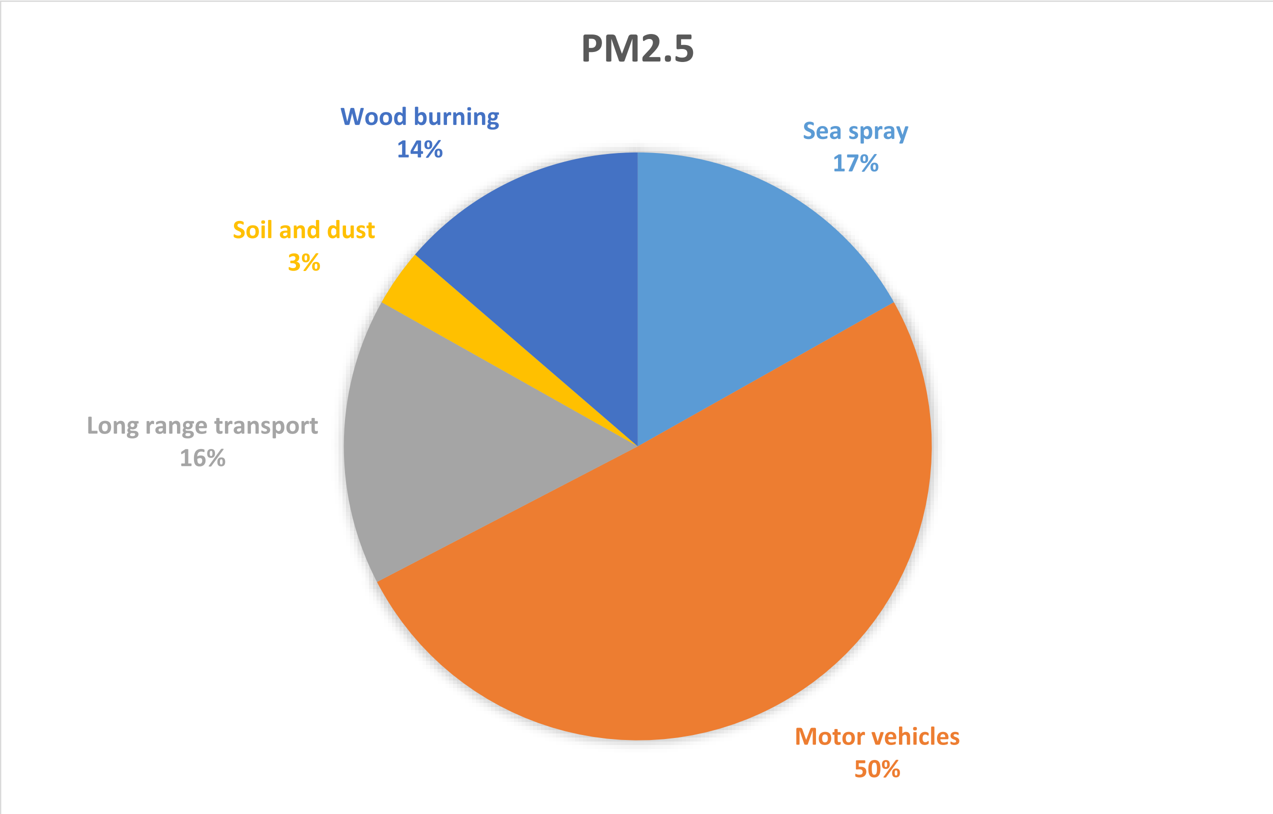


Figure 23. Relative source contribution to $PM_{2.5}$ in Auckland.

5.3.4 The rise of non-tailpipe emissions

While vehicle exhaust emissions have decreased thanks to cleaner technologies and regulations, non-exhaust emissions (NEE) – from brake, tyre, and road surface wear, and road dust resuspension – remain largely uncontrolled. Recent studies in Europe show that NEE can now rival or exceed exhaust emissions. Our Auckland data supports this trend: chemical speciation and source apportionment reveal that a significant portion of PM from road transport is non-exhaust in origin (P. Davy and Trompetter 2021).

5.3.5 Conclusion

Over the past decade, the mix of PM sources in Auckland has remained relatively stable with combustion sources dominating the finer fraction and seas spray the most significant source of PM_{10} on average. However, as we transition away from fossil fuels and combustion-based transport, the relative contribution of sources – especially non-tailpipe emissions – is likely to change. Understanding these dynamics is essential for designing effective air quality policies and protecting public health.

6 Discussion

This report shows that Auckland has made substantial progress in improving air quality over the past decade, particularly in reducing NO_2 concentrations. The consistent downward trend in NO_2, especially in high-traffic areas like Queen Street and Customs Street, reflects the effectiveness of policies promoting low-emission vehicles and shifts to public and active transport modes. These gains are particularly notable given Auckland's population and vehicle growth during the same period.

However, the trends for particulate matter (PM_{10} and $PM_{2.5}$) are more nuanced. While regional PM levels have remained relatively stable, some sites – particularly those affected by construction or increased traffic – have shown increases. The case of Queen Street, where PM concentrations rose due to construction-related activity, illustrates the tension between urban development and air quality.

A key theme emerging from this analysis is the spatial variability in air quality across Auckland. While central areas benefit from dense monitoring and visible improvements, peripheral and fast-growing regions – particularly in the north-west and south – remain under-monitored. This limits our ability to assess exposure and health risks for all Aucklanders and may mask localised pollution hotspots. Expanding the monitoring network, including the deployment of low-cost sensors, is essential to address these gaps.

The COVID-19 lockdowns provided a rare natural experiment, demonstrating the significant impact of reduced traffic on urban air quality. The sharp declines in NO_2 during Level 4 restrictions highlight the dominant role of mobile combustion sources in Auckland's pollution profile. While lockdowns are not a viable tool for air quality and exposure management, they do offer a glimpse into what could be achieved through long-term shifts in transport behaviour and infrastructure.

Our air quality monitoring programme will continue to develop and adapt to address current and emerging issues in the region. Specifically, we will continue the use of new technologies to address gaps in our understanding of the population exposure profiles of Aucklanders with the aim to develop policies that achieve improved outcomes in terms of health and economic impacts. It is expected that this report will be updated in the future as part of our environmental reporting plans.

7 References

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Appendix A: Theil-Sen method for long-term trend analysis

Air quality data typically shows strong seasonal patterns and is not normally distributed, making traditional statistical methods less suitable for trend analysis.

The Theil-Sen estimator is a non-parametric method for linear trend estimation that is particularly robust to outliers and non-normal data distributions. Unlike a least squares regression, which minimis es the sum of squared residuals and can be sensitive to extreme values, the Theil-Sen method calculates the median of all possible pairwise slopes between data points. This makes it highly suitable for environmental datasets, such as air quality measurements, which often contain irregularities due to episodic events or measurement noise.

In the context of this report, the Theil-Sen estimator is applied to deseasonalised data to isolate the long-term trend from seasonal fluctuations. Once the seasonal effects are removed, the Theil-Sen method fits a robust linear model to the remaining data, providing a clear estimate of the direction and magnitude of change over time.

By calculating the median of all pairwise slopes, the resulting trend line is less influenced by short-term anomalies and better reflects the central tendency of the data. Additionally, confidence intervals can be constructed around the trend estimate, offering insight into the uncertainty of the trend.

The plots used in this report (Figure 24) were generated using the TheilSen function within the Openair package and the key elements of the resulting plot are:

- Deseasonalised data: The full blue line is the deseasonalised monthly averages for the period.
- Central trend line: The full red line corresponds to the linear model trend for the data and the dashed red lines indicate the 95% confidence interval of the estimate
- Trend estimate: The green text at the top of the graph indicates the estimated long term linear slope, expressed as concentration change per year in the same units as the vertical axis and with the 95% confidence interval. The * next to the estimate indicate the level of statistical significance of the central estimate based on their “p” value:

Symbol	P-value Range	Significance Level
***	$p < 0.001$	Highly statistically significant
**	$0.001 \leq p < 0.01$	Statistically significant
*	$0.01 \leq p < 0.05$	Moderately statistically significant
.	$0.05 \leq p < 0.1$	Marginally statistically significant
	$p \geq 0.1$	Not statistically significant

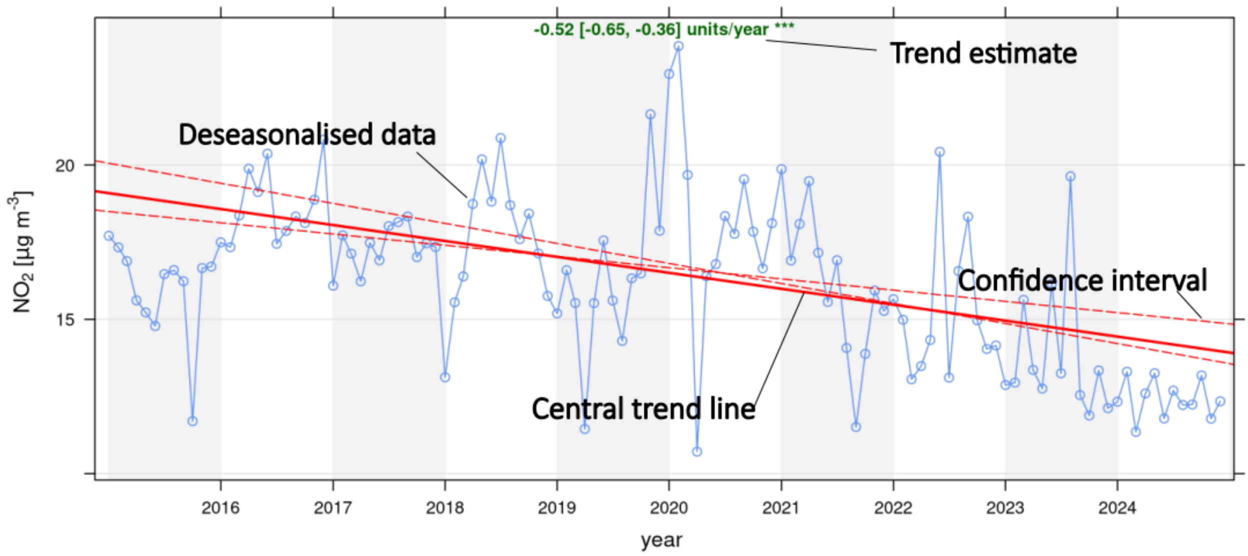


Figure 24. Typical Theil-Sen long-term trend plot, highlighting the key components of the plot. Refer to the text for more details.

Appendix B: Observational summaries by site

Henderson

Site description

The Henderson air quality monitoring station has been operating since late 1993 and is designated as a residential peak site. It measures key pollutants such as nitrogen dioxide (NO_2) and particulate matter (PM_{10}), along with meteorological variables. In 2017, the site became the first in the Auckland region to be equipped with a real-time black carbon monitor (Aethalometer).

Situated within the grounds of Henderson Intermediate School, the station is positioned approximately 10 metres to the west of Lincoln Road – a major arterial route connecting the western suburbs to the north-western motorway (see Figure 25). The surrounding area features a mix of residential and commercial land uses. Te Pai Park's industrial zone, which includes warehousing and light industry, lies about 500 metres to the northeast, while Waitakere Hospital is located roughly 300 metres southeast of the site.

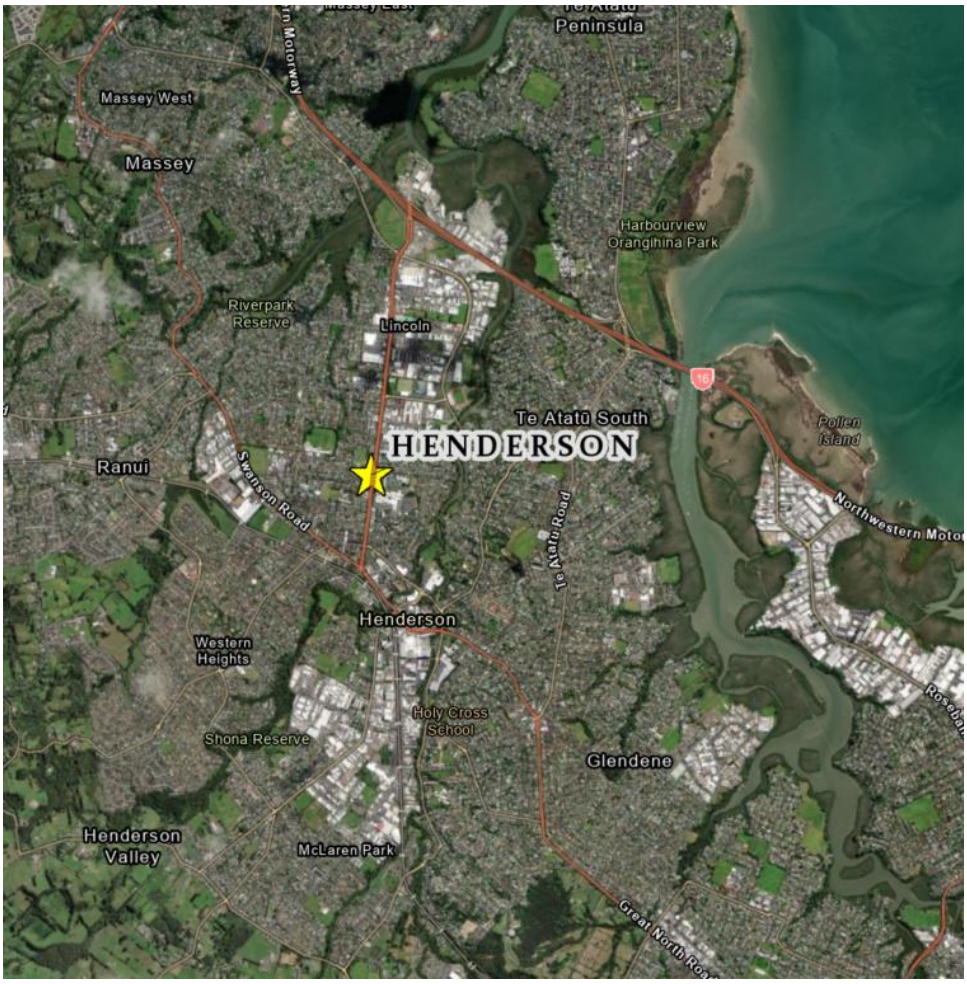
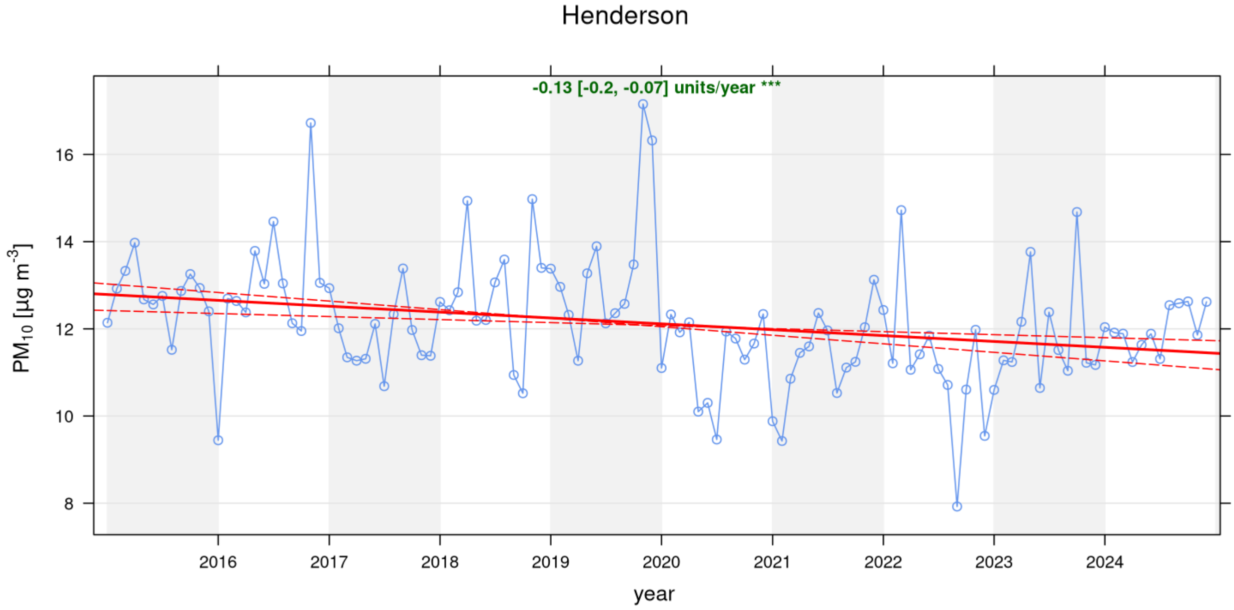


Figure 25. Map of the location of Henderson air quality monitoring site.

PM_{10} trends

The deseasonalised long-term trend show a 0.13 µg/m^3 year on year reduction in PM_{10} since 2015, but a slowing of that trend with no statistically significant change between 2020 and 2024.

The diurnal, annual and weekly variation of PM_{10} concentrations at the Henderson site indicate no significant seasonal variability and only a low diurnal cycle with peak concentrations just after midnight.



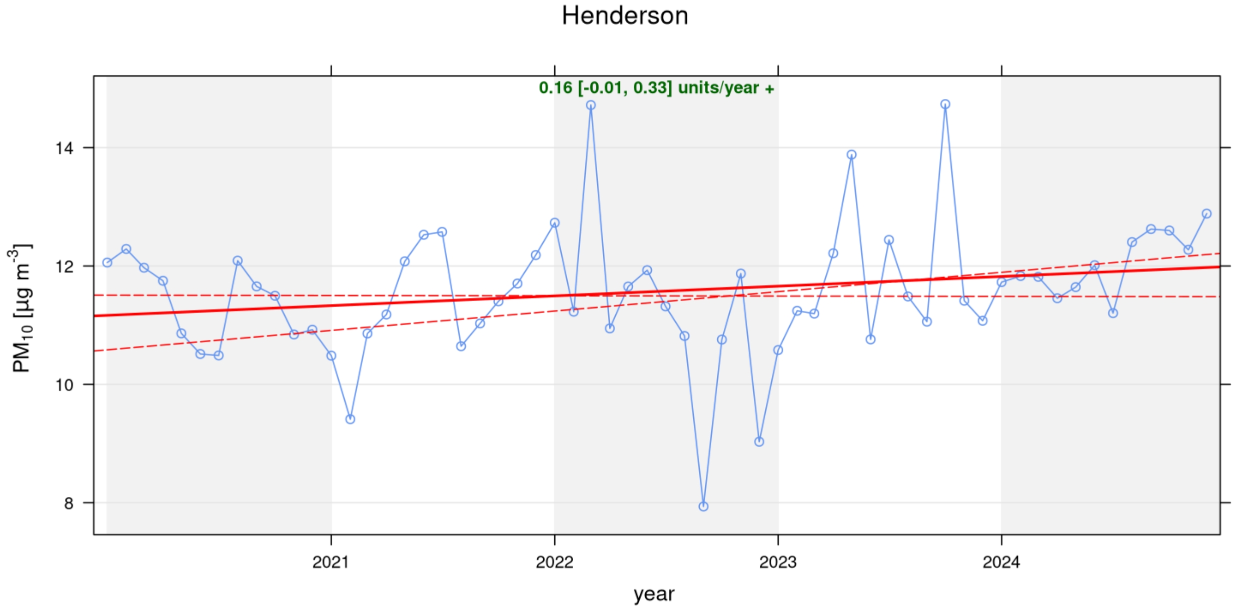


Figure 26. Theil-Sen deseasonalised trends for PM_{10} at Henderson, 2015-2024 (top) and 2020-2024 (bottom).

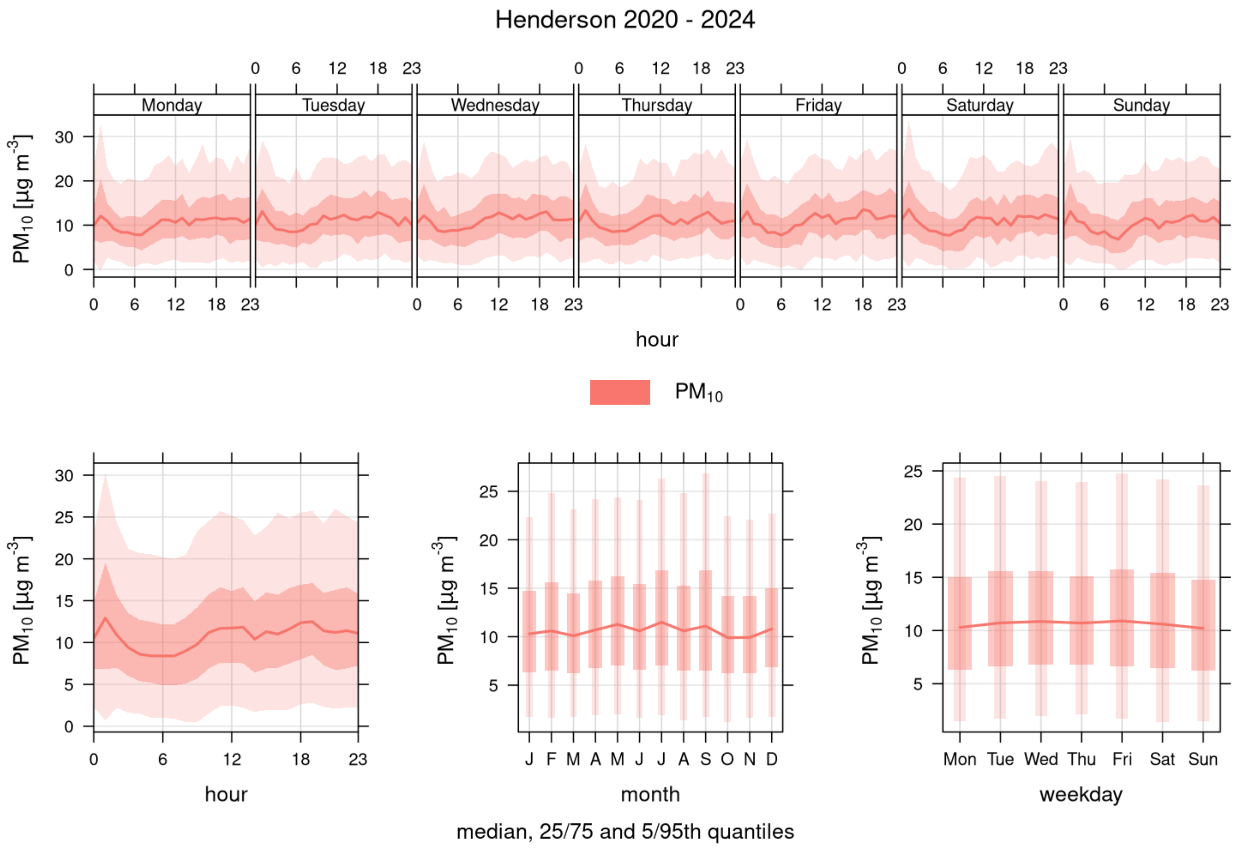


Figure 27. Temporal variability of the median PM_{10} concentration at Henderson for the past 5 years (2020-2024), including hourly, weekday and monthly plots. The shaded areas show the 5%, 25%, 75% and 95% percentiles.

Black carbon (BC) measurements

Black carbon measurements started in 2019 so only the trend for the past five years can be presented. The deseasonalised trend shows a 39.4 ng/m^3 year on year reduction in BC since 2020.

The diurnal, annual and weekly variation of BC concentrations at the Henderson site indicate a strong seasonal and diurnal variability. Concentrations are higher in winter and during the morning and evening commuting rush hour, consistent with BC being primarily driven by traffic sources.

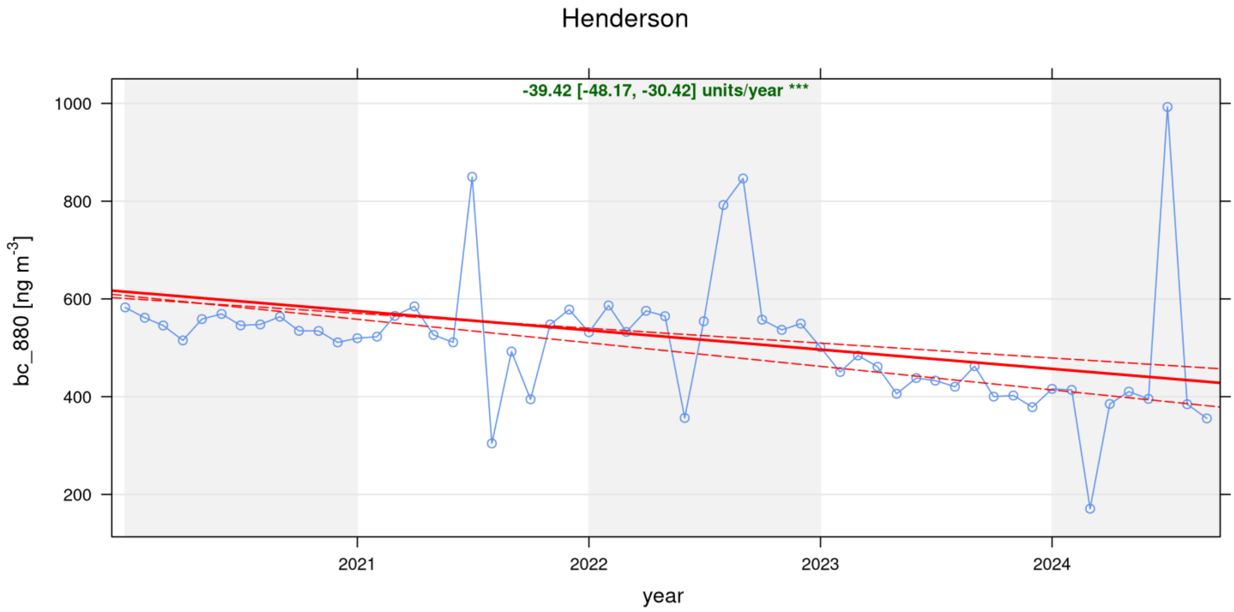


Figure 28. Theil-Sen deseasonalised trends for BC at Henderson 2020-2024.

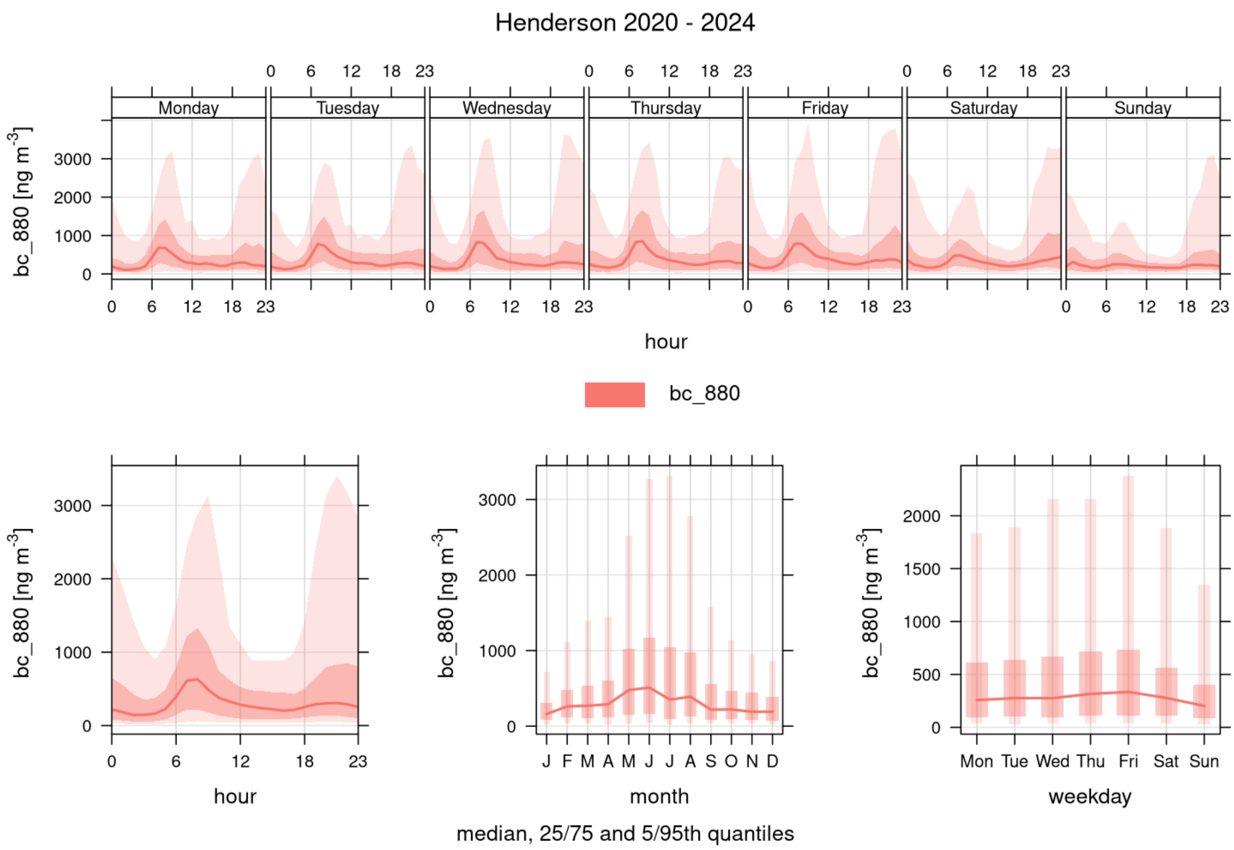
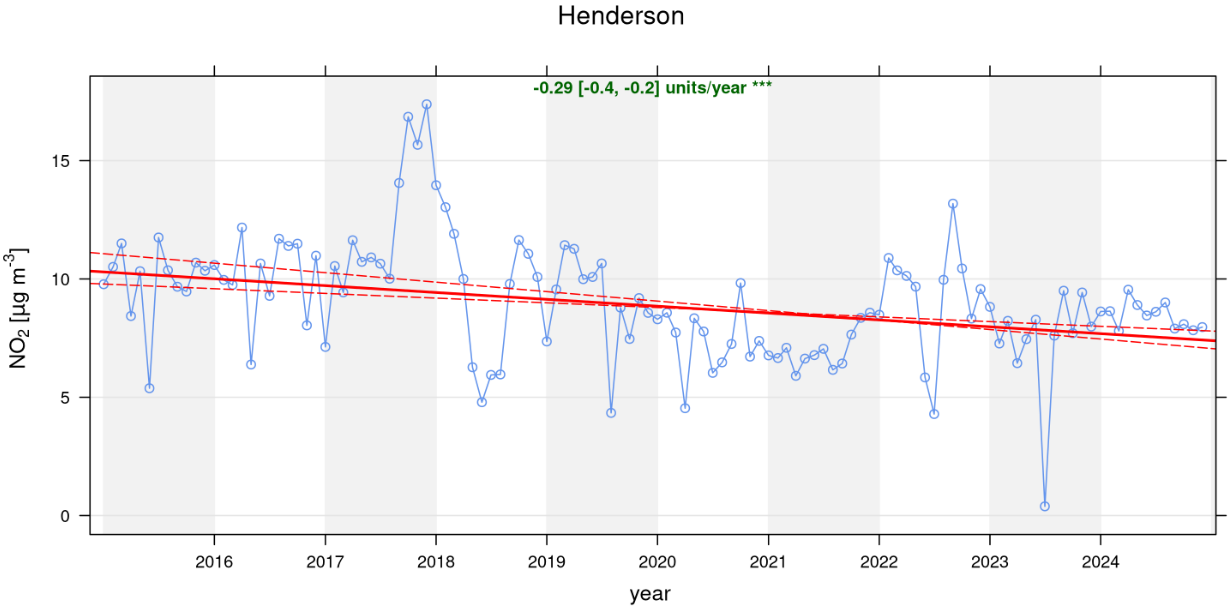


Figure 29. Temporal variability of the median BC concentration at Henderson for the past 5 years (2020-2024), including hourly, weekday and monthly plots. The shaded areas show the 5%, 25%, 75% and 95% percentiles.

NO_2 trends

The deseasonalised long-term trend show a 0.29 μg/m³ year on year reduction in NO_2 since 2015, but a slowing of that trend with no statistically significant change between 2020 and 2024.

The diurnal, annual and weekly variation of NO_2 concentrations at the Henderson site indicate a strong seasonal and diurnal variability. Concentrations are higher in winter and during the morning and evening commuting rush hour, consistent with NO_2 being primarily driven by traffic sources.



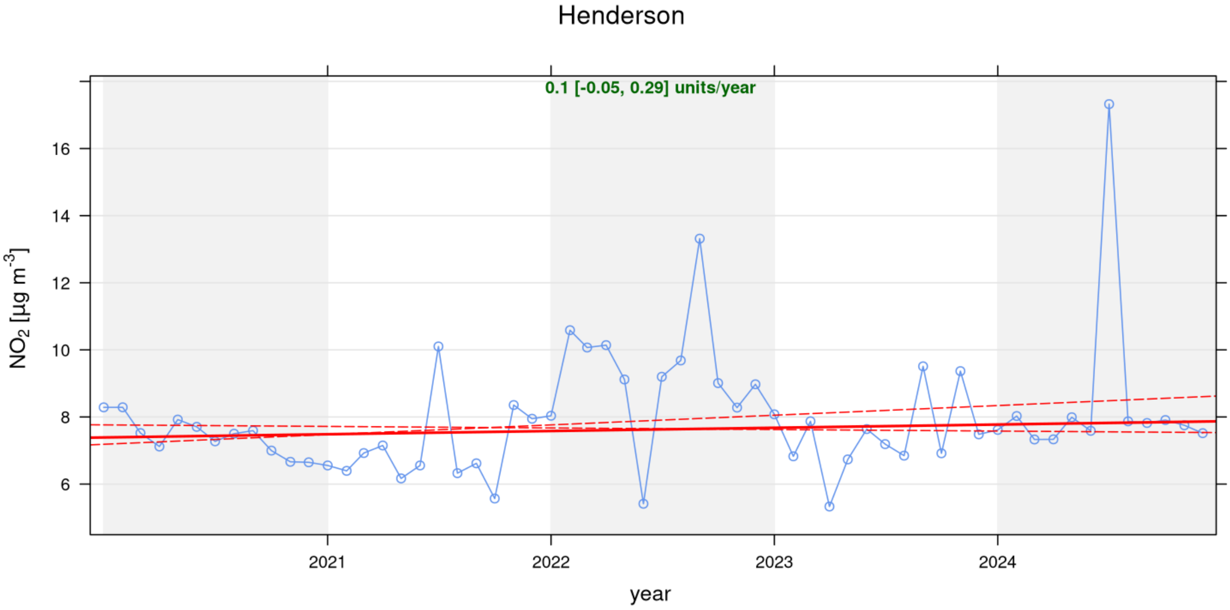


Figure 30. Theil-sen deseasonalised trends for NO_2 at Henderson, from 2015-2024 (top) and 2020-2024 (bottom).

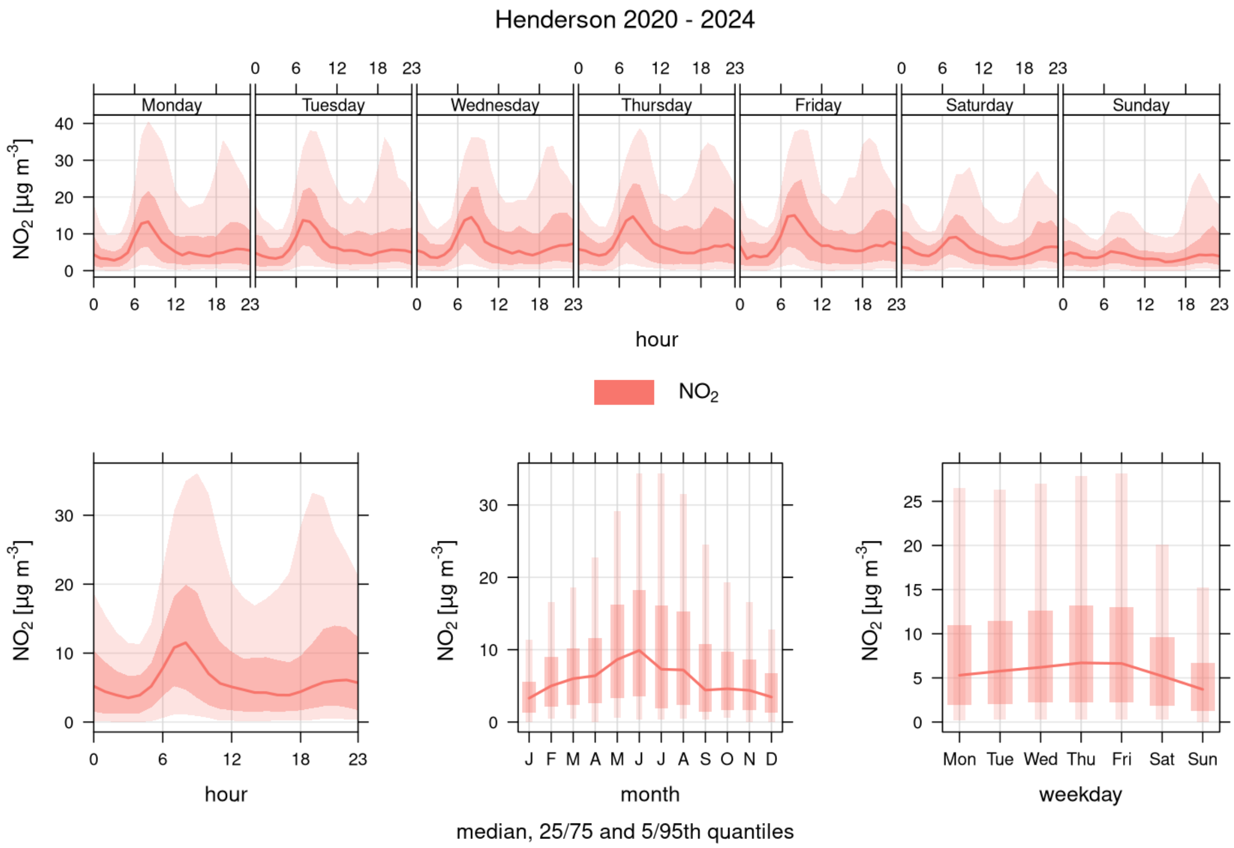


Figure 31. Temporal variability for NO_2 at Henderson, including hourly and weekday plots, 2020-2024.

Takapuna

Site description

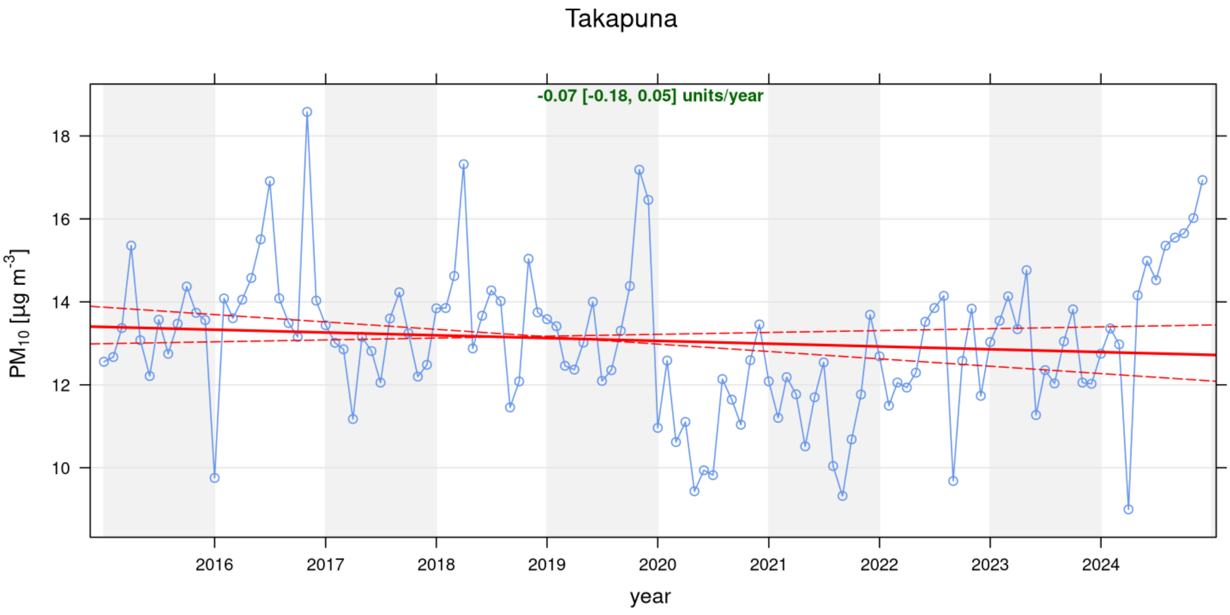
Takapuna air quality monitoring station is located within the grounds of Westlake Girls High School, off Taharoto Road, Takapuna (Figure 32) and is approximately 3.5 km northwest of the Takapuna shopping and commercial centre and 50 m east of the Northern Motorway. Land use in the area is a mixture of residential and commercial activities with the Wairau industrial area (mainly warehousing and light industrial activities). During 2011, the fields around the monitoring stations were substantially redeveloped to provide a netball facility and artificial turf surfaces for hockey fields.

Figure 32. Map of the location of Takapuna air quality monitoring site (Google Maps 2018).

PM_{10} trends

The deseasonalised long-term analysis show no statistically significant trend in PM_{10} since 2015, but a 0.75 $\mu g/m^3$ year on year increase since 2020.

The diurnal, annual and weekly variation of PM_{10} concentrations at the Takapuna site indicate no significant seasonal variability and only a low diurnal cycle with peak concentrations just before midnight.



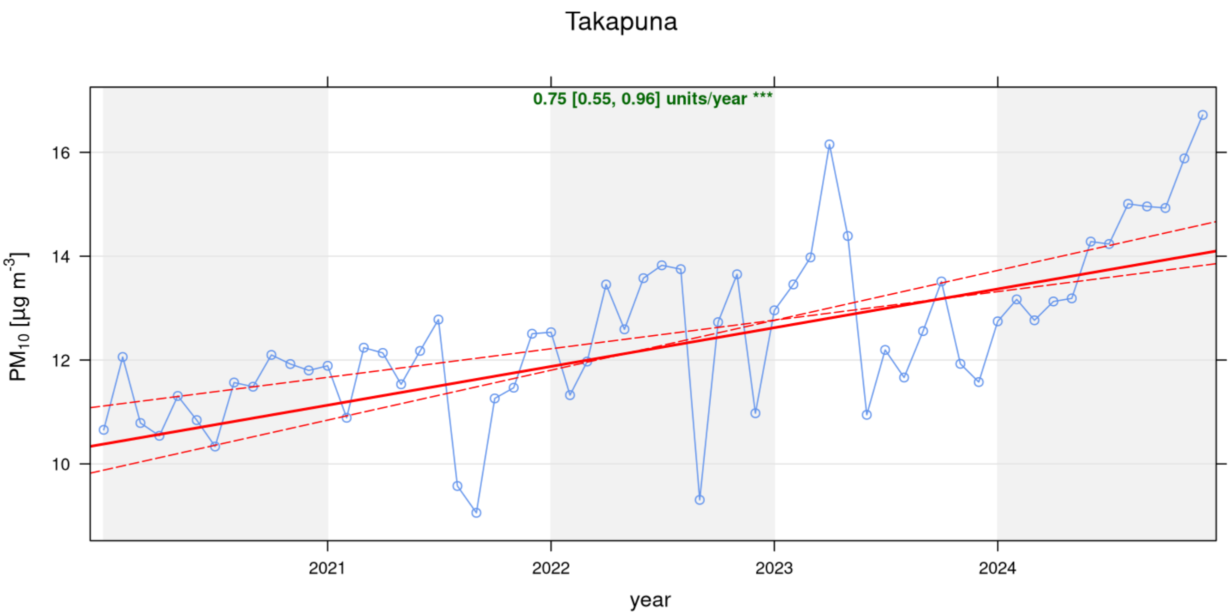


Figure 33. Theil-sen deseasonalised trends for PM_{10} at Takapuna, 2015-2024 (top) and 2020-2024 (bottom).

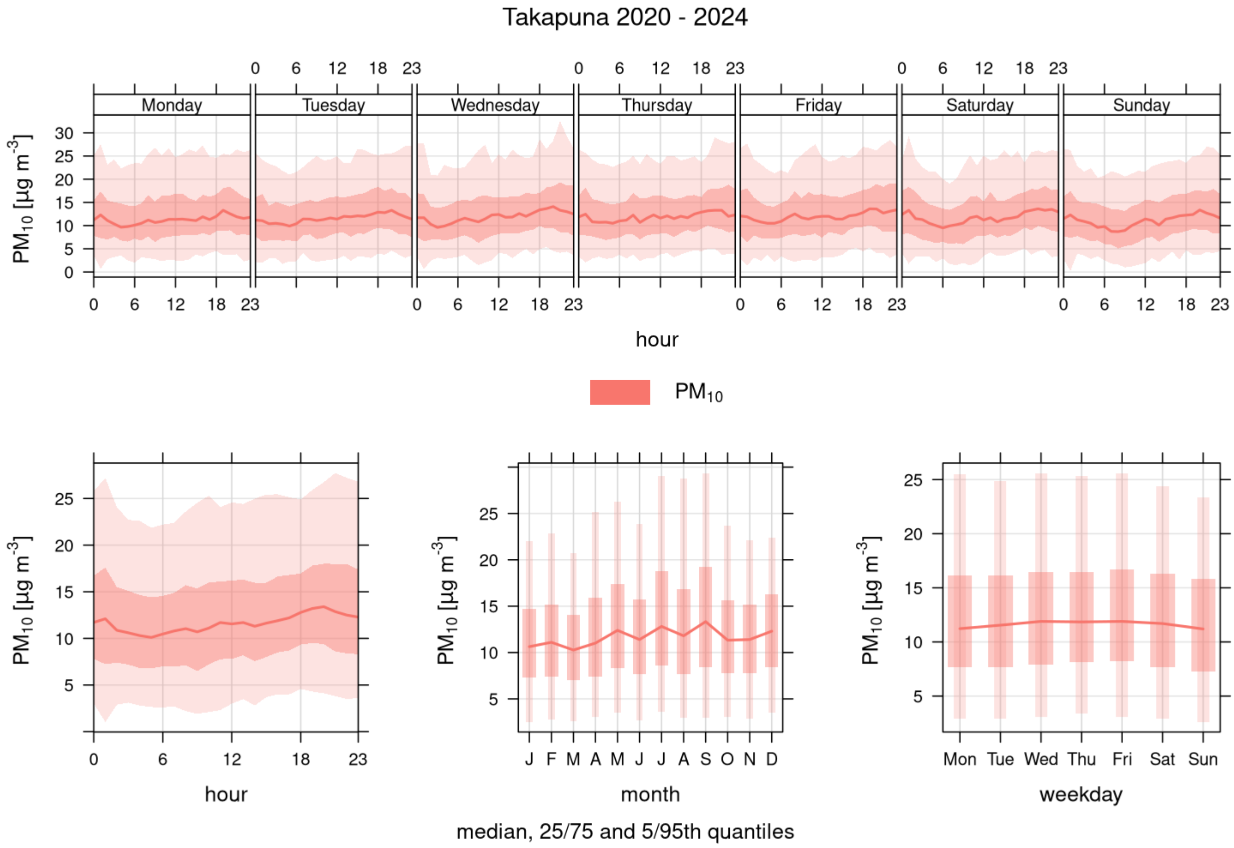
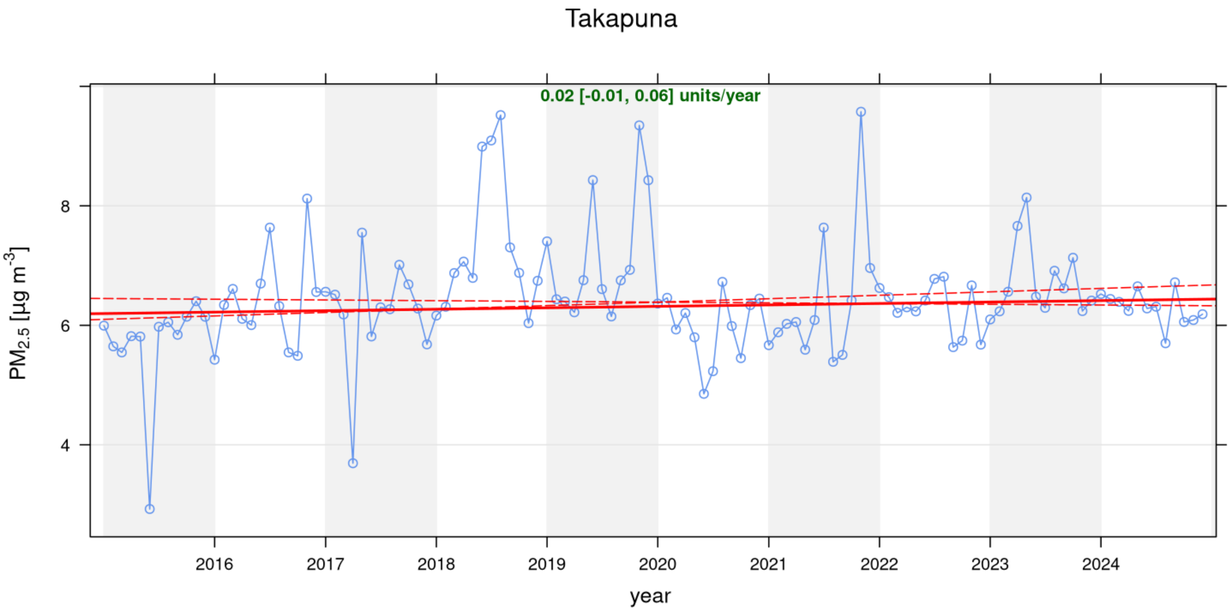


Figure 34. Temporal variability for PM_{10} at Takapuna, including hourly, weekday and monthly plots, 2020-2024.

$PM_{2.5}$ trends

The deseasonalised long-term analysis show no statistically significant trend in PM_{10} since 2015, and a very small a 0.08 µg//m^3 year on year increase since 2020.

The diurnal, annual and weekly variation of $PM_{2.5}$ concentrations at the Takapuna site indicate a significant seasonal variability with higher concentrations in late winter (June to September) as well as a marked diurnal cycle with significantly higher concentrations after 6pm and lower concentrations after midday.



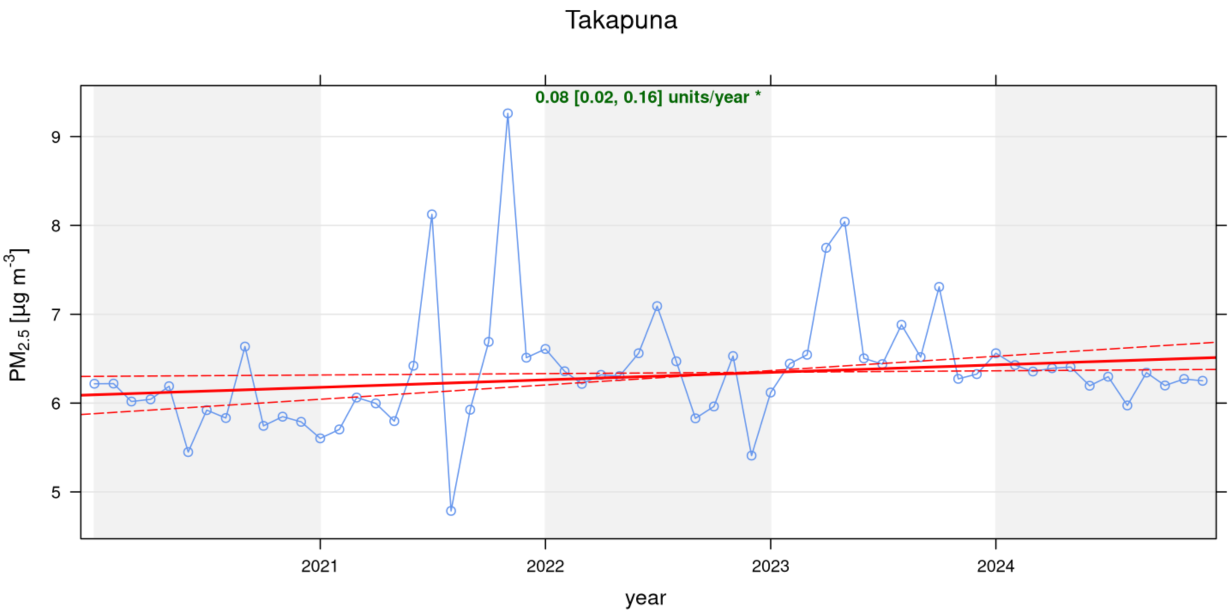


Figure 35. Theil-sen deseasonalised trends for $PM_{2.5}$ at Takapuna, 2015-2024 (top) and 2020-2024 (bottom).

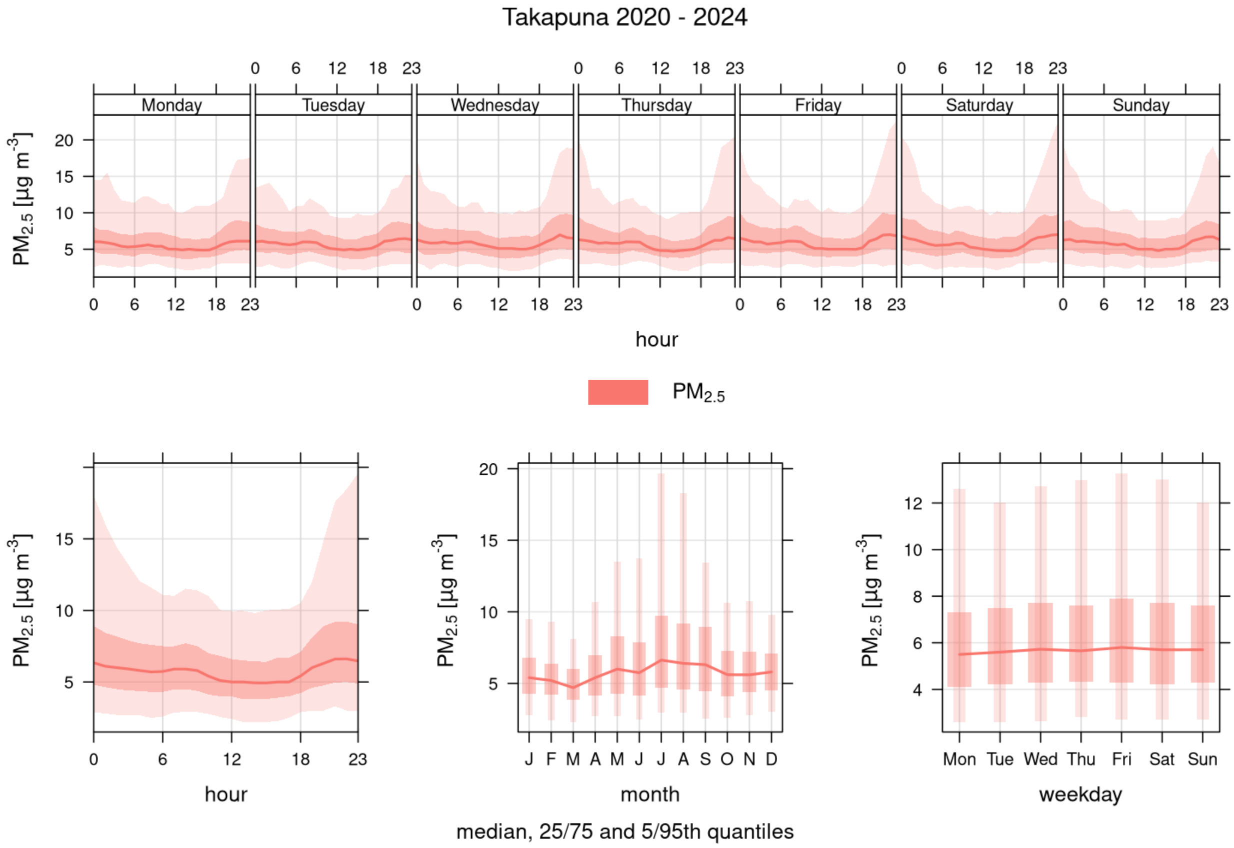
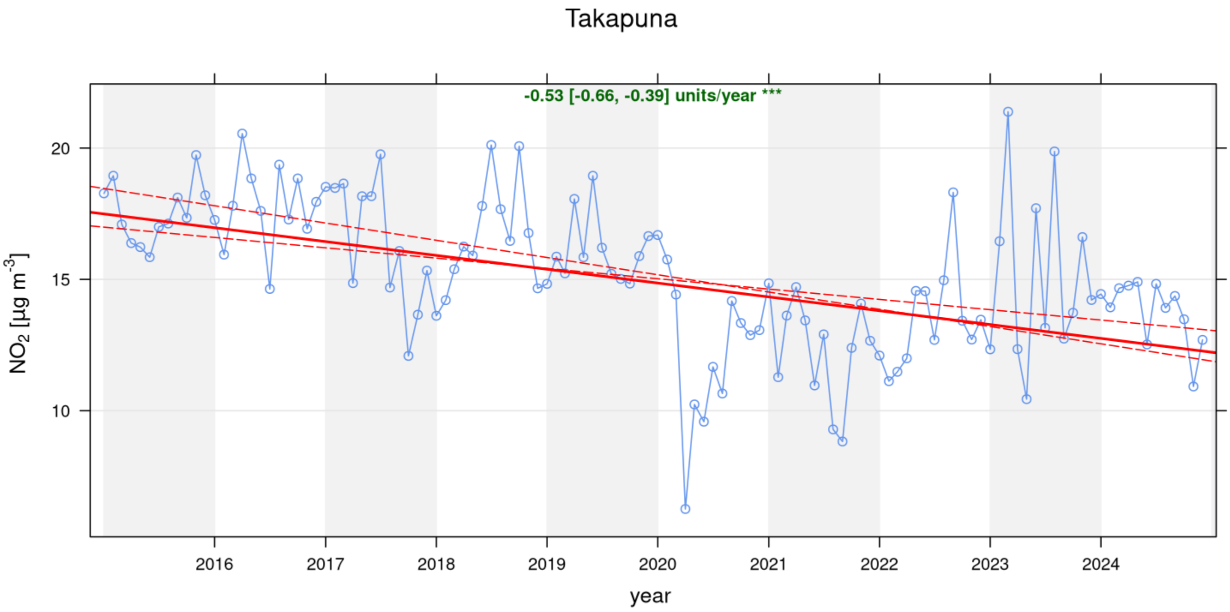


Figure 36. Temporal variability for $PM_{2.5}$ at Takapuna, including hourly, weekday and monthly plots, 2020-2024.

NO_2 trends

The deseasonalised long-term trend show a 0.53 µg/m^3 year on year reduction in NO_2 since 2015, but an increase of 0.41 µg/m^3 year on year since 2020.

The diurnal, annual and weekly variation of NO_2 concentrations at the Takapuna site show a strong seasonal and diurnal variability. Concentrations are nearly double from March to August, compared to October to February. The diurnal variability of NO_2 follows the traffic peaks with high concentrations coinciding with the morning and evening commuting rush hour, consistent with NO_2 being primarily driven by traffic sources.



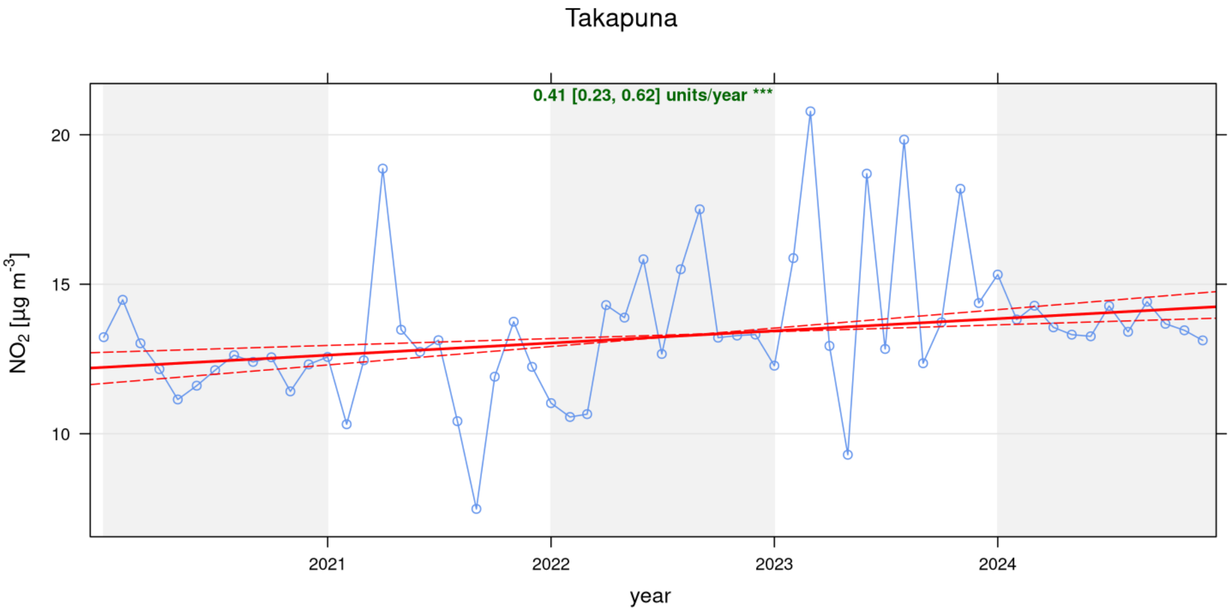


Figure 37. Theil-sen deseasonalised trends for NO_2 at Takapuna, 2015-2024 (top) and 2020-2024 (bottom).

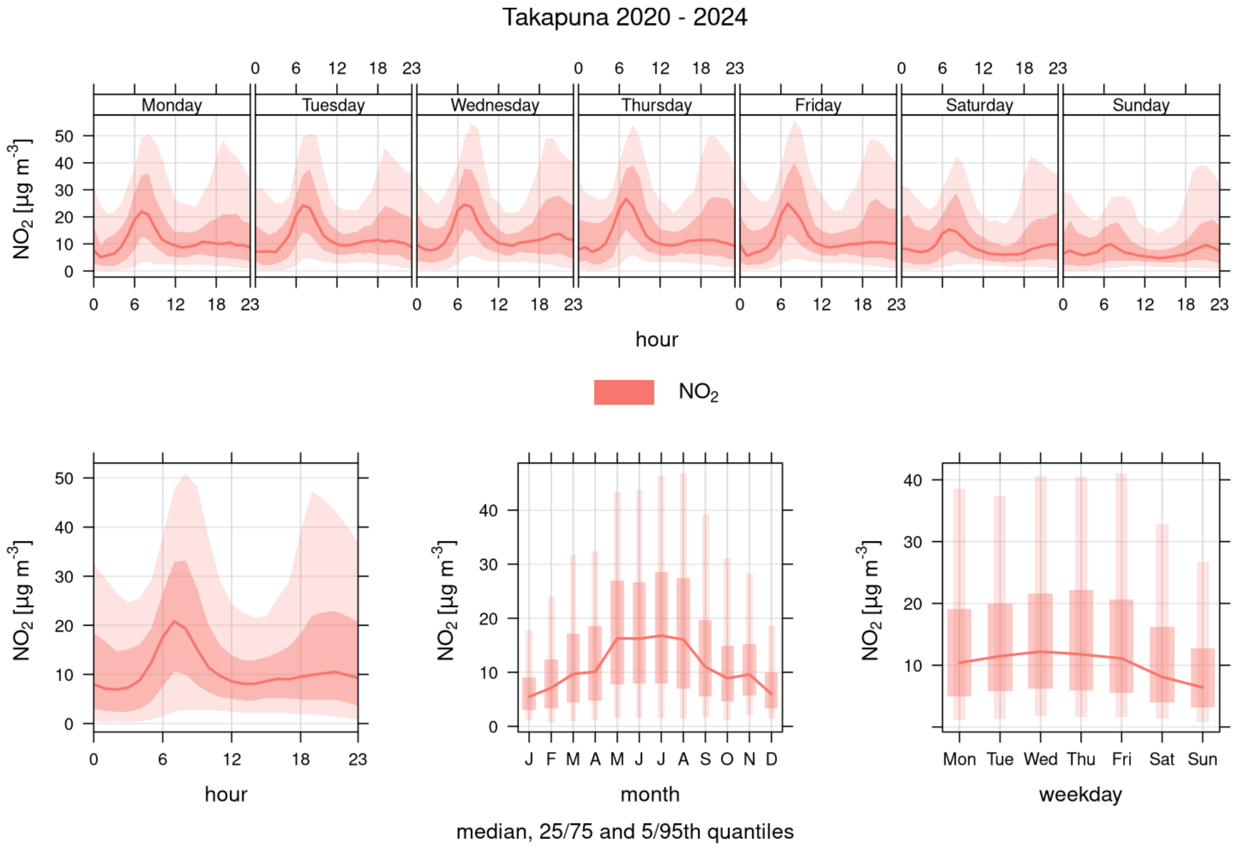


Figure 38. Temporal variability for NO_2 at Takapuna, including hourly, weekday and monthly plots, 2020-2024.

Penrose

Site description

The Penrose air quality monitoring site is within the Gavin Street substation, 106 m to the eastern side of the Southern motorway, aligned north-west to south-west (Figure 39). To the north-west and south are industrial premises including concrete batching facilities and glass manufacturing. Residential suburbs are located to the north and beyond the industrial area to the southwest.

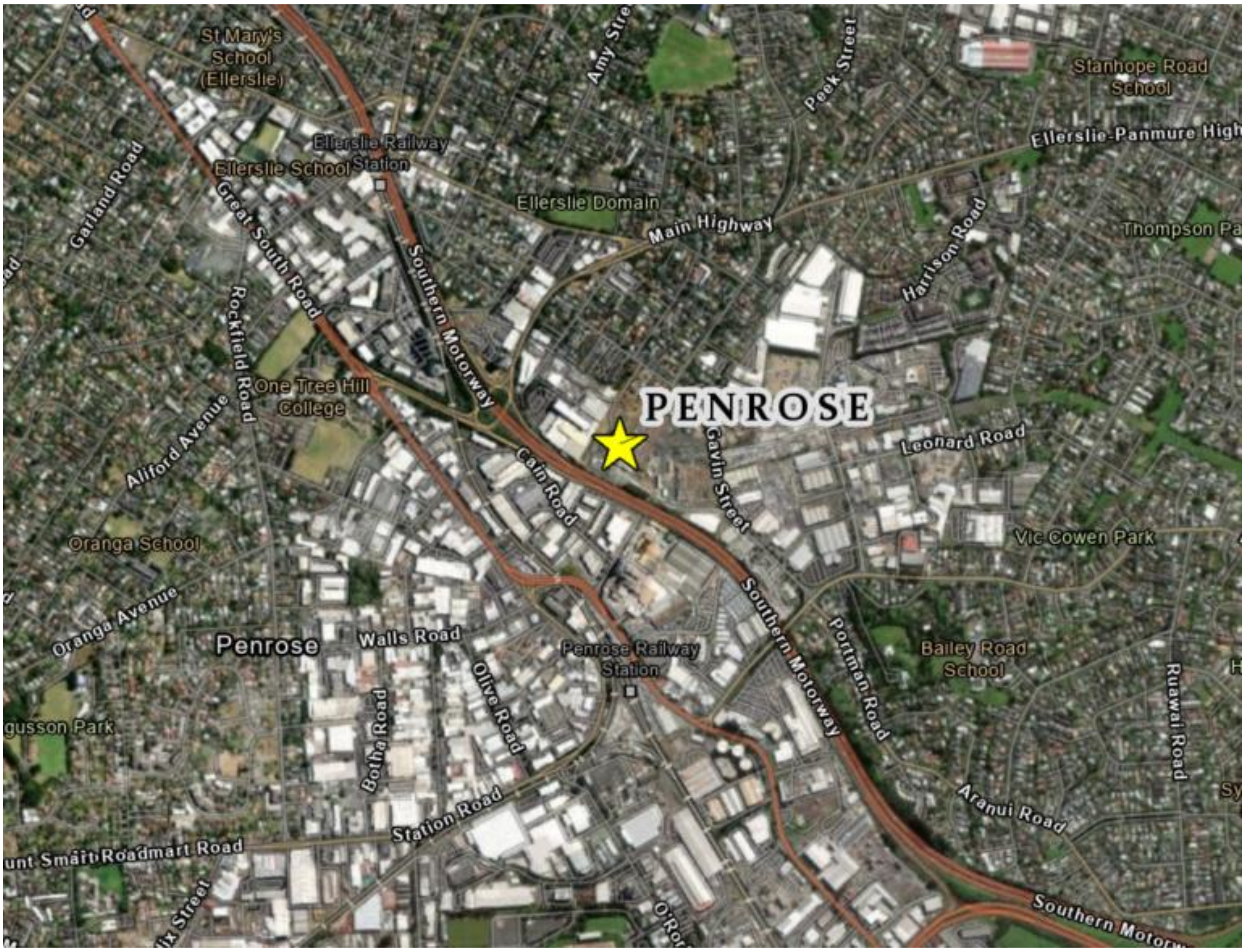
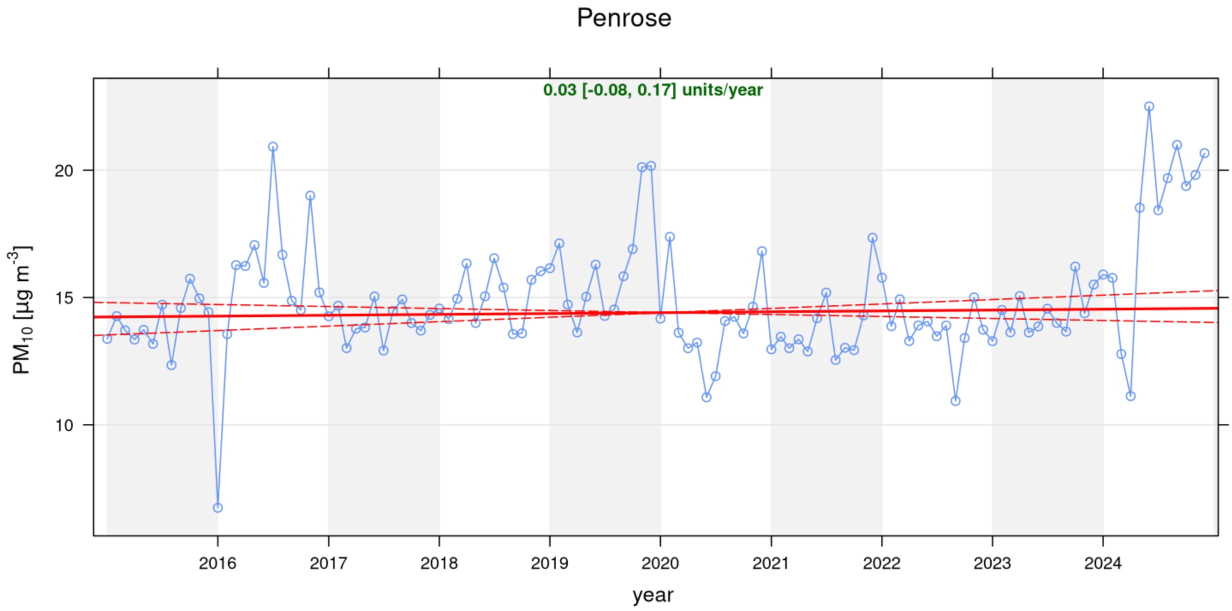


Figure 39. Map of the location of Penrose air quality monitoring site (Google Maps 2018).

PM_{10} trends

The deseasonalised long-term analysis show no statistically significant trend in PM_{10} since 2015, but a 0.64 μg/m³ year on year increase since 2020.

The diurnal, annual and weekly variation of PM_{10} concentrations indicate no significant seasonal variability and only a very subtle diurnal cycle with concentrations increasing after 6pm until just after midnight.



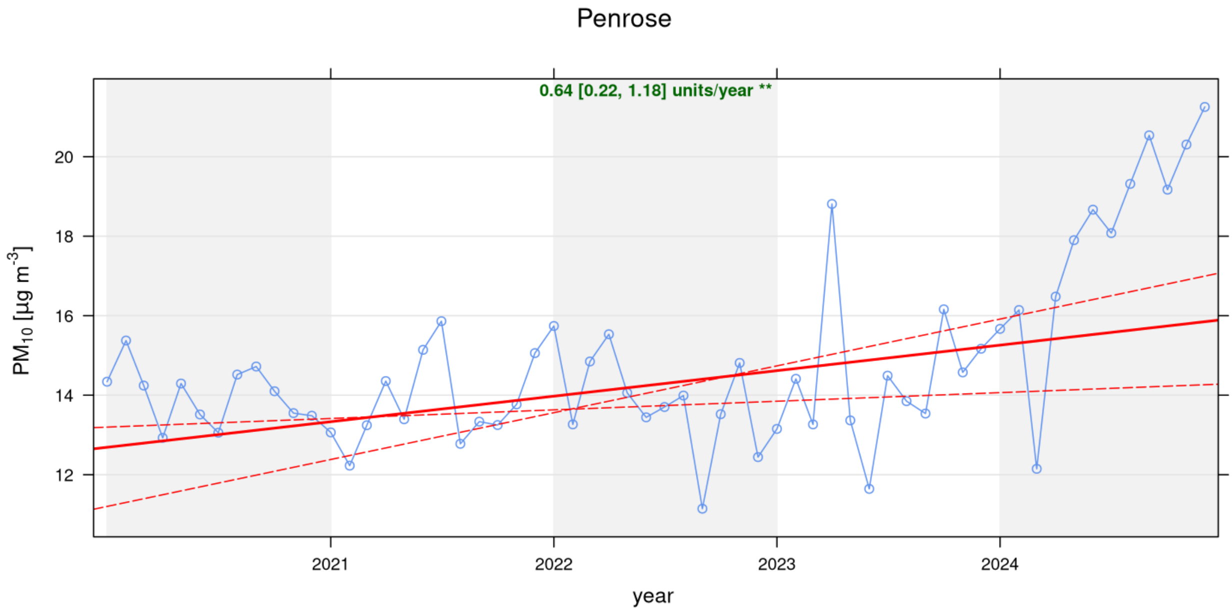


Figure 40. Theil-sen deseasonalised trends for PM_{10} at Penrose, 2015-2024 (top) and 2020-2024 (bottom).

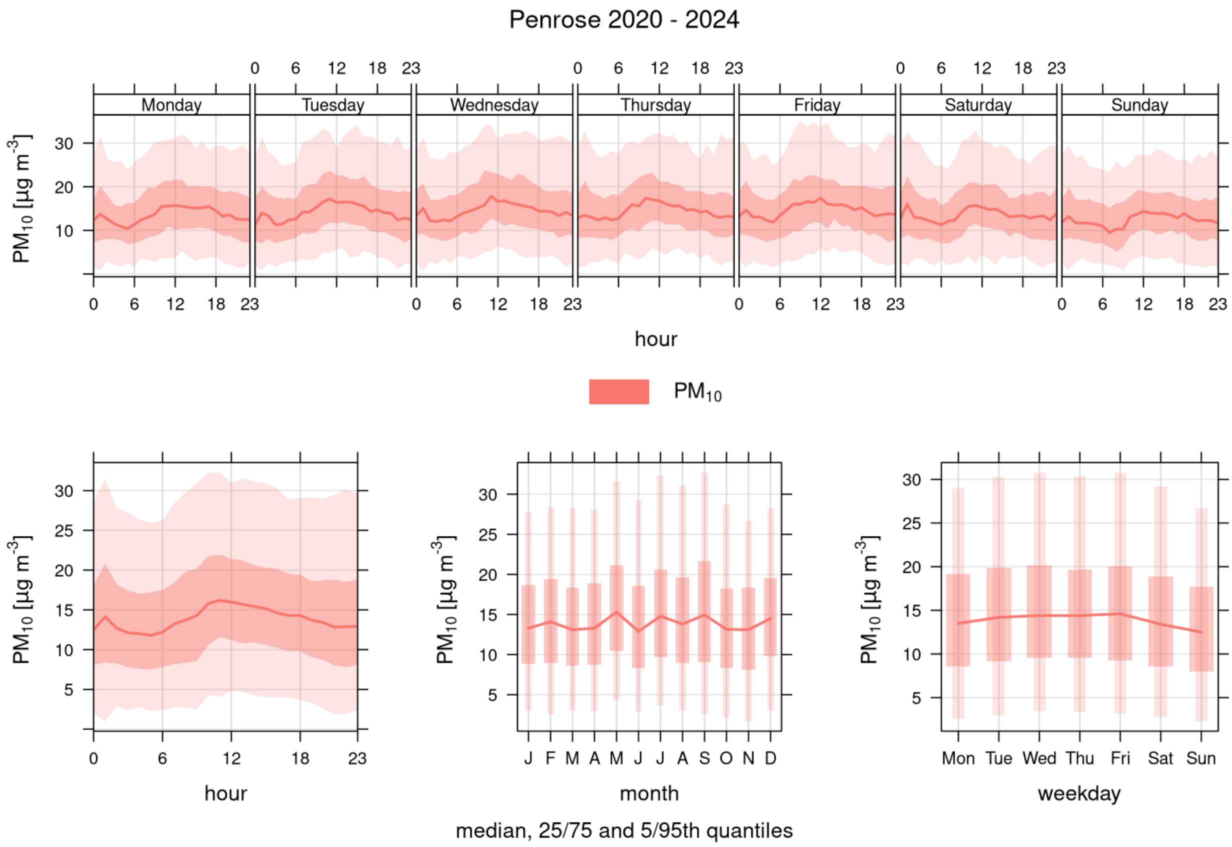
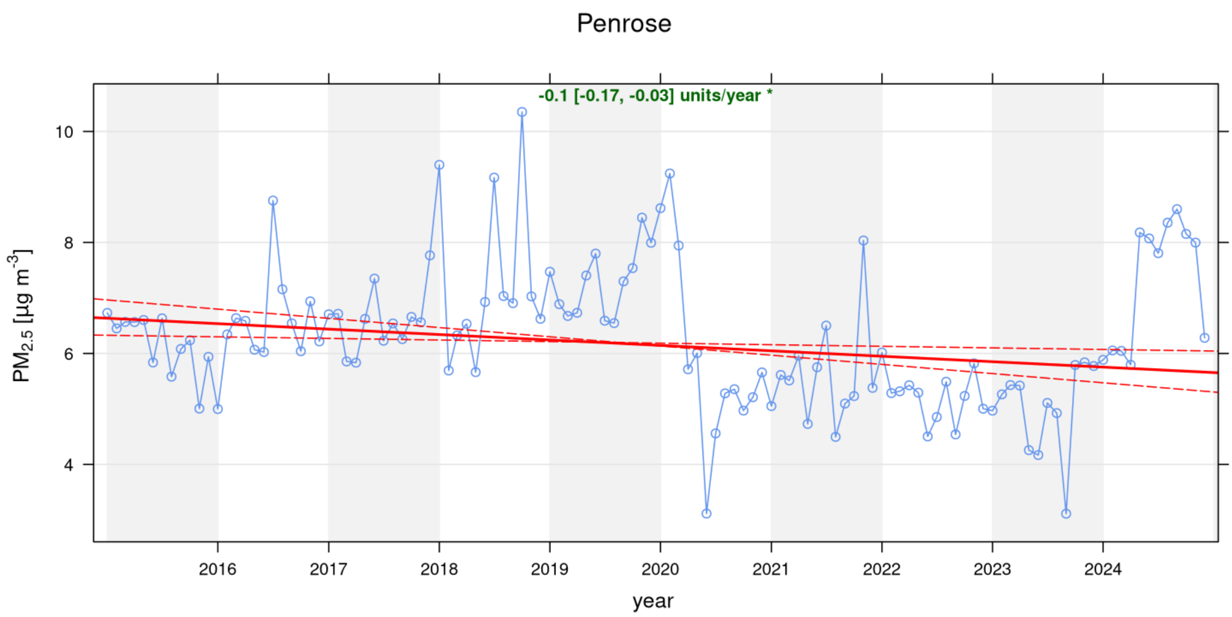


Figure 41. Temporal variability for PM_{10} at Penrose, including hourly, weekday and monthly plots, 2020-2024.

$PM_{2.5}$ trends

The deseasonalised long-term analysis shows a small 0.1 $\mu g/m^3$ decrease in $PM_{2.5}$ concentrations since 2015 but a significant increase of 0.31 $\mu g/m^3$ year on year since 2020.

The diurnal, annual and weekly variation of $PM_{2.5}$ concentrations indicate a small seasonal variability with higher concentrations during winter (March to August) as well as a marked diurnal cycle with three significant peaks. The largest one coinciding with the morning rush hour, and two smaller ones just before 6pm and just after midnight. These variations relate to the site reflecting the impact of both traffic and industrial sources in the area.



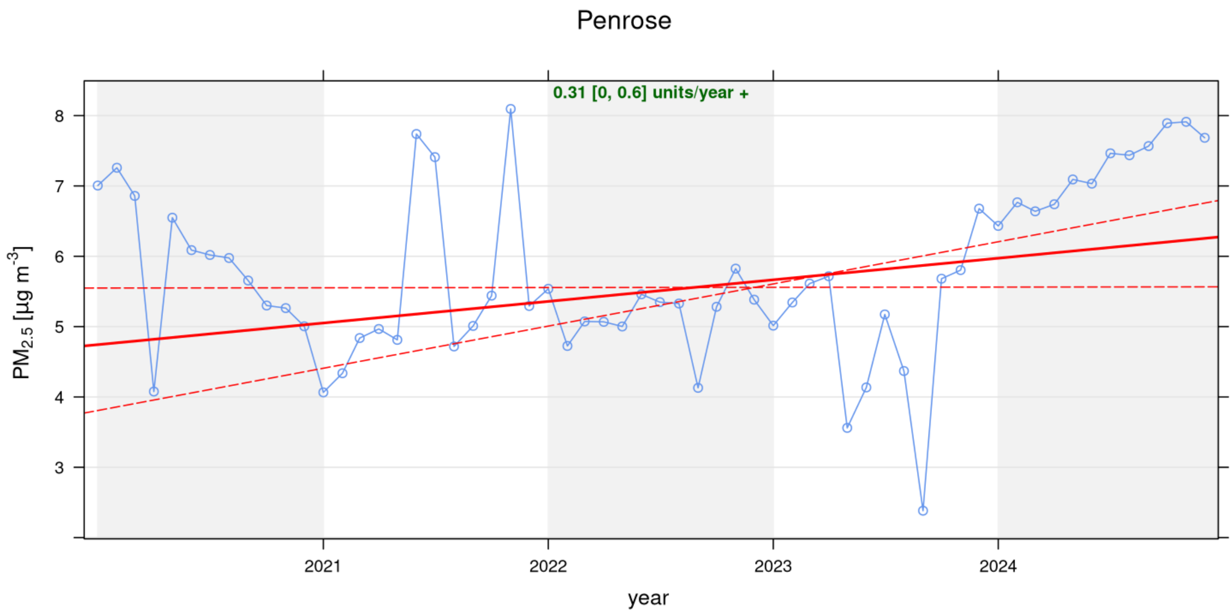


Figure 42. Theil-sen deseasonalised trends for $PM_{2.5}$ at Penrose, 2015-2024 (top) and 2020-2024 (bottom).

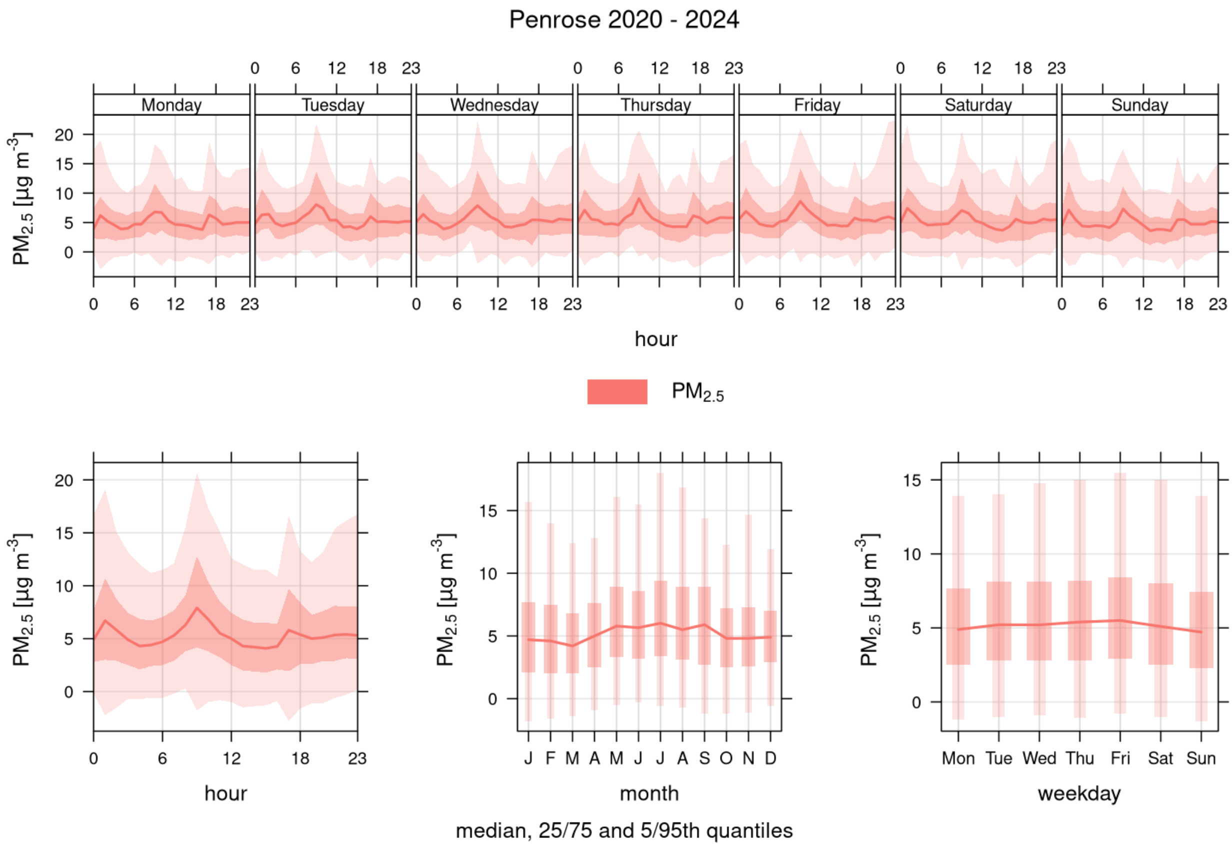


Figure 43. Temporal variability for $PM_{2.5}$ at Penrose, including hourly, weekday and monthly plots, 2020-2024.

NO_2 trends

The deseasonalised long-term trend show a significant year on year reduction in NO_2 since 2015 (0.53 µg/m^3). This trend is also evident in the shorter time frame since 2020 with a decrease of 0.66 µg/m^3 year on year.

The diurnal, annual and weekly variation of NO_2 concentrations show a strong seasonal and diurnal variability, similar to other traffic impacted sites. Concentrations are higher from March to August, and lowest between December and January. The diurnal variability of NO_2 follows the traffic peaks with high concentrations coinciding with the morning and evening commuting rush hour, consistent with NO_2 being primarily driven by traffic sources.

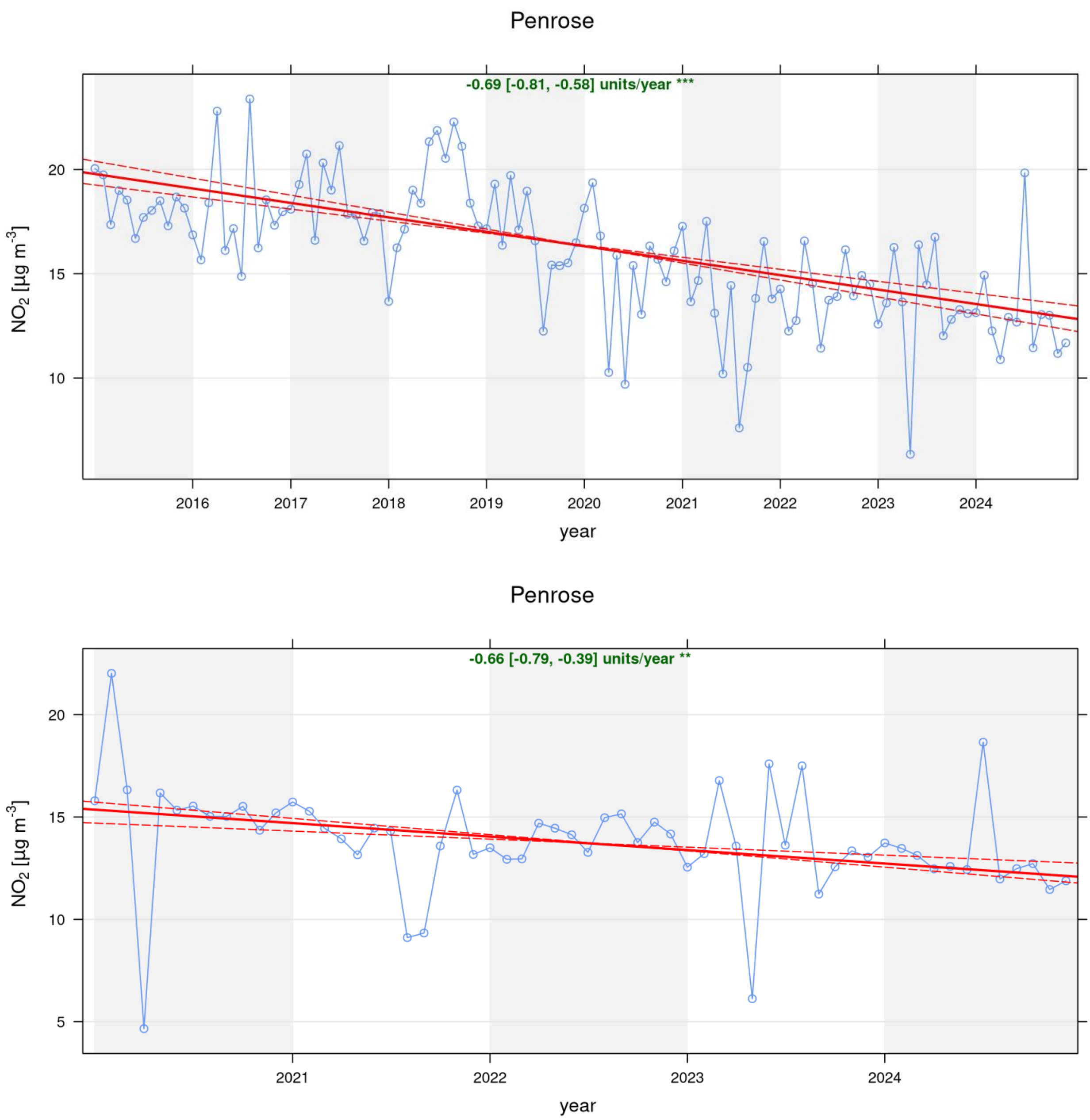


Figure 44. Theil-sen deseasonalised trends for NO_2 at Penrose, 2015-2024 (top) and 2020-2024 (bottom).

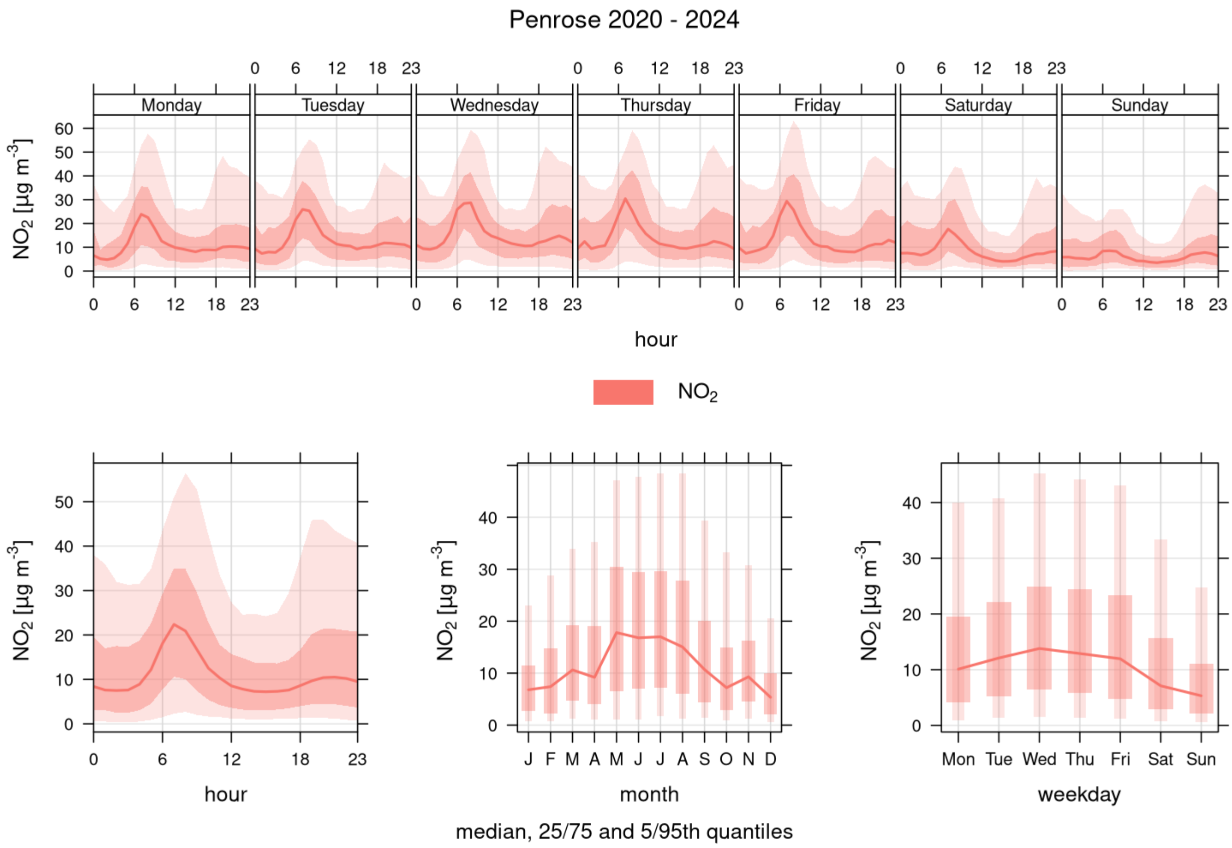
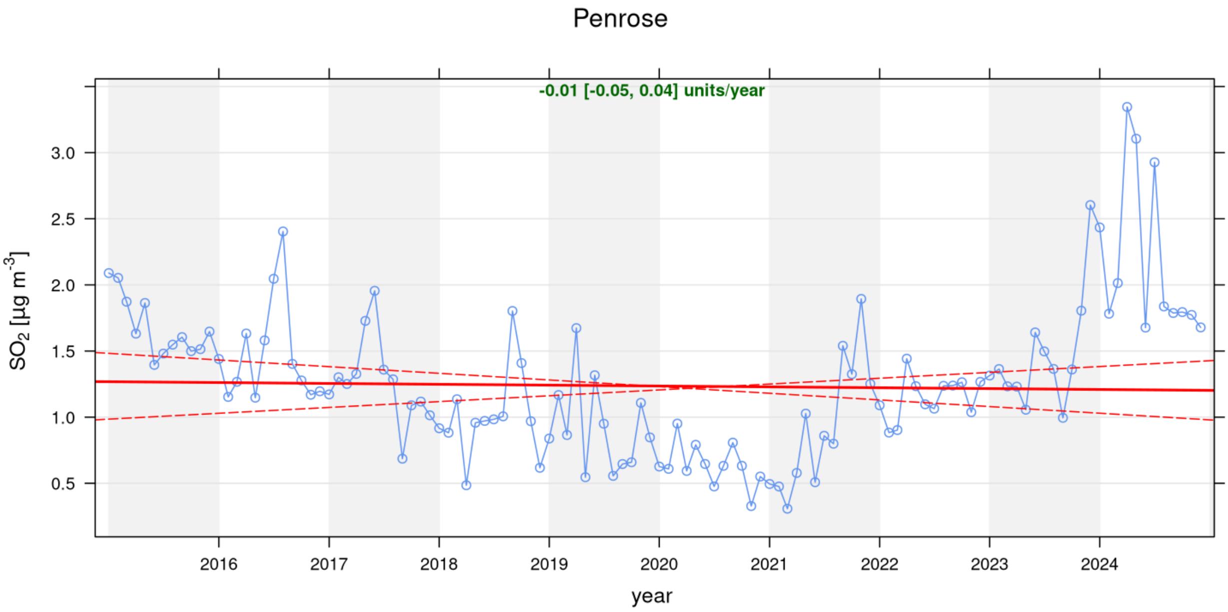


Figure 45. Temporal variability for NO_2 at Penrose, including hourly, weekday and monthly plots, 2020-2024.

Sulphur dioxide trends

The deseasonalised long-term trend analysis shows that since 2015 there hasn't been a significant variation in the SO_2 concentrations at Penrose. However, the shorter timeframe since 2020 has seen a significant year on year increase of SO_2 of 0.39 µg/m^3.

The diurnal, annual and weekly variation of SO_2 concentrations show a subtle seasonal and a strong diurnal variability. Concentrations are slightly elevated in late summer as well as more variable. During the day, the highest concentrations are after 6am which coincides with the morning rush hour, but the absence of an evening peak indicates that this is more likely related to industrial activities than traffic.



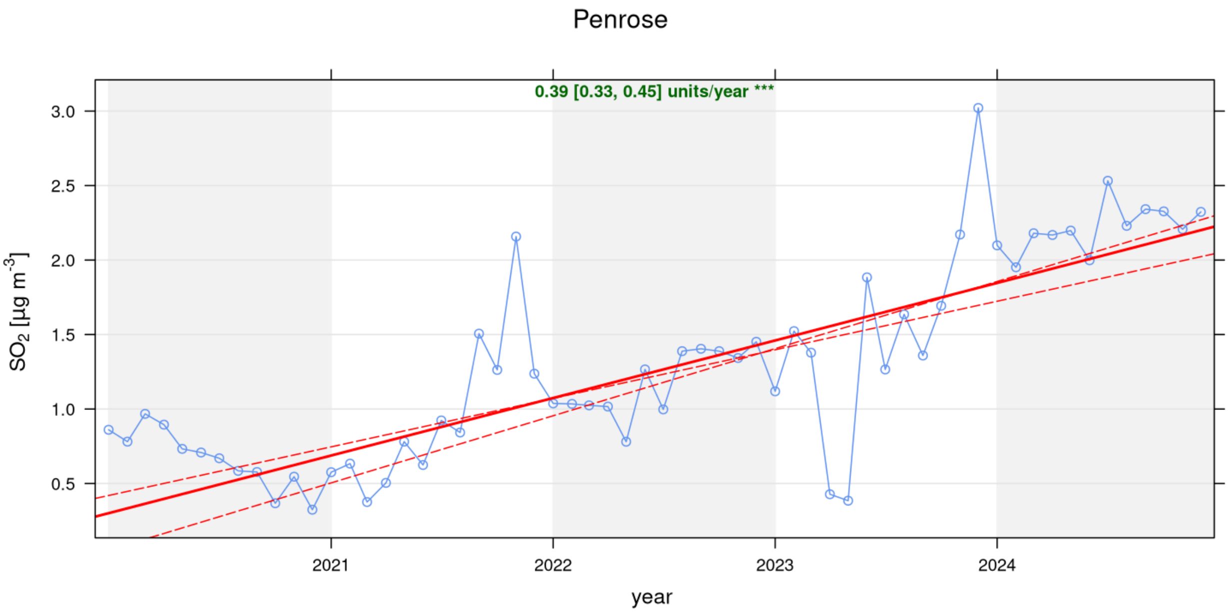


Figure 46. Theil-sen deseasonalised trends for SO_2 at Penrose, 2015-2024 (top) and 2020-2024 (bottom).

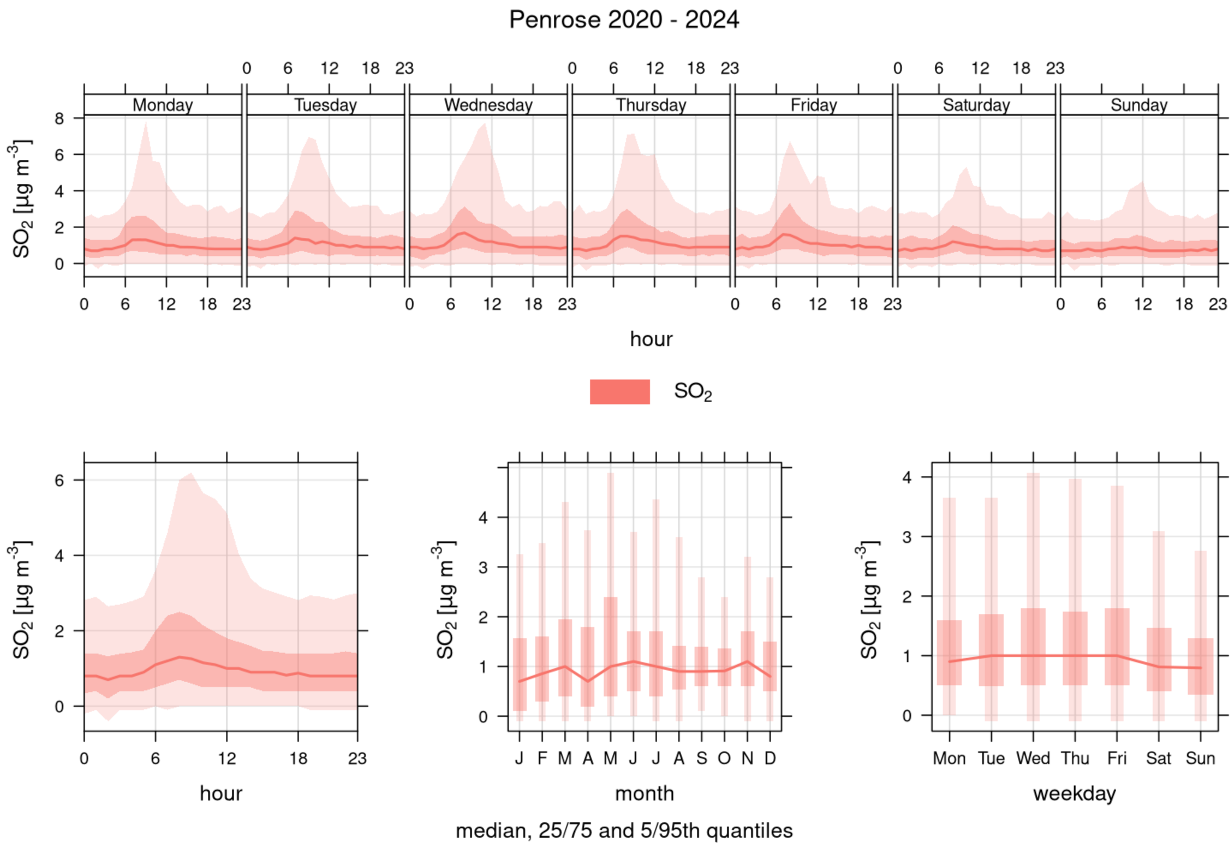


Figure 47. Temporal variability for SO_2 at Penrose, including hourly, weekday and monthly plots, 2020-2024.

Queen Street

Site description

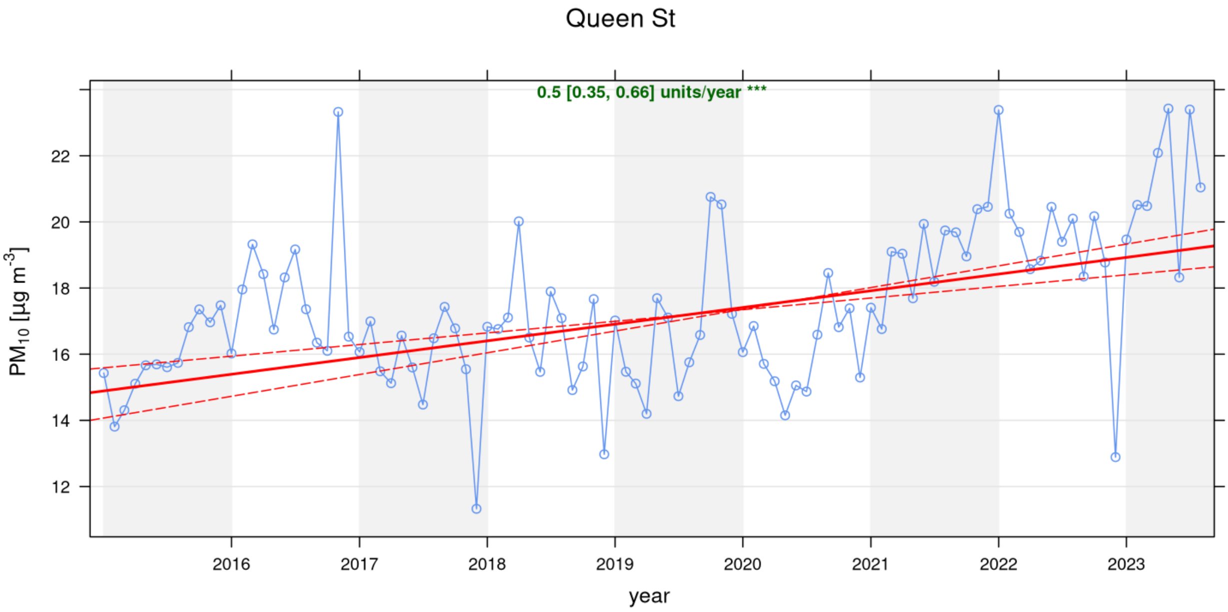
Queen Street monitoring station is located on a first-floor canopy on the corner of Queen Street and Wyndham Street (Figure 48). The key emission source measured at this site is combustion emissions from vehicle exhausts (Talbot et al., 2017). This site provides information on possible personal exposure in one of the most densely populated areas of Auckland with several million people walking below the monitoring site every year (Talbot & Lehn, 2018). The site was unavailable since August 2023 due to significant structural work to the building where it is located.

Figure 48. Map of the location of Queen Street air quality monitoring site (Google Maps 2018).

PM_{10} trends

The deseasonalised long-term analysis shows a significant increase in PM_{10} since 2015 (0.5 $\mu g/m^3$ year on year). This trend has been accelerated since 2020 with a year on year increase of 1.3 $\mu g/m^3$.

The diurnal, annual and weekly variation of PM_{10} concentrations show a small increase in July with a diurnal pattern that mirrors the activity of the city, but without the morning and evening rush hour peaks.



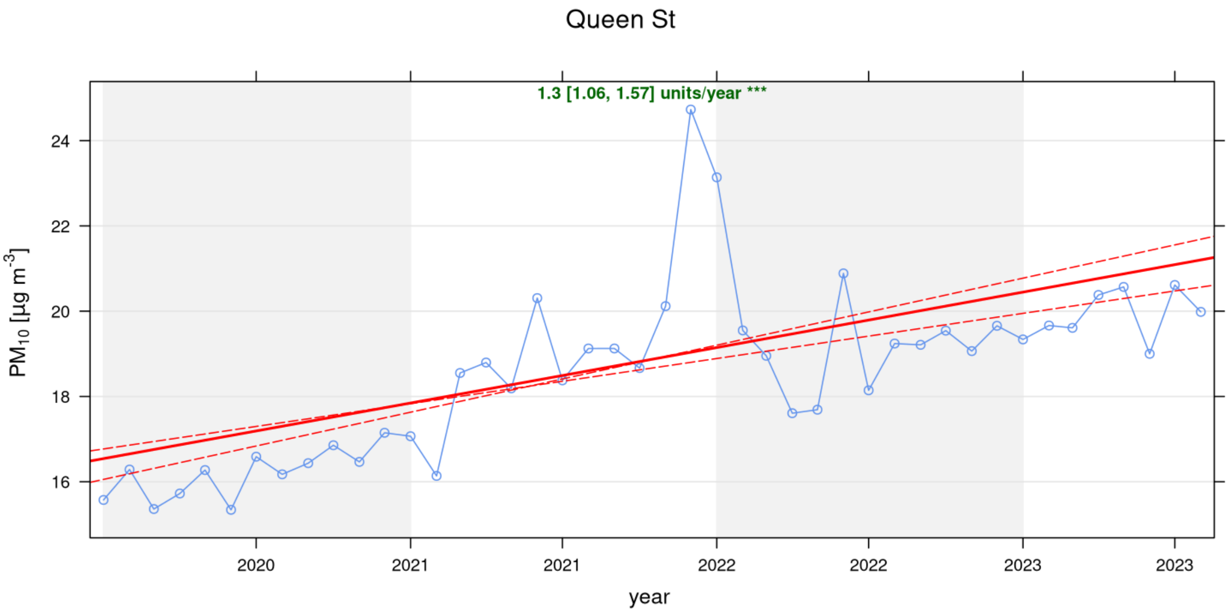


Figure 49. Theil-sen deseasonalised trends for PM_{10} at Queen Street, 2015-2024 (top) and 2020-2024 (bottom).

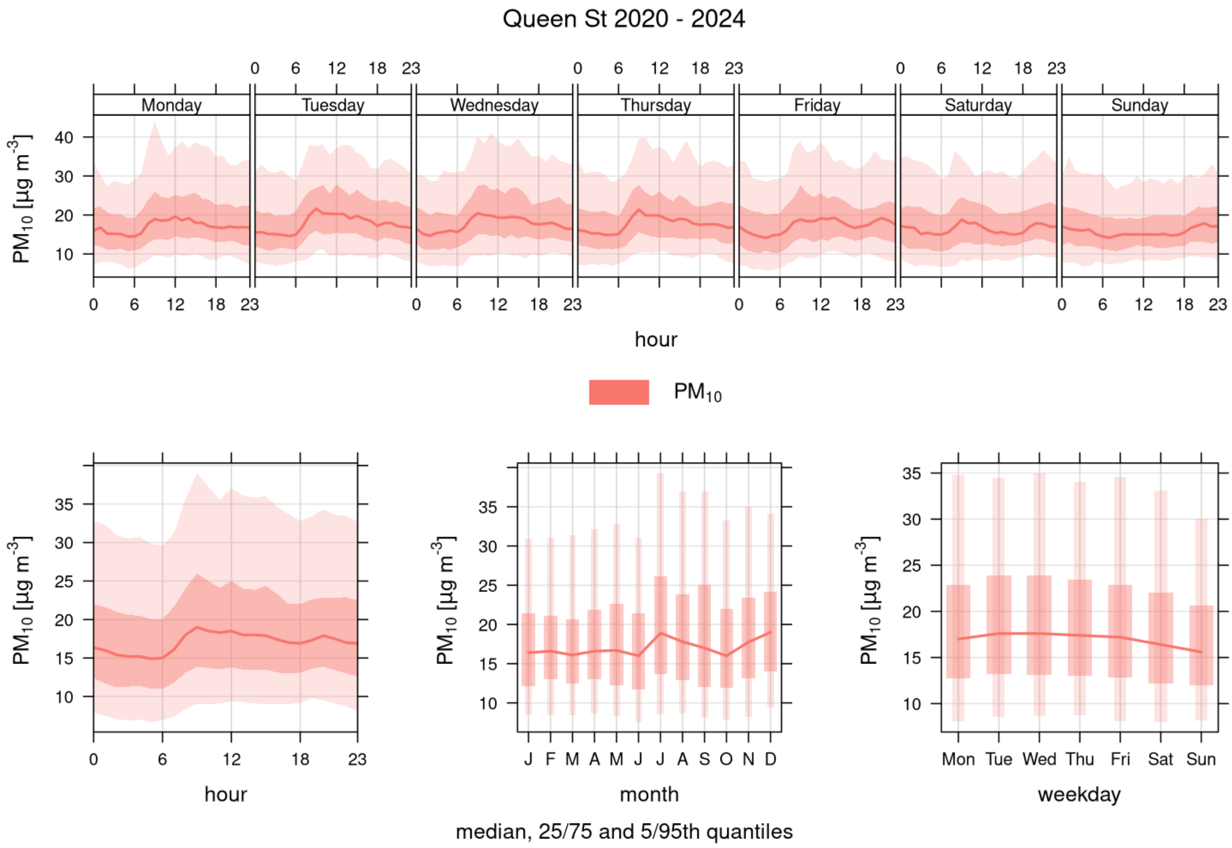
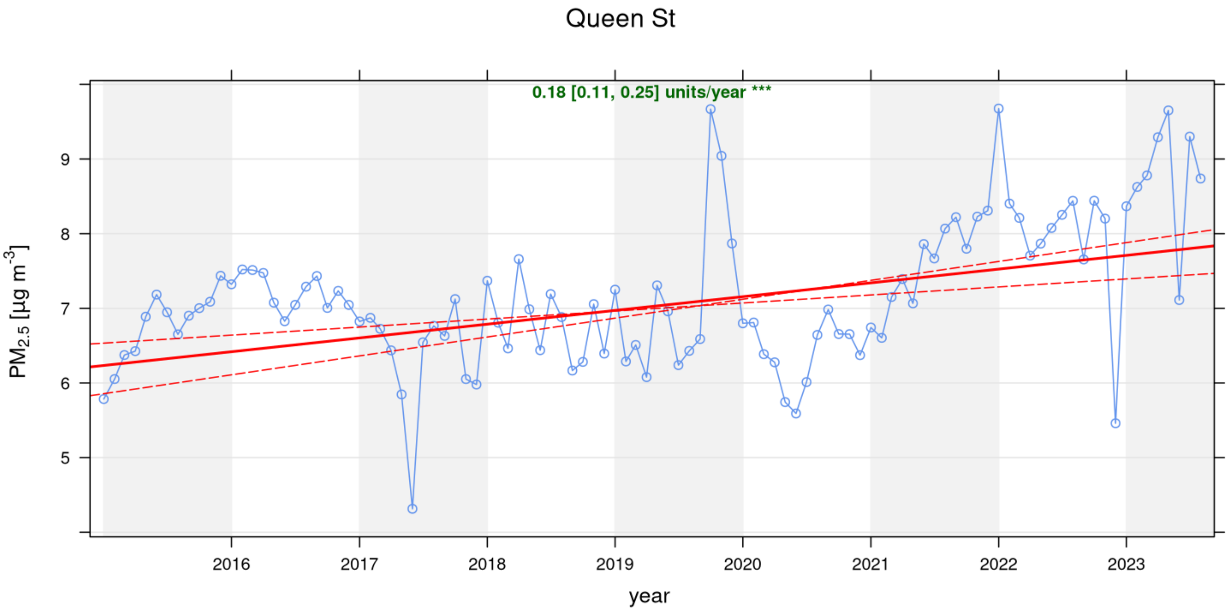


Figure 50. Temporal variability for PM_{10} at Queen Street, including hourly, weekday and monthly plots, 2020-2024.

$PM_{2.5}$ trends

Similarly to PM_{10}, the deseasonalised long-term analysis shows a significant increase in $PM_{2.5}$ since 2015 (0.18 µg/m^3 year on year) and an acceleration of this trend since 2020 with a year on year increase of 0.67 µg/m^3.

The diurnal, annual and weekly variation of $PM_{2.5}$ concentrations show a small increase in July, also observed in the PM_{10} concentrations. The diurnal pattern, however, is different from that for PM_{10} with generally lower concentrations during the day and a peak observed after 6pm. With $PM_{2.5}$ responding more to traffic than PM_{10}, this indicates that the source of PM_{10} concentrations is not direct traffic emissions which is consistent with construction activity being the main source of PM_{10} and traffic for $PM_{2.5}$.



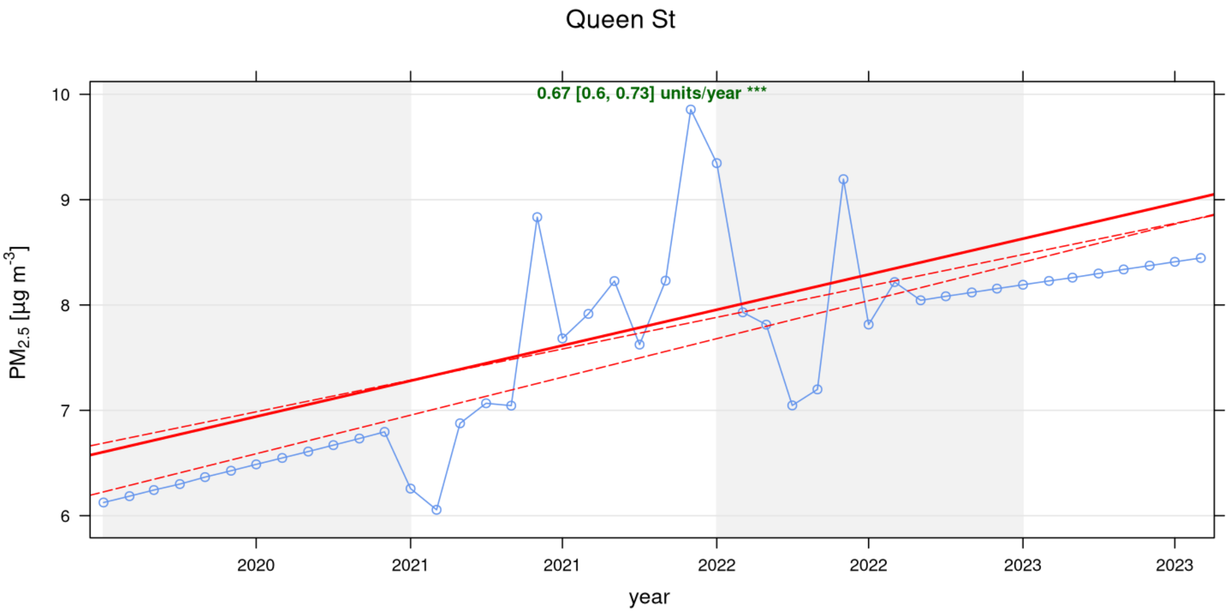


Figure 51. Theil-sen deseasonalised trends for $PM_{2.5}$ at Queen Street, 2015-2024 (top) and 2020-2024 (bottom).

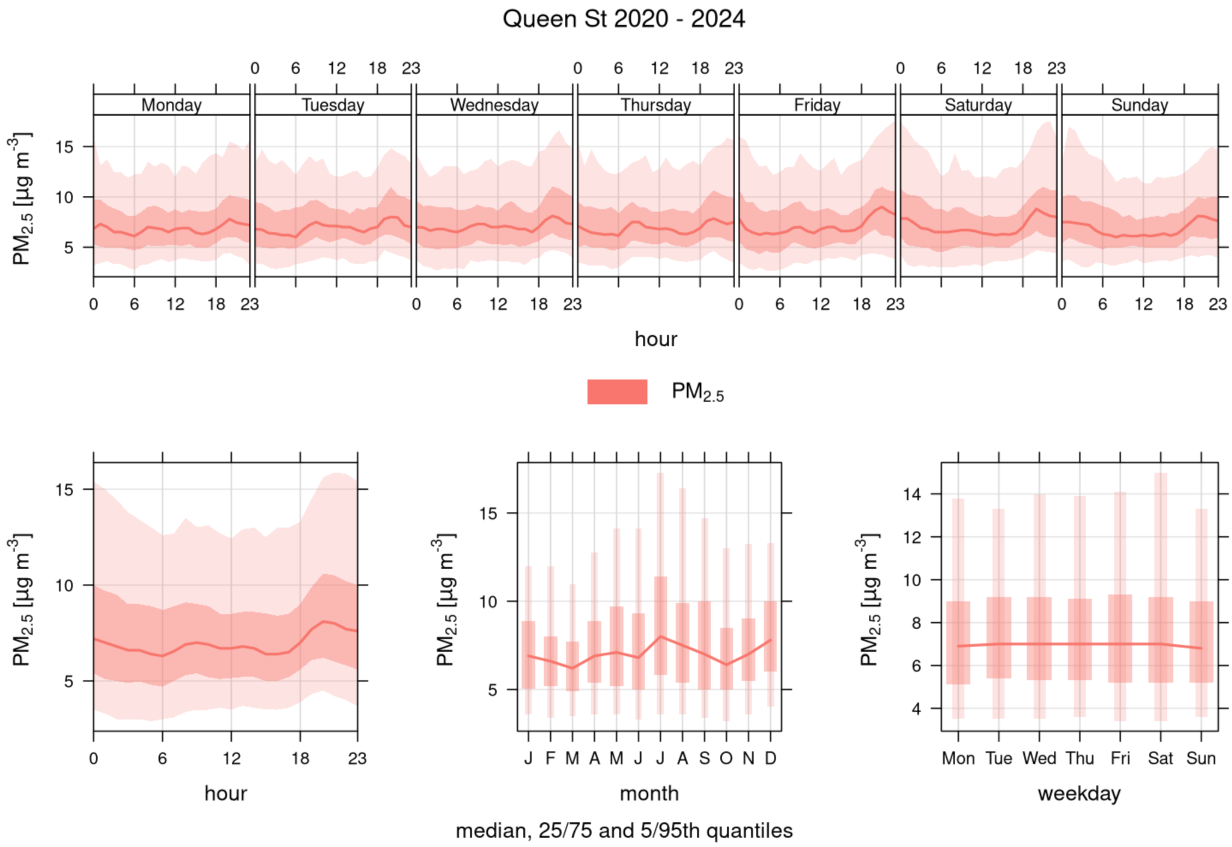


Figure 52. Temporal variability for $PM_{2.5}$ at Queen Street, including hourly, weekday and monthly plots, 2020-2024.

NO_2 trends

The deseasonalised long-term trend show a significant reduction of NO_2 concentrations since 2015 that has accelerated after 2020. Since 2015 the year on year decrease has been of 1.92 µg/m^3 while since 2020 that reduction has increased to 5.88 µg/m^3 year on year since.

The diurnal, annual and weekly variation of NO_2 concentrations show a strong seasonal and diurnal variability. Concentrations increase steadily from April to July and then decrease until January. The diurnal variability of NO_2 follows the traffic peaks with high concentrations coinciding with the morning and evening commuting rush hour, consistent with NO_2 being primarily driven by traffic sources. However, the difference between the rush hours and the non-rush hour daytime hours is much smaller than in other sites, indicating that the activity in the city centre is more consistent during the day.

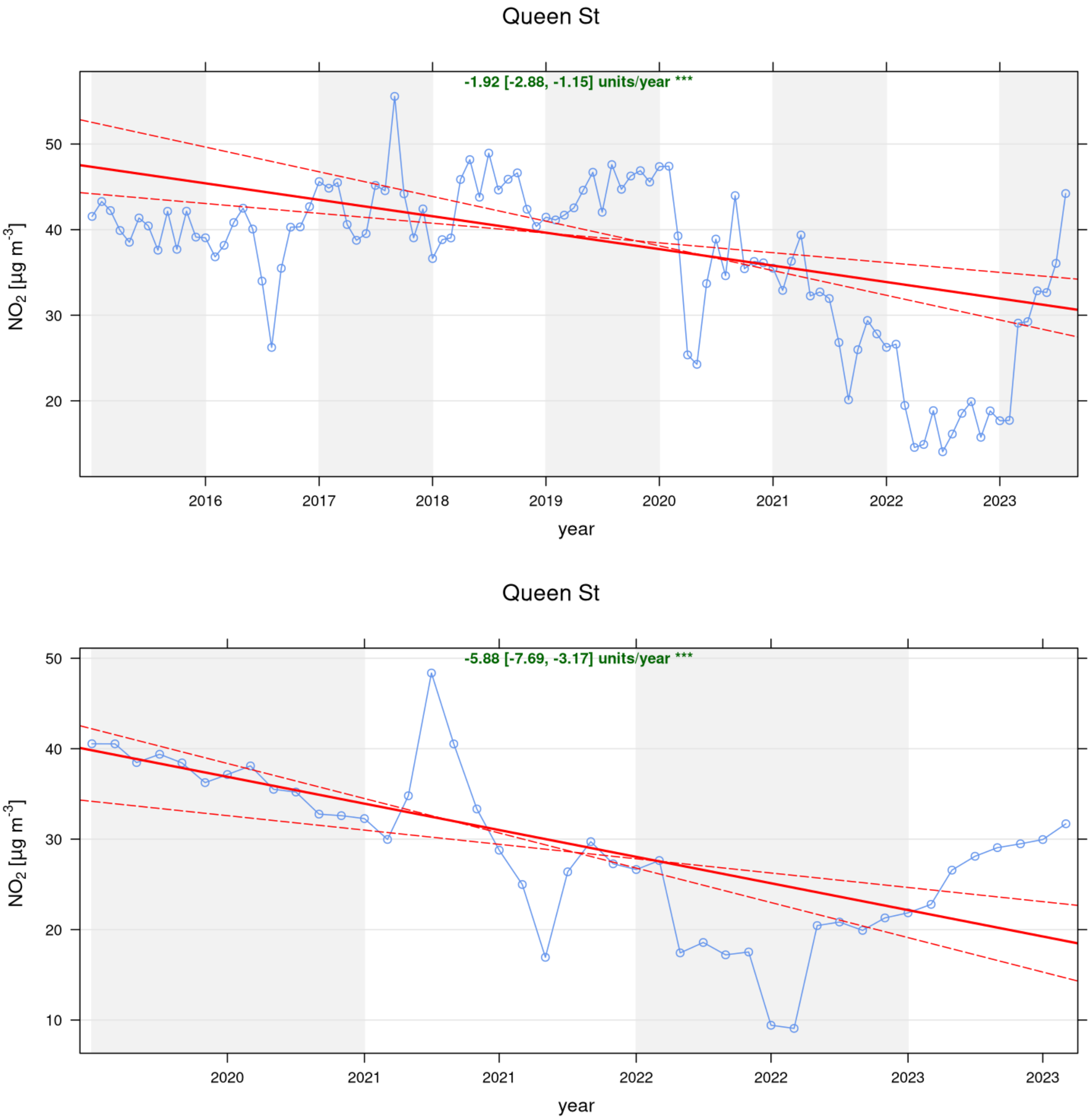


Figure 53. Theil-sen deseasonalised trends for NO_2 at Queen Street, 2015-2024 (top) and 2020-2024 (bottom).

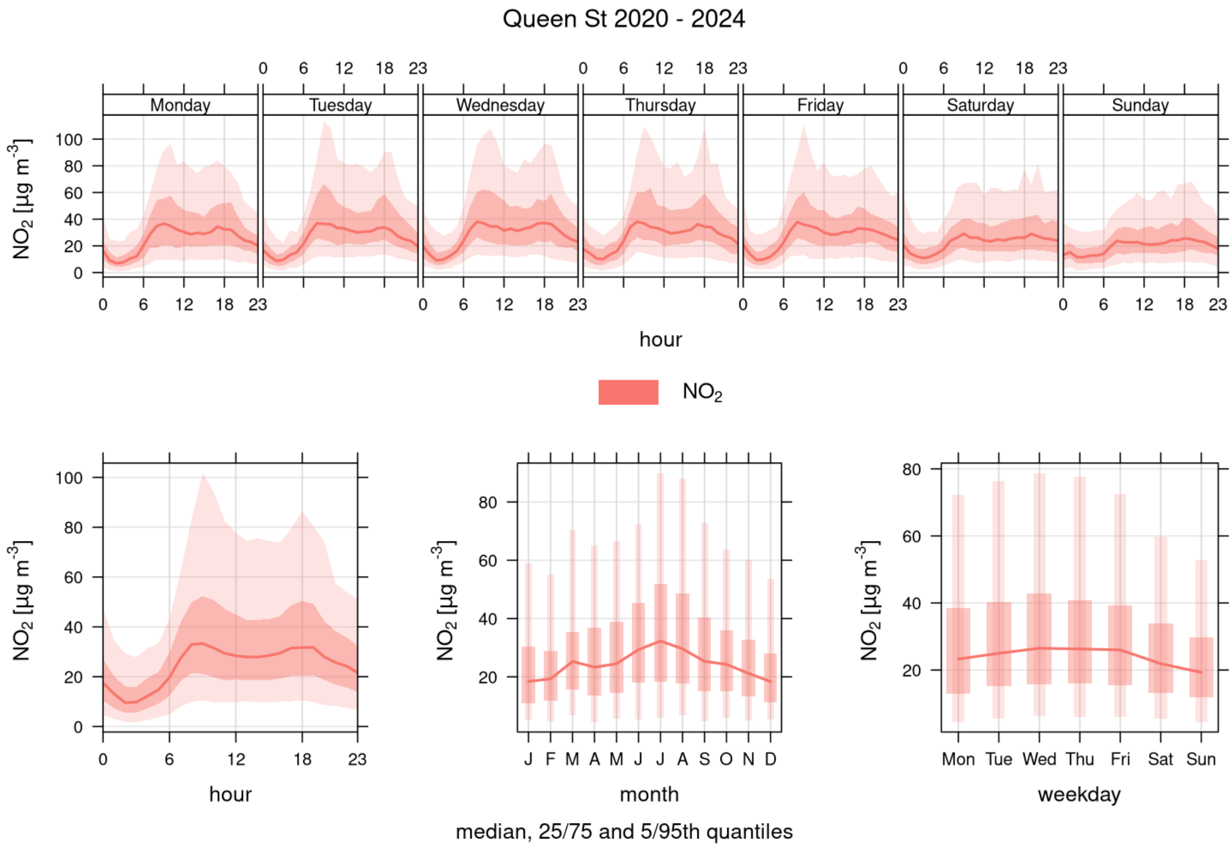


Figure 54. Temporal variability for NO_2 at Queen Street, including hourly, weekday and monthly plots, 2020-2024.

Glen Eden

Site description

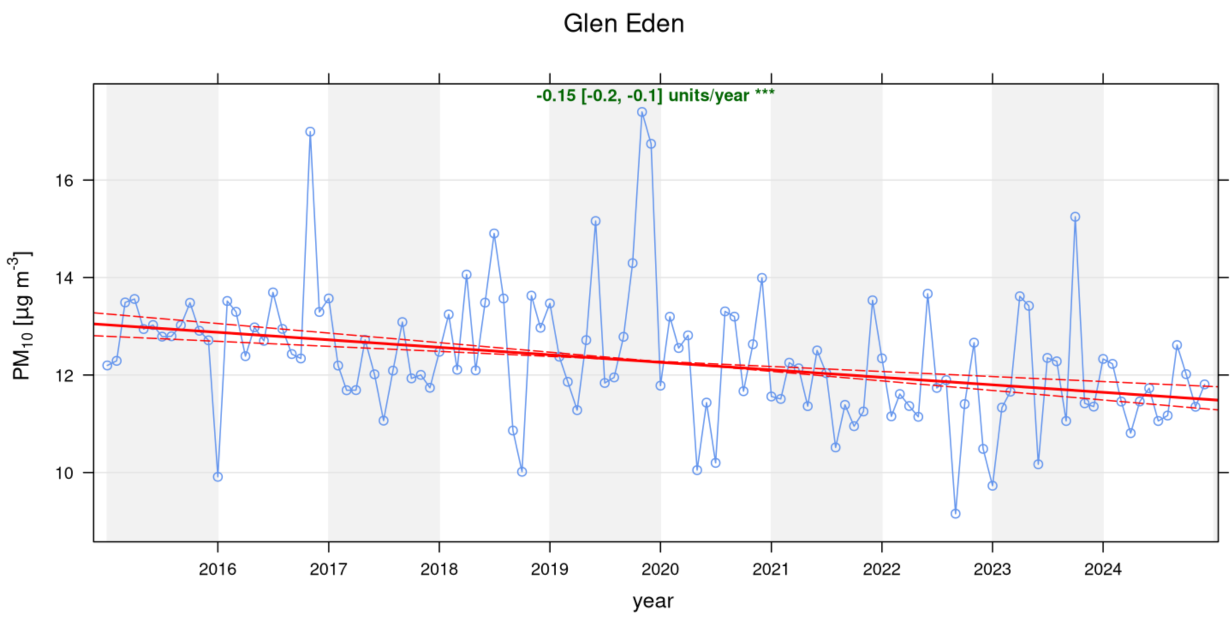
The Glen Eden monitoring site is set away from immediate air pollution sources and as such, can be referred to as an urban background site (Figure 55). Most houses in the immediate area date from the 1980s and newer (medium-sized sections, few chimneys), but the area to the north has more older houses (1960s) on larger sections. Over the past few years, a significant intensification of the area has taken place.

Figure 55. Map of the location of Glen Eden air quality monitoring site (Google Maps 2018).

PM_{10} trends

The deseasonalised long-term trend show a 0.15 µg/m^3 year on year reduction in PM_{10} since 2015. For the period from 2020, that trend has remained largely constant with a year on year reduction of 0.13 µg/m^3 between 2020 and 2024.

The diurnal, annual and weekly variation of PM_{10} concentrations indicate a small seasonal variability with higher concentrations during the winter months and a subtle diurnal cycle with lower concentrations around 6am and mostly uniform concentrations during the rest of the day.



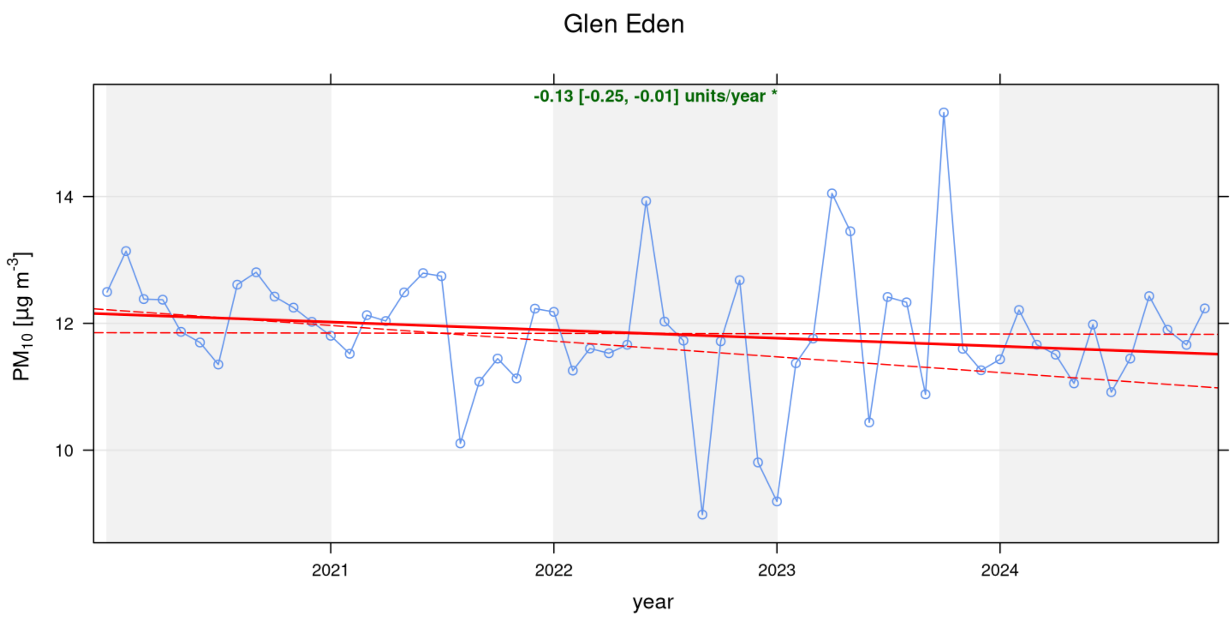


Figure 56. Theil-sen deseasonalised trends for PM_{10} at Glen Eden, 2015-2024 (top) and 2020-2024 (bottom).

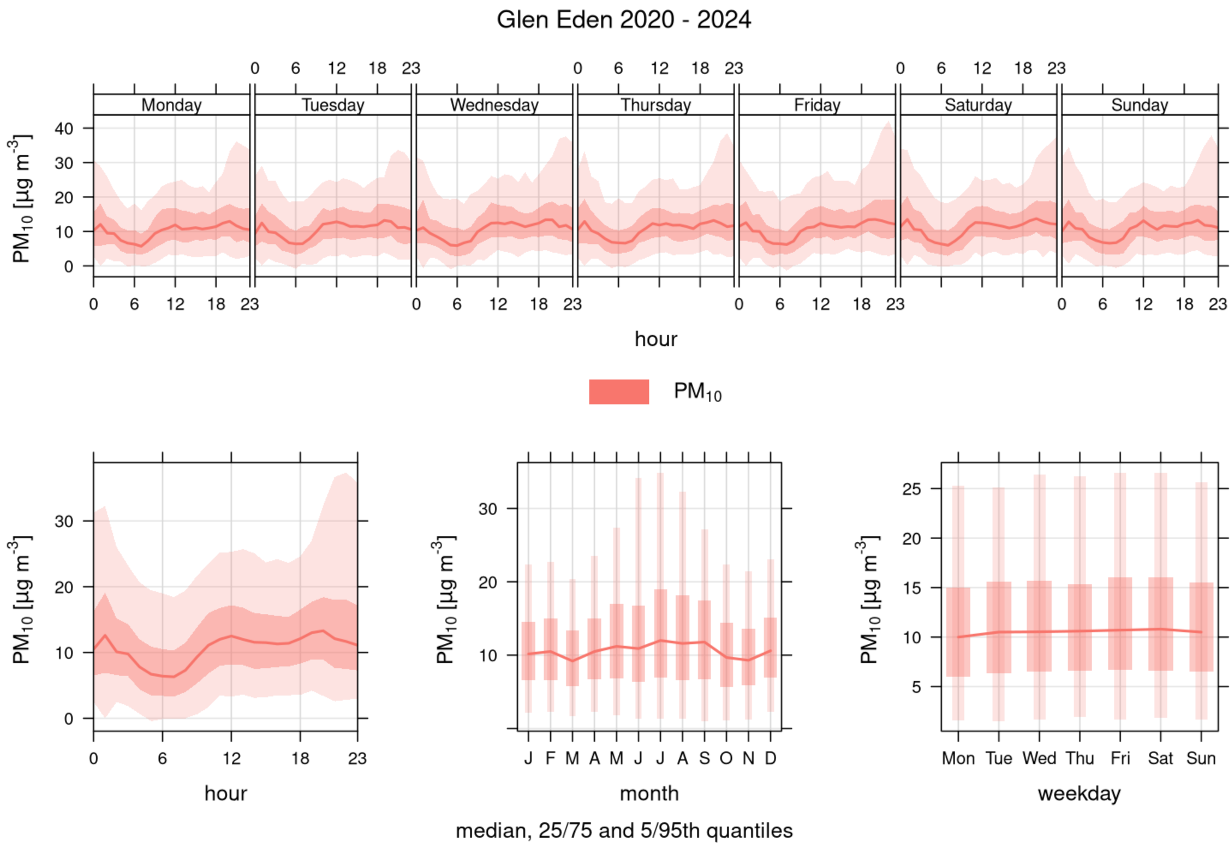
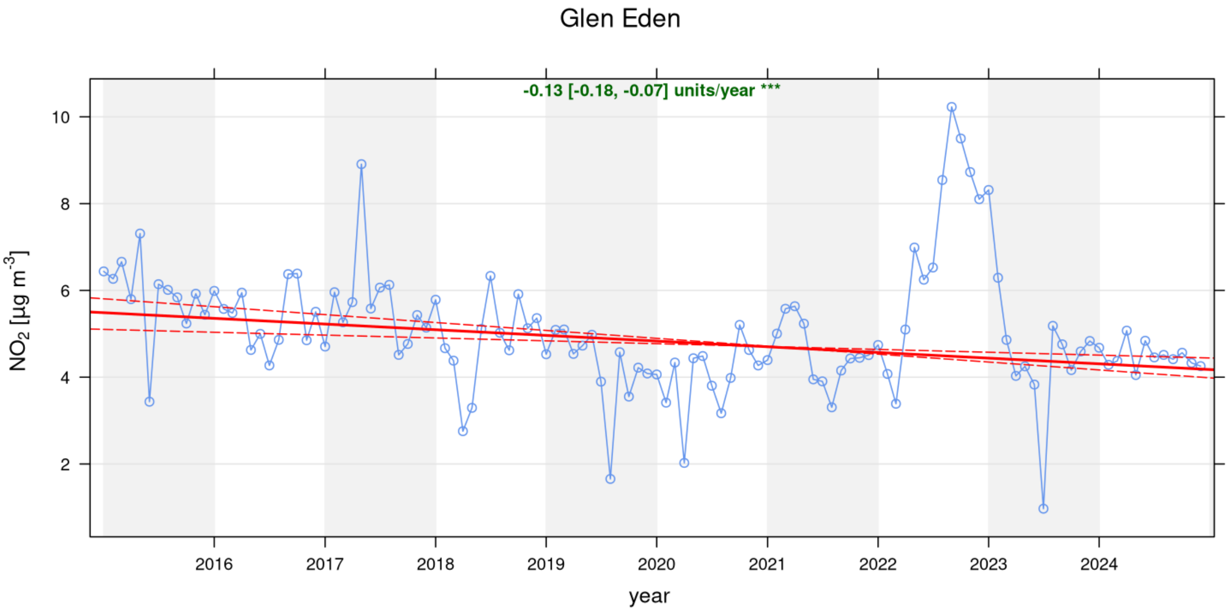


Figure 57. Temporal variability for PM_{10} at Glen Eden, including hourly, weekday and monthly plots, 2020-2024.

NO_2 trends

The deseasonalised long-term trend show a 0.13 µg/m^3 year on year reduction in NO_2 since 2015, but a reversal of that trend since 2020 with a year on year increase of 0.11 µg/m^3 between 2020 and 2024.

The diurnal, annual and weekly variation of NO_2 concentrations at the Henderson site indicate a strong seasonal and diurnal variability. Concentrations are higher in winter and during the morning and evening commuting rush hour, consistent with NO_2 being primarily driven by traffic sources and with this site being in a suburban area where most traffic activity is commuting to and from work.



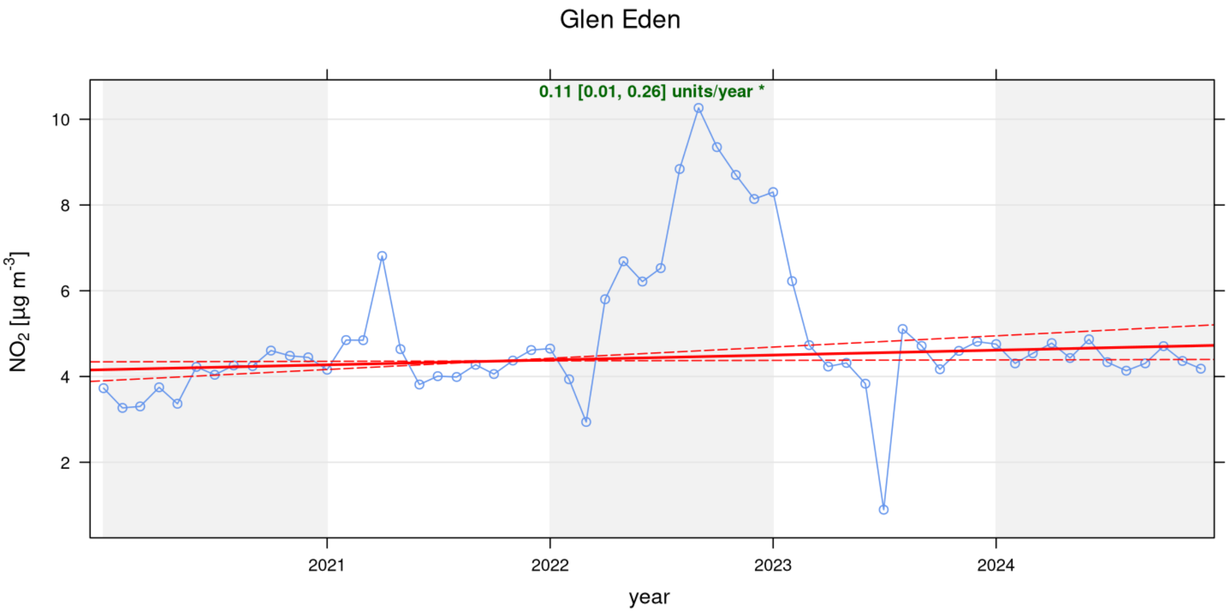


Figure 58. Theil-sen deseasonalised trends for NO_2 at Glen Eden, 2015-2024 (top) and 2020-2024 (bottom).

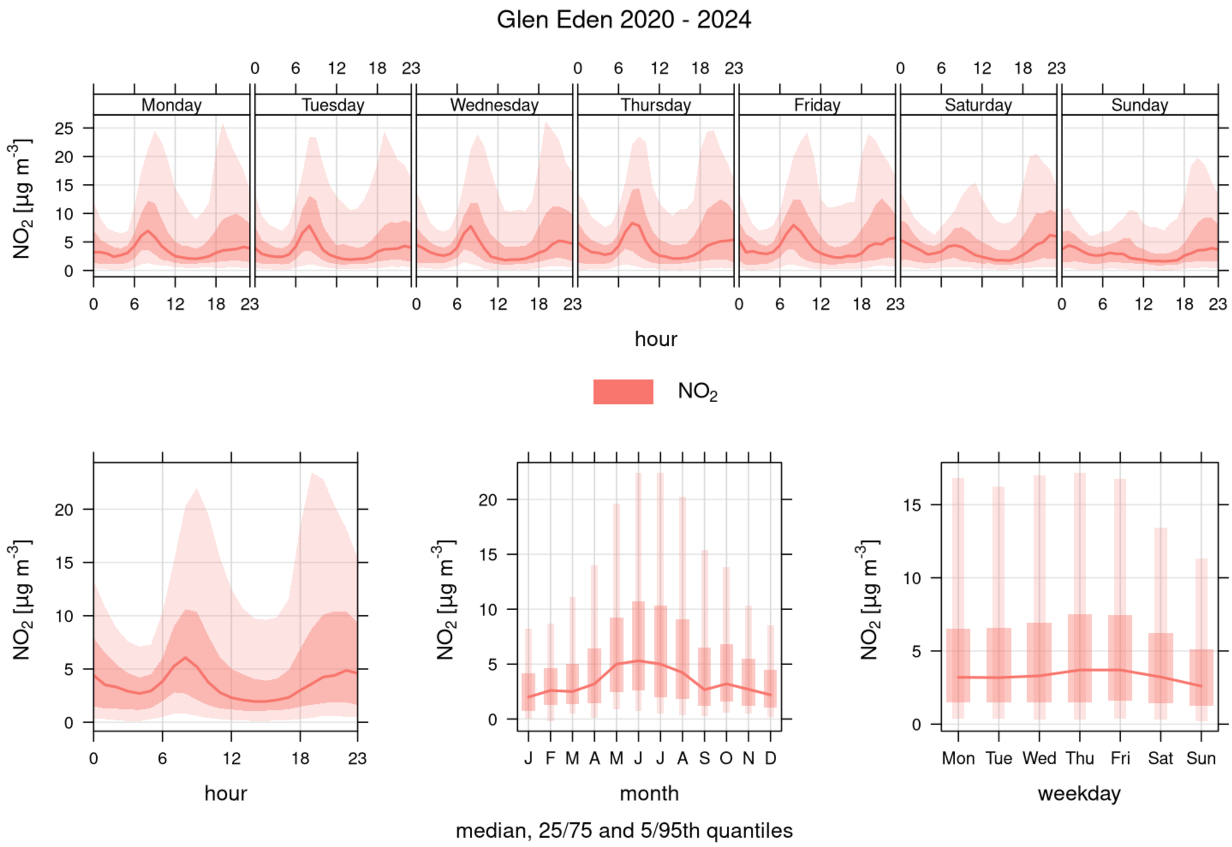


Figure 59. Temporal variability for PM_{10} at Glen Eden, including hourly, weekday and monthly plots, 2020-2024.

Pakuranga

Site description

The Pakuranga air quality monitor is in the southwest corner of Bell Reserve about 75 m from Pakuranga Road (Figure 60). The Pakuranga monitor only measures PM_{10} and meteorology. Houses in the area are of mixed age – from 1960s to <5 years old, mostly on medium sized sites. About 50% of houses have chimneys. Pakuranga Road is a major arterial road carrying around 25,000 vehicles per day.

Figure 60. Map of the location of Pakuranga air quality monitoring site (Google Maps 2018).

PM_{10} trends

The deseasonalised long-term trend show a 0.26 $\mu g/m^3$ year on year reduction in PM_{10} since 2015. However, since 2020, that trend has been reversed and it now shows an increase of 0.59 $\mu g/m^3$ year on year between 2020 and 2024.

Similarly to other residential sites , the diurnal, annual and weekly variation of PM_{10} concentrations indicate a small seasonal variability with higher concentrations during the winter months and a subtle diurnal cycle with lower concentrations around 6am and mostly uniform concentrations during the rest of the day.

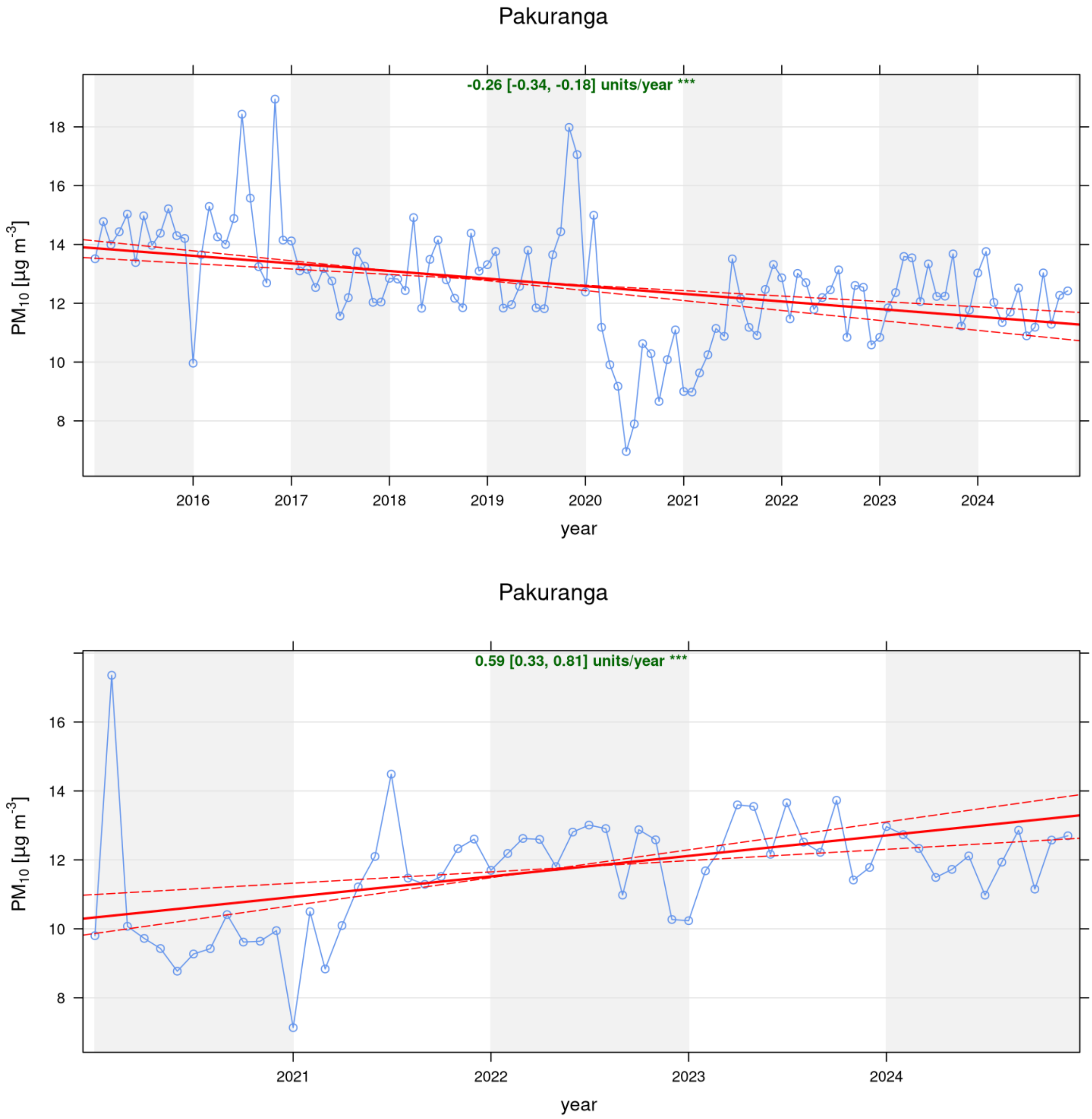


Figure 61. Theil-sen deseasonalised trends for PM_{10} at Pakuranga, 2015-2024 (top) and 2020-2024 (bottom).

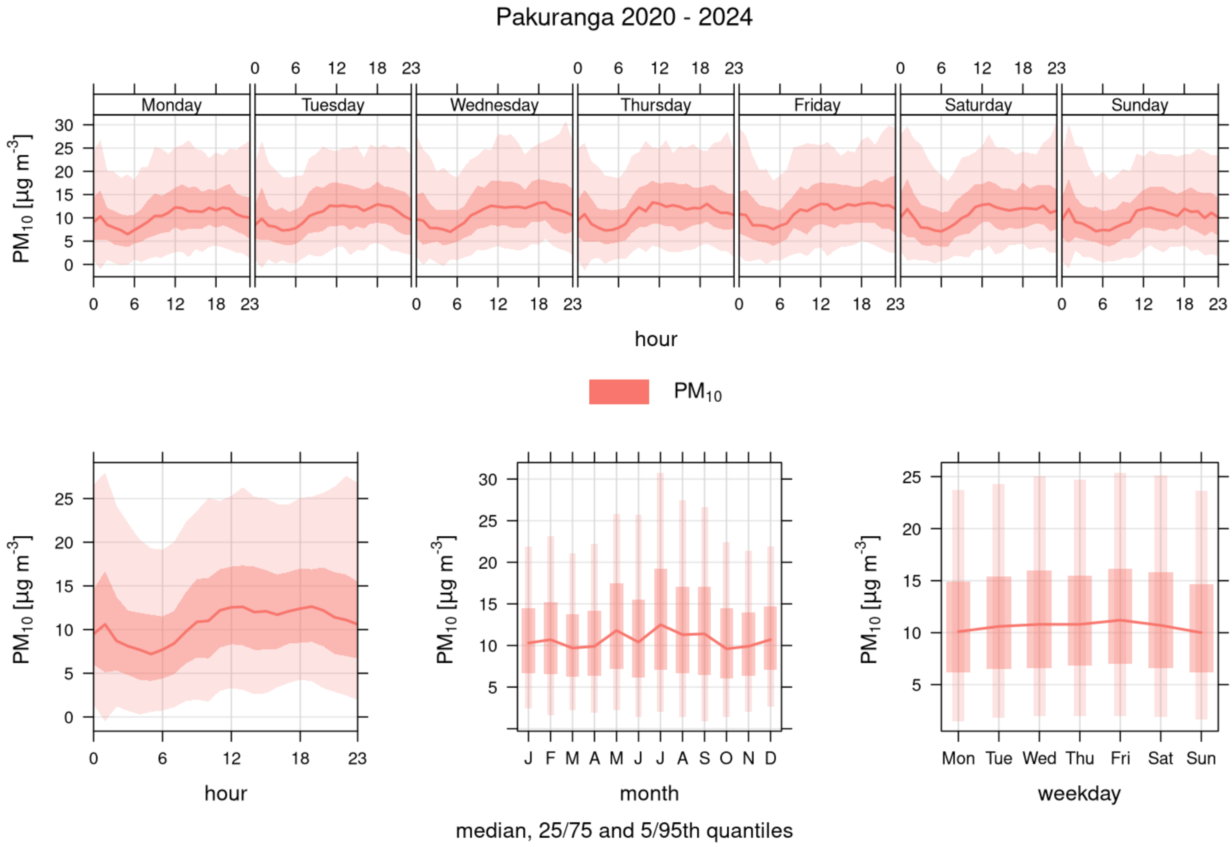


Figure 62. Temporal variability for PM_{10} at Pakuranga, including hourly, weekday and monthly plots, 2020-2024.

$PM_{2.5}$ trends

$PM_{2.5}$ measurements at Pakuranga started only in 2018 so no long-term trend could be established before 2020. Since 2020, the $PM_{2.5}$ concentrations have remained largely constant with no statistically significant year on year change.

The diurnal, annual and weekly variation of $PM_{2.5}$ concentrations are consistent with a site impacted by residential wood burning. $PM_{2.5}$ concentrations are significantly higher in July and the diurnal cycle shows higher concentrations during nighttime, particularly around midnight and no significant impact of traffic around the rush hours.

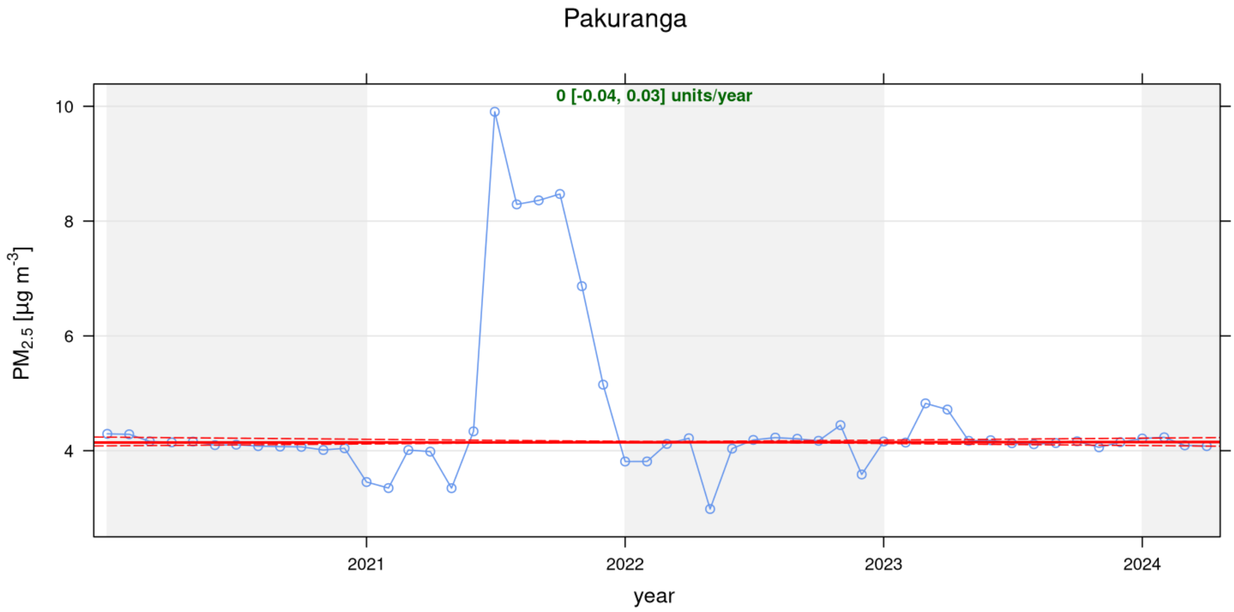


Figure 63. Theil-sen deseasonalised trends for $PM_{2.5}$ at Pakuranga between 2020-2024.

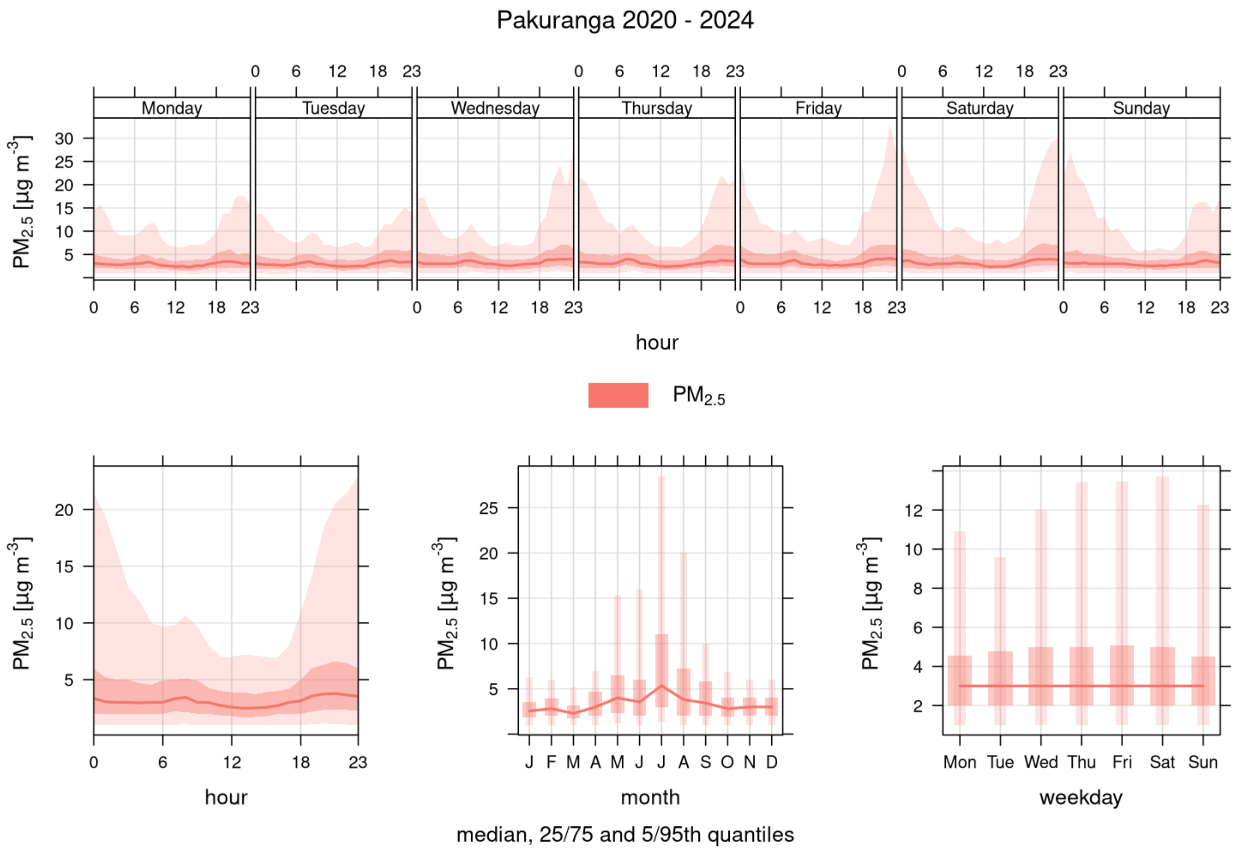


Figure 64. Temporal variability for $PM_{2.5}$ at Pakuranga, including hourly, weekday and monthly plots, 2020-2024.

Customs Street

Site description

The Customs Street air quality monitor is in the newest site in the network. It became operational in 2019 and it sits on the south side of Customs Street West, between Queen Street and Albert Street (Figure 65). The Customs street site also serves as a testing site for new instrumentation as the mix of sources impacting it is very wide. This site is also the main port surveillance site.

Figure 65. Map of the location of Customs Street air quality monitoring site (Google Maps 2018).

$PM_{2.5}$ trends

The deseasonalised trend analysis show a steady decrease in $PM_{2.5}$ since 2020 of 0.2 $\mu g/m^3$ year on year. The diurnal, annual and weekly variation of $PM_{2.5}$ concentrations indicate a small seasonal variability with concentrations increasing between March and September, followed by a sharp decrease until December. The diurnal variation shows similar features to Queen Street but with a more marked impact of traffic as the morning and evening rush hour peaks more evident.

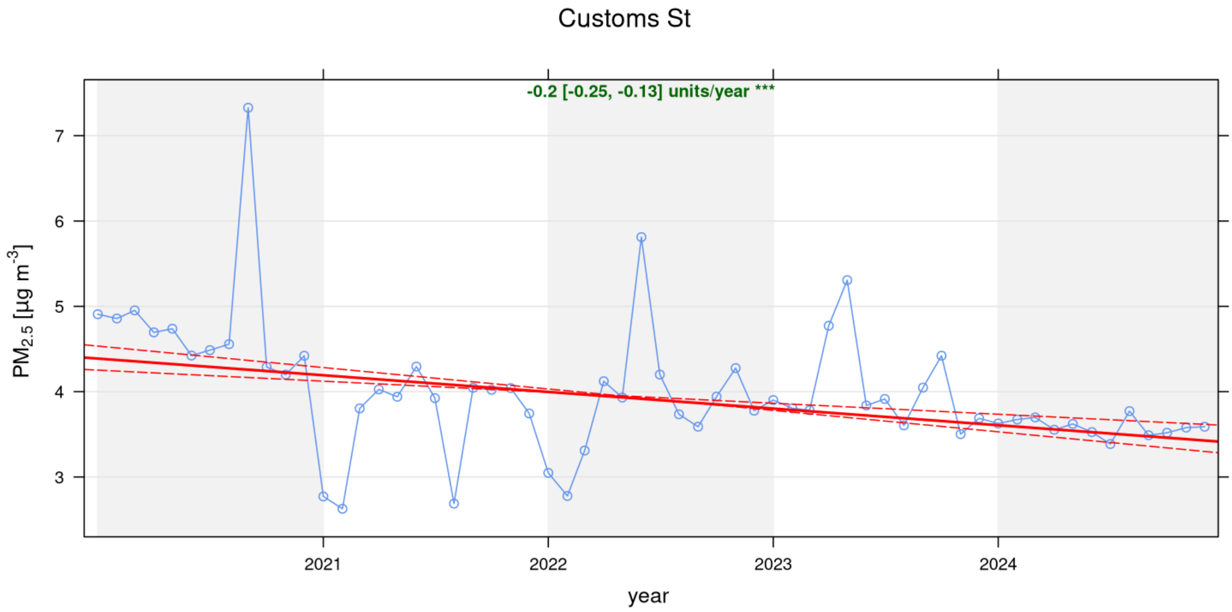


Figure 66. Theil-sen deseasonalised trends for $PM_{2.5}$ at Customs Eden, 2020-2024.

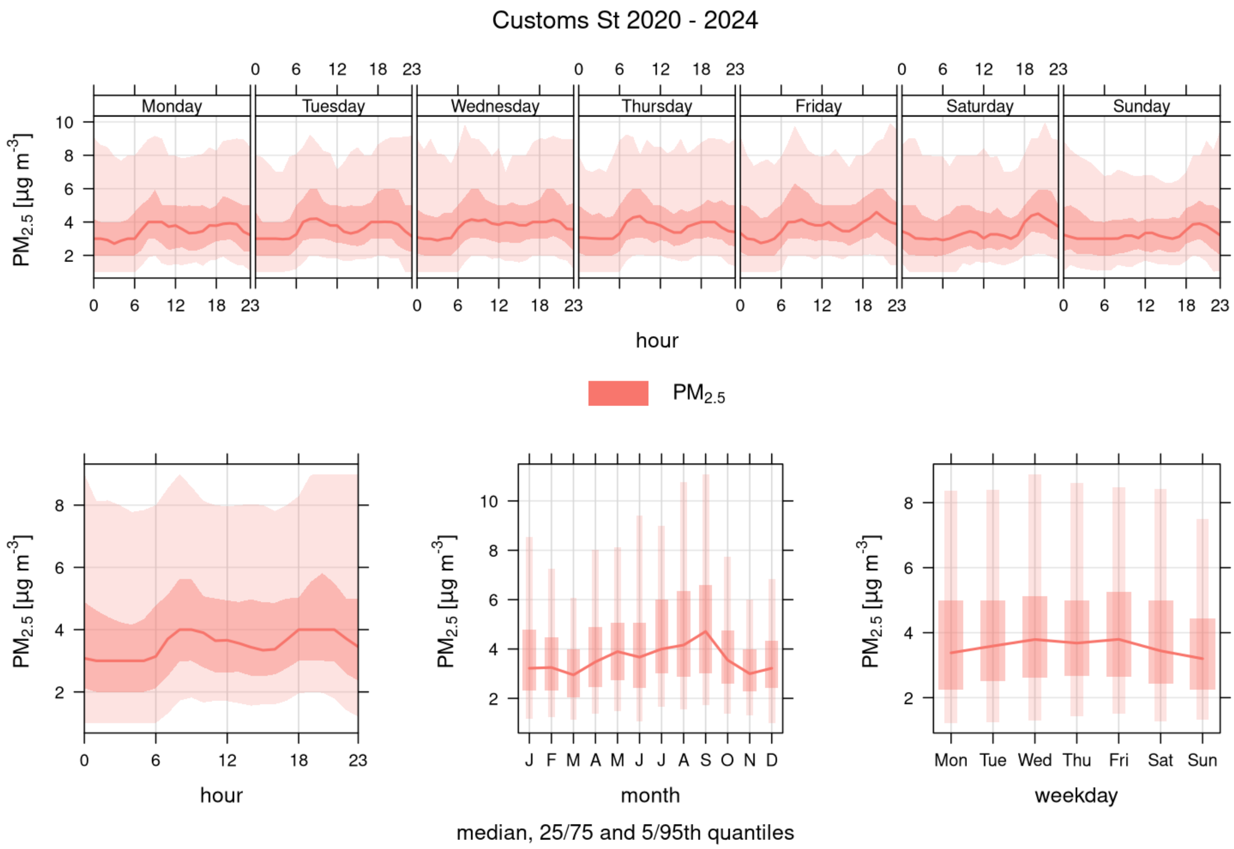


Figure 67. Temporal variability for $PM_{2.5}$ at Customs Street, including hourly, weekday and monthly plots, 2020-2024.

Black Carbon (BC) trends

Black carbon concentrations show a steady decline with a long-term trend of 31.25 ng/m^3 reduction year on year since 2020.

The seasonal and diurnal variation shows that BC is a specific marker of traffic. Winter concentrations are only slightly higher than the rest of the year. However, the diurnal cycle shows significant peaks in concentrations coinciding with the morning and evening rush hour, albeit more aligned to the "workplace departure time" which is about an hour earlier than the arrival time.

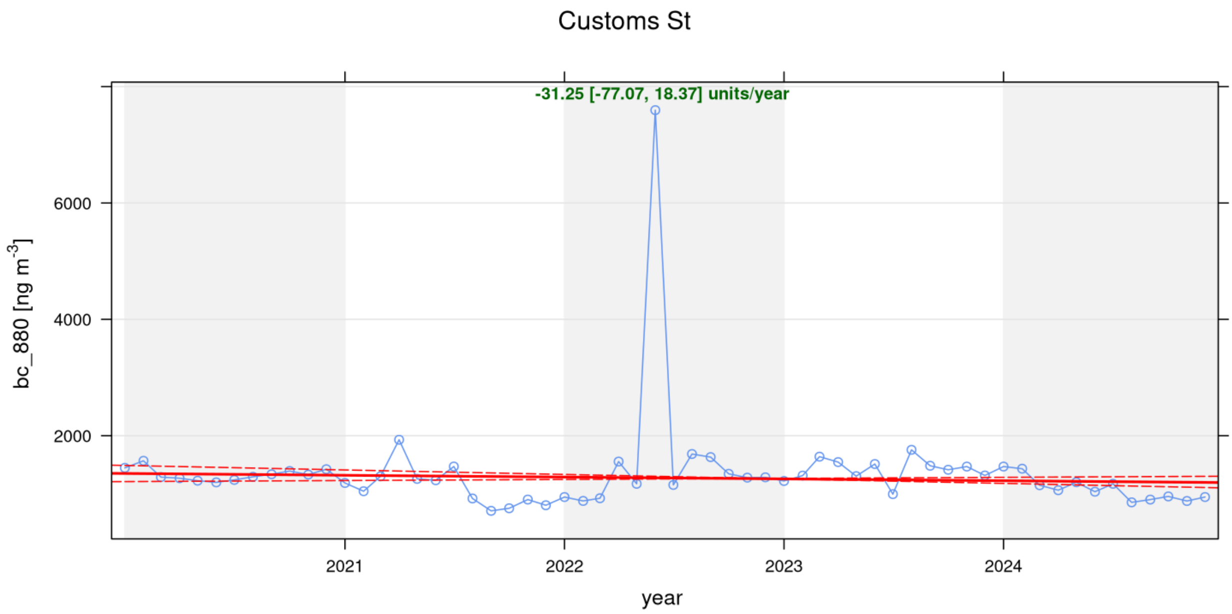


Figure 68. Theil-sen deseasonalised trends for Black Carbon at Customs Street between 2020-2024.

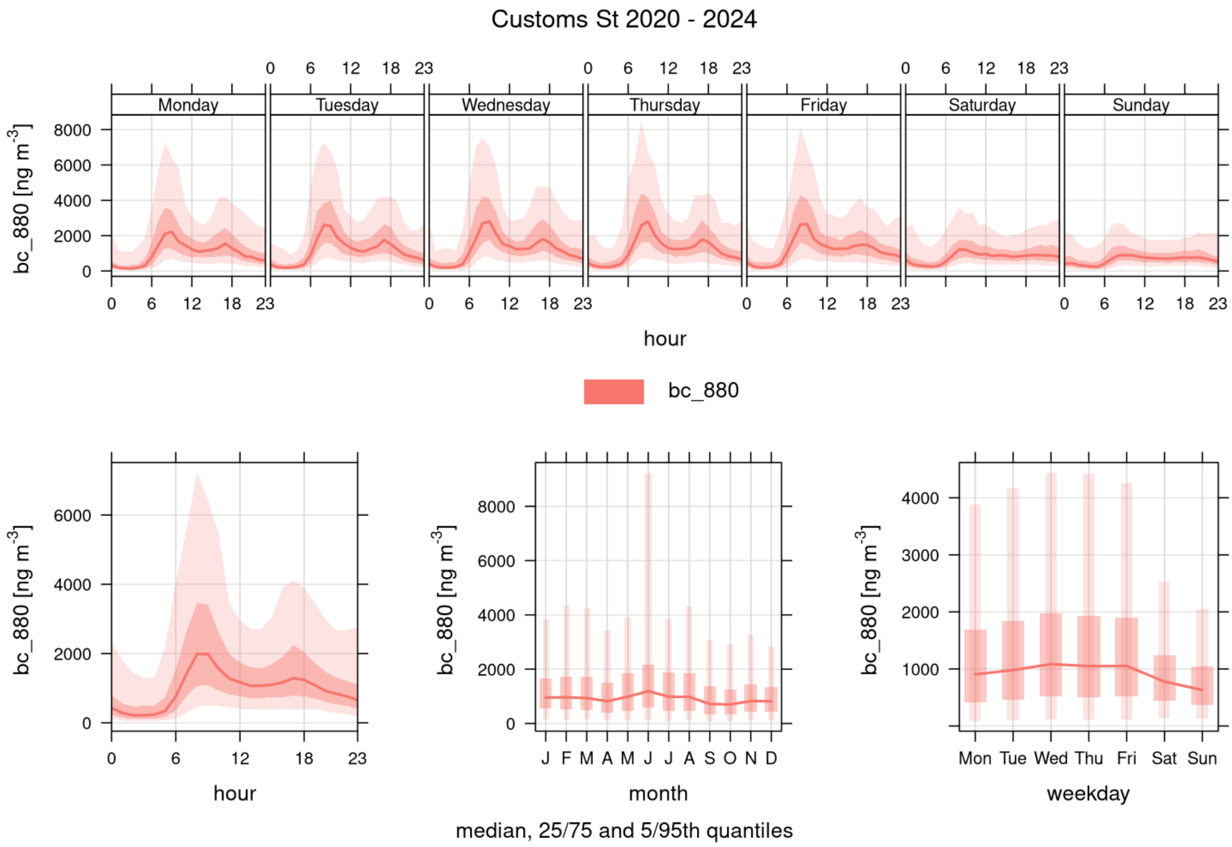


Figure 69. Temporal variability for Black Carbon at Customs Street, including hourly, weekday and monthly plots, 2020-2024.

NO_2 trends

The deseasonalised long-term trend show a significant reduction of NO_2 concentrations since 2020 with a year on year decrease of 4.26 µg/m^3 .

The diurnal, annual and weekly variation of NO_2 concentrations show very similar patterns to those observed at Queen Street. Concentrations increase steadily from April to July and then decrease until January. The diurnal variability of NO_2 follows the traffic peaks with high concentrations coinciding with the morning and evening commuting rush hour, consistent with NO_2 being primarily driven by traffic sources. However, the difference between the rush hours and the non-rush hour daytime hours is larger than in Queen Street, indicating that there is more traffic activity in the immediate vicinity of the Customs Street site than on Queen Street.

Figure 70. Theil-sen deseasonalised trends for NO_2 at Customs Street, 2020-2024.

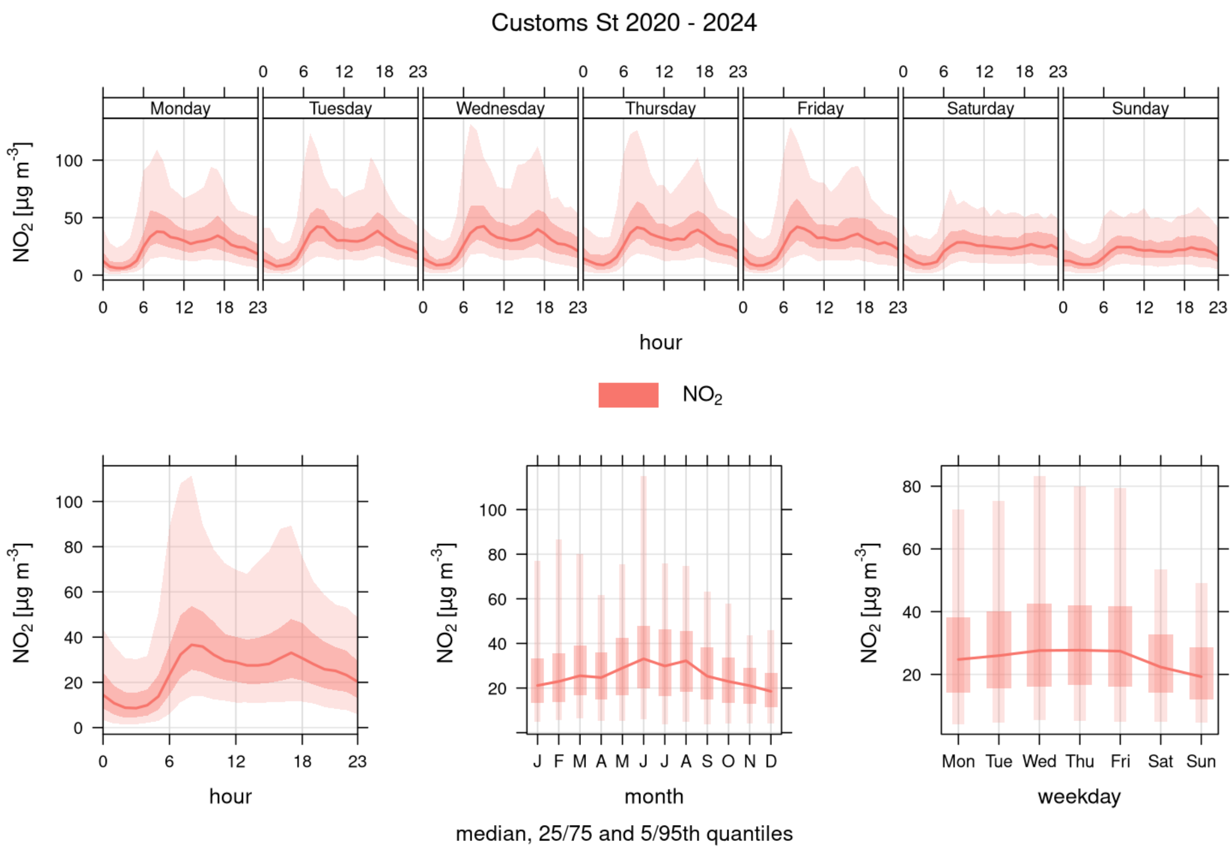


Figure 71. Temporal variability for NO_2 at Customs Street, including hourly, weekday and monthly plots, 2020-2024.

SO_2 trends

The deseasonalised trend since 2020 shows an increase of 0.29 µg/m3 year on year, however, as shown in the main report, concentrations have been decreasing significantly since 2022 as a result of the implementation of the MARPOL VI regulations on marine transport.

The diurnal variation are consistent with traffic being a significant driver with morning and evening rush hour peaks. However, the seasonal variation, besides the winter increased concentrations, also shows a small increase in SO_2 concentrations from January to March that aligns with the increased cruise activity in the port.

Figure 72. Theil-sen deseasonalised trends for SO_2 at Customs Street, 2020-2024.

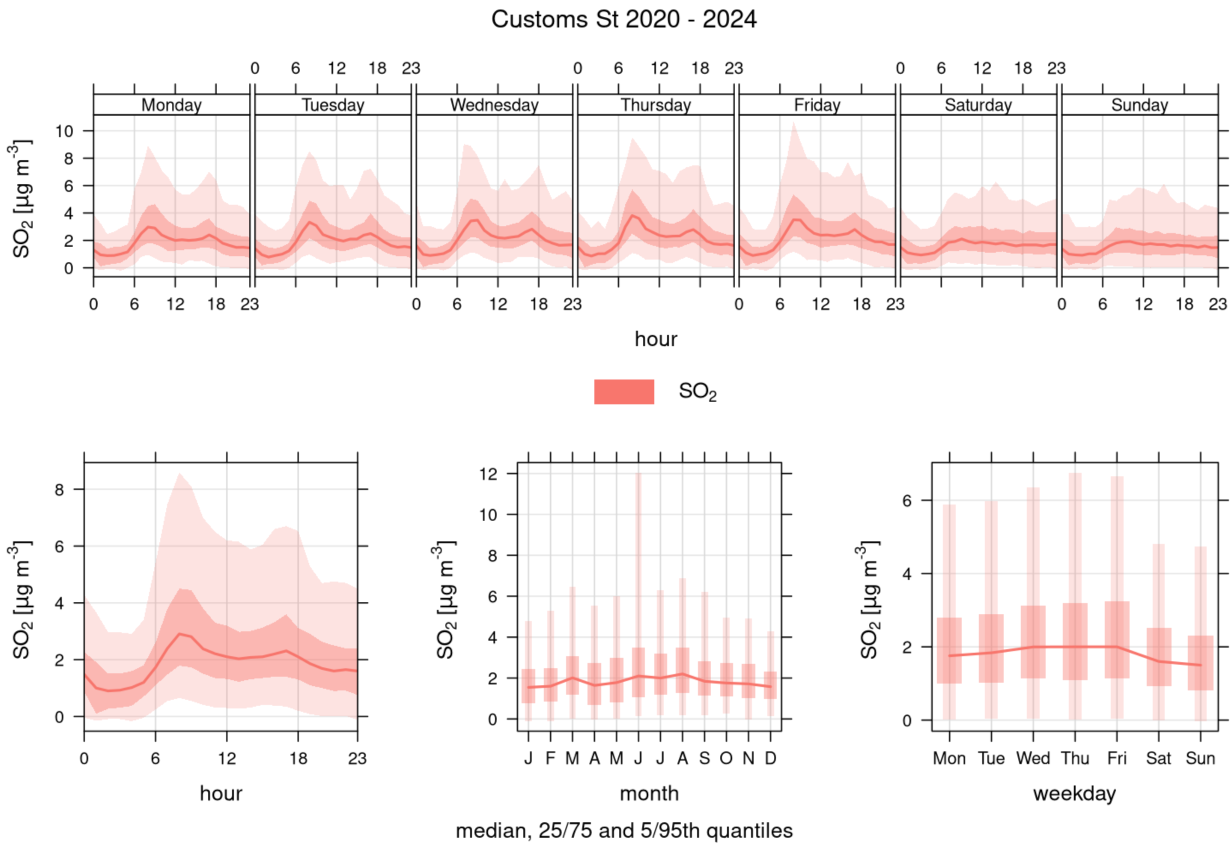


Figure 73. Temporal variability for SO_2 at Customs Street, including hourly, weekday and monthly plots, 2020-2024

Khyber Pass

Site description

The Khyber Pass site was re-activated in 2019. It is located on the southern side of Khyber Pass Road near the intersection with Mountain Road. Khyber Pass Road is a significant traffic source, as it is part of the rapid transit network in the city. Other significant sources include the construction work in the Auckland University campus across the road and Auckland Hospital located a kilometre to the north of the site.

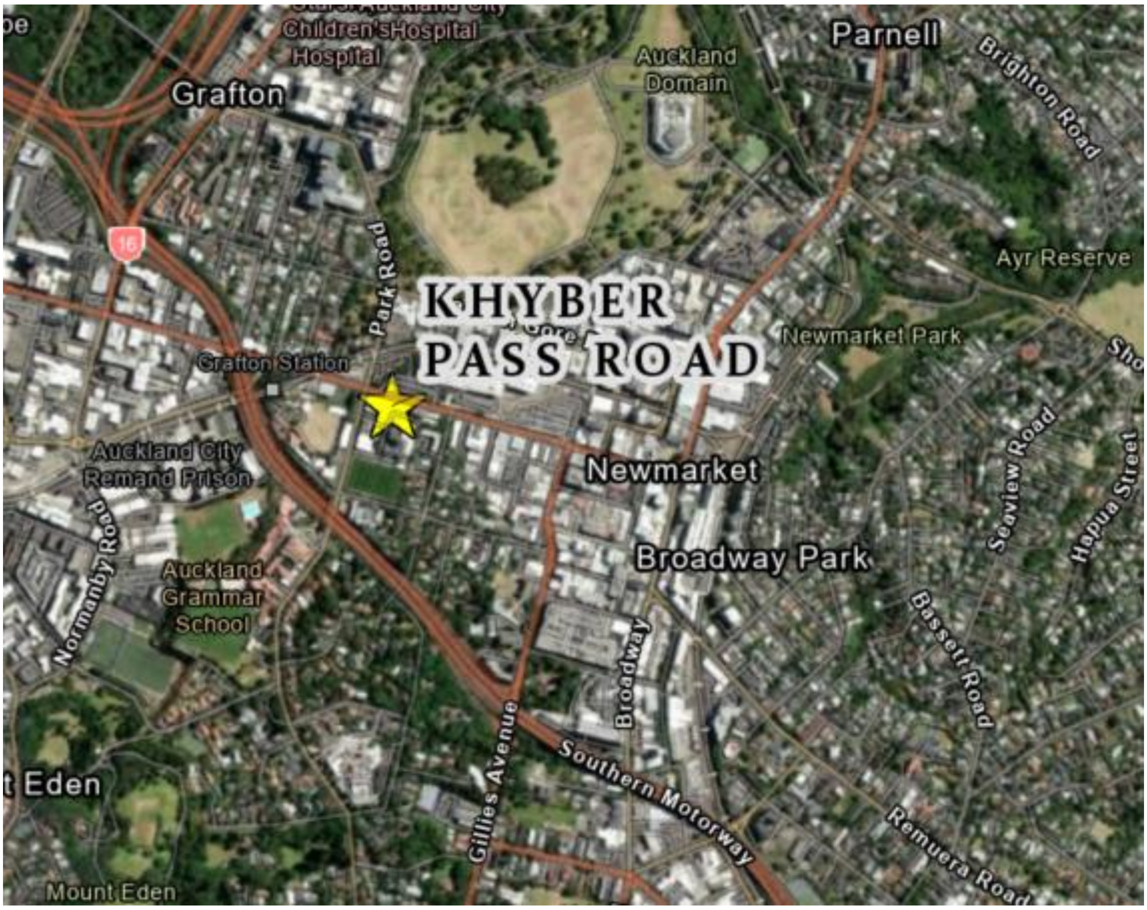


Figure 74. Map of the location of Khyber Pass air quality monitoring site (Google Maps 2018).

PM_{10} trends

The deseasonalised trend of PM_{10} concentrations shows a significant increase of 1.02 μg/m^3 year on year since 2020. The seasonal plot shows relatively constant concentrations throughout the year which is more consistent with a natural rather than a human-generated source. The diurnal variation shows a different patter to most of the other sites with the highest concentrations observed after midday which is consistent with natural sources that respond to wind speed, rather than traffic or other human-generated sources.

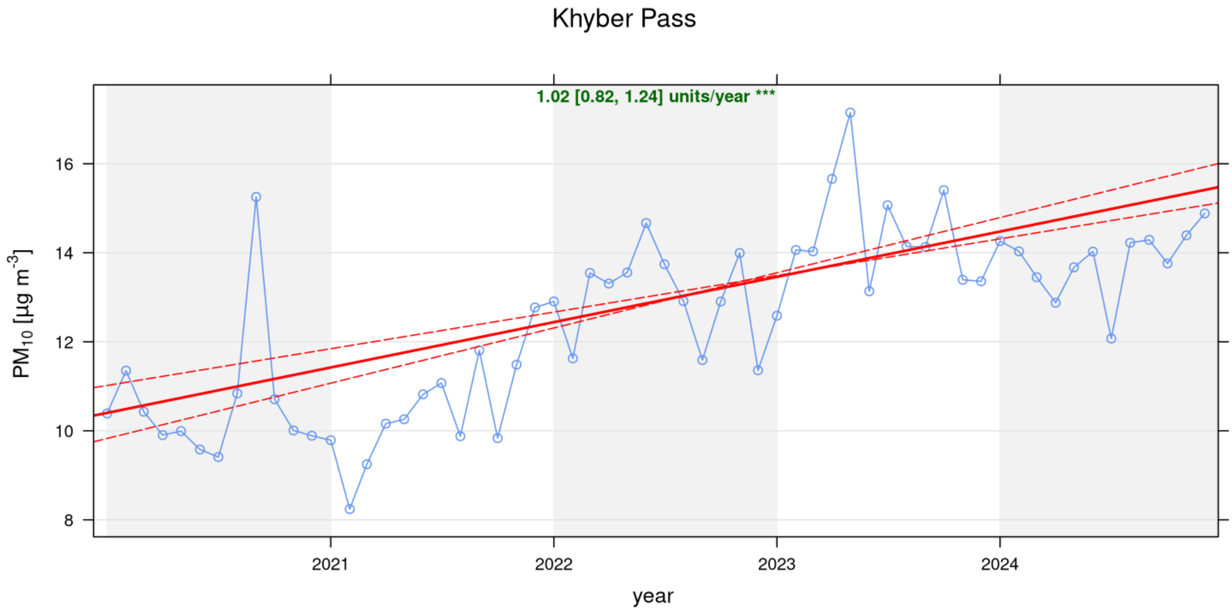


Figure 75. Theil-sen deseasonalised trends for PM_{10} at Khyber Pass, 2020-2024.

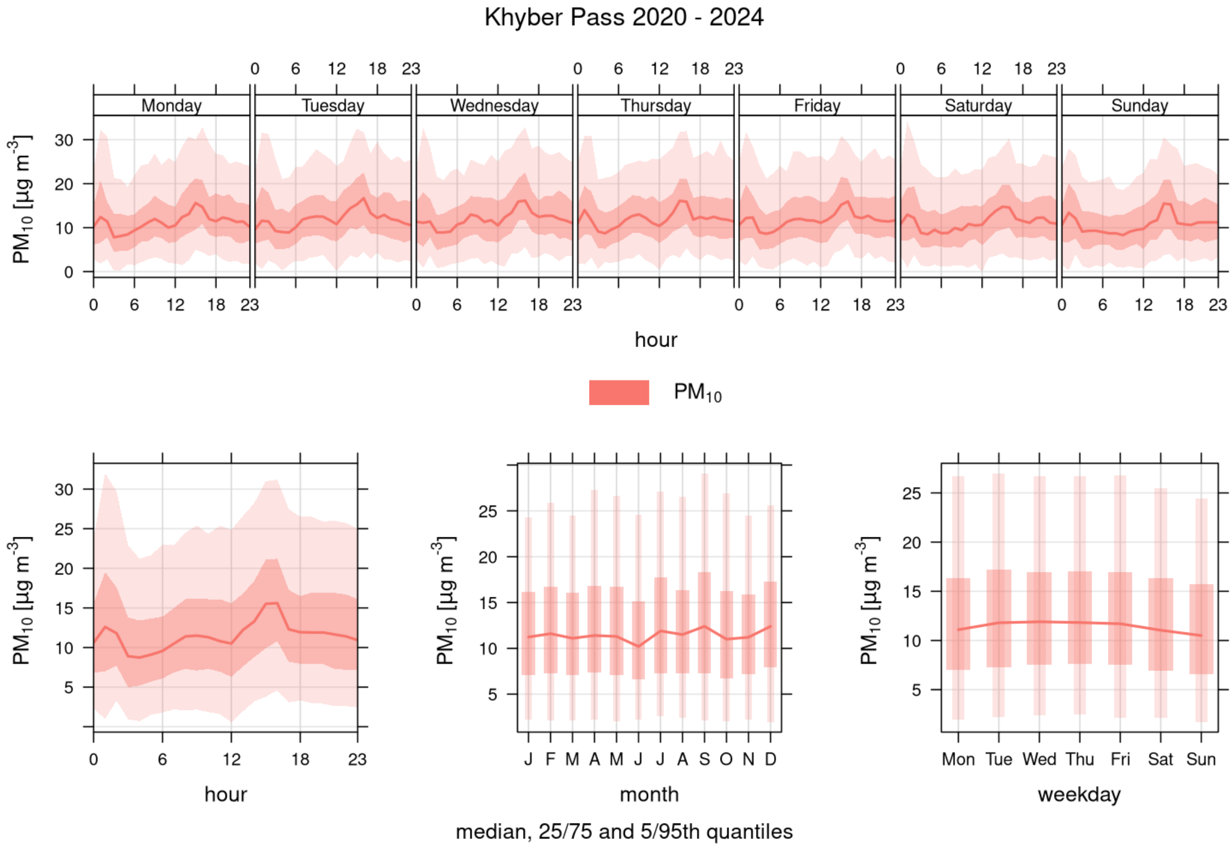


Figure 76. Temporal variability for PM_{10} at Khyber Pass, including hourly, weekday and monthly plots, 2020-2024

NO_2 trends

The deseasonalised trend shows a significant year on year reduction in NO_2 of 1.26 µg/m^3 since 2020.

The diurnal, annual and weekly variation of NO_2 concentrations show a strong seasonal and diurnal variability, similar to other traffic impacted sites. Concentrations are higher from March to August, and lowest between December and January. The diurnal variability of NO_2 follows the traffic peaks with high concentrations coinciding with the morning and evening commuting rush hour, however the evening peak is considerably smaller and more spread than the morning peak. This is consistent with NO_2 being primarily driven by traffic sources in the area.

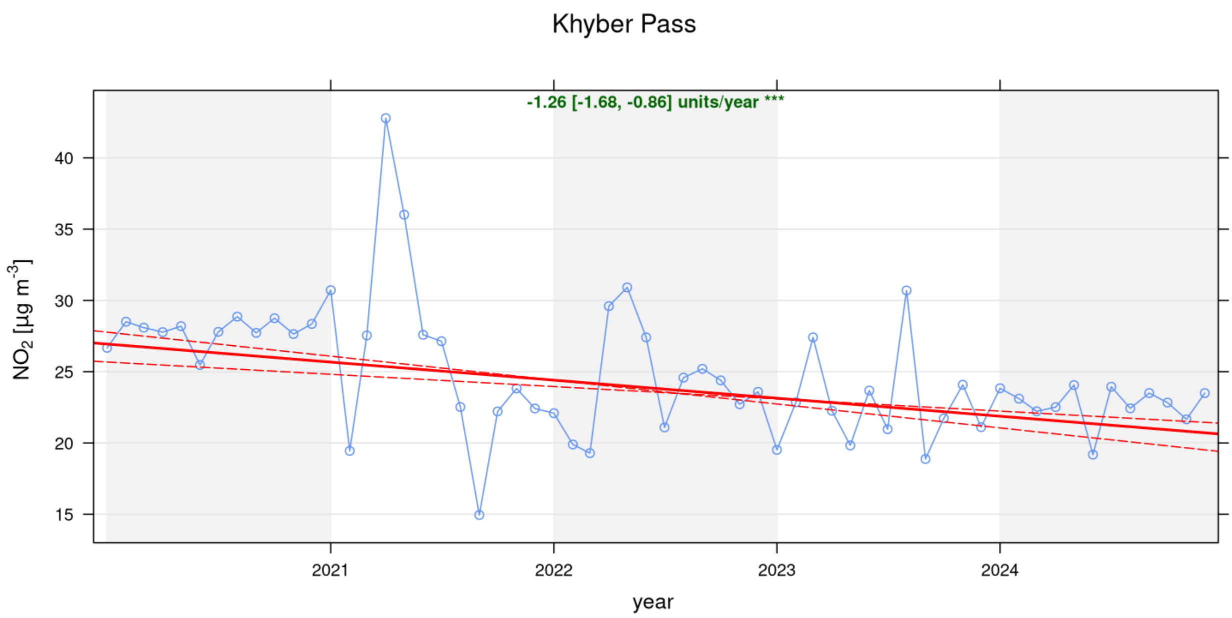


Figure 77. Theil-sen deseasonalised trends for NO_2 at Khyber Pass, 2020-2024.

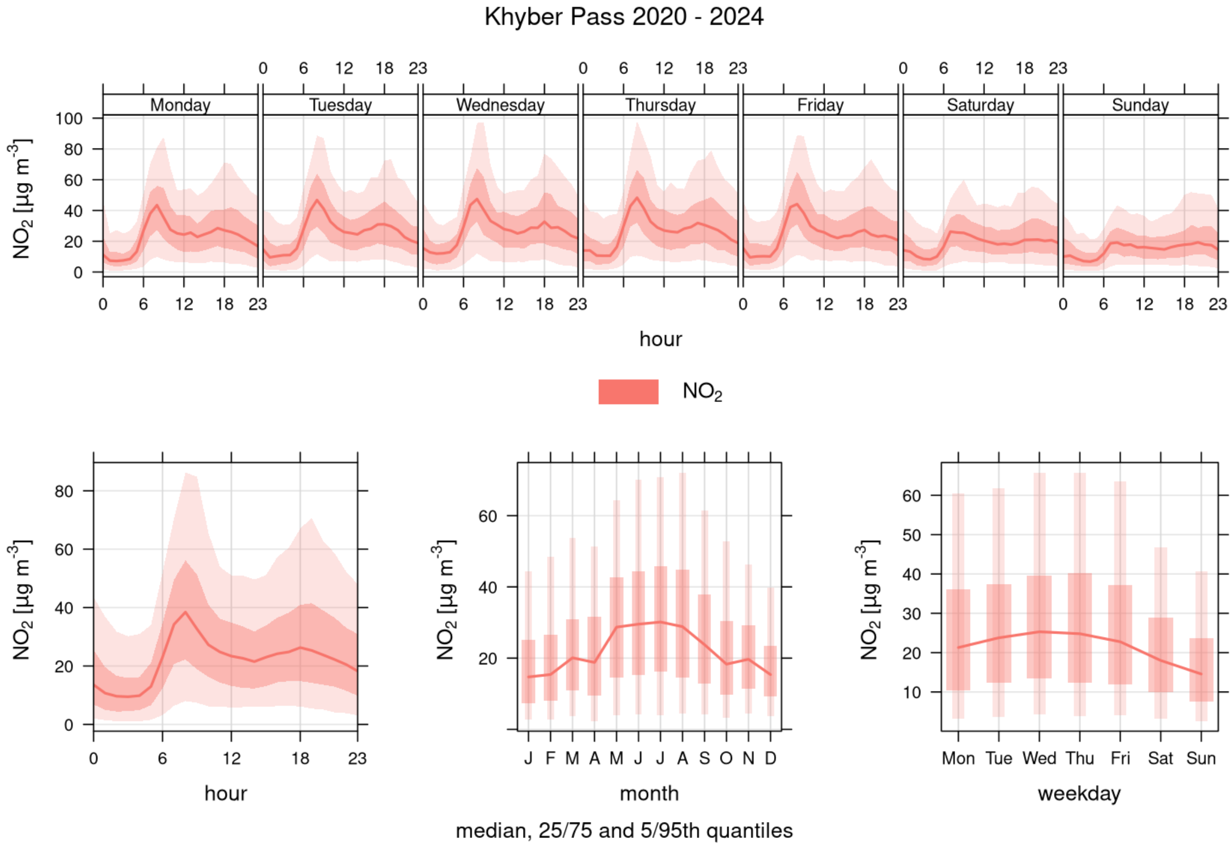


Figure 78. Temporal variability for NO_2 at Khyber Pass Street, including hourly, weekday and monthly plots, 2020-2024.

CO trends

Khyber Pass is the only site with real time CO measurements and it is used to identify significant changes in the traffic CO emissions in the city. The concentrations over the past five years have been steadily decreasing with a year on year reduction of 0.01 µg/m^3 which is about 5% of the observed concentrations.

The seasonal and diurnal variation are similar to those for NO_2, with increased concentrations during winter and marked morning and evening rush hour peaks. This is consistent with traffic being the main contributor to both NO_2 and CO concentrations at the site.

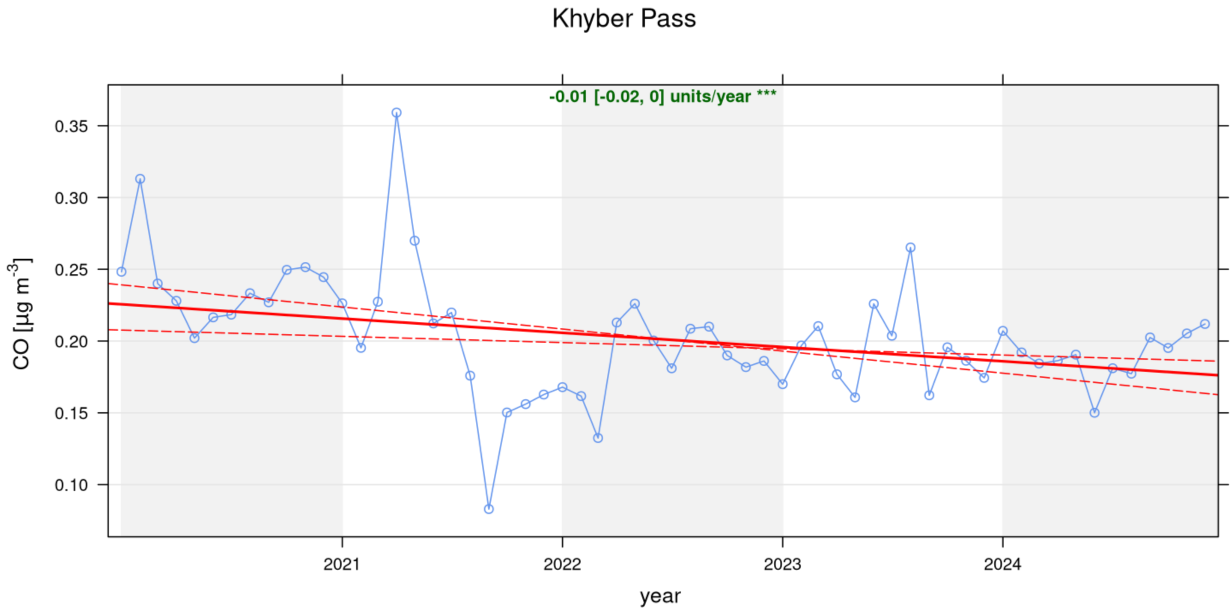


Figure 79. Theil-sen deseasonalised trends for CO at Khyber Pass, 2020-2024.

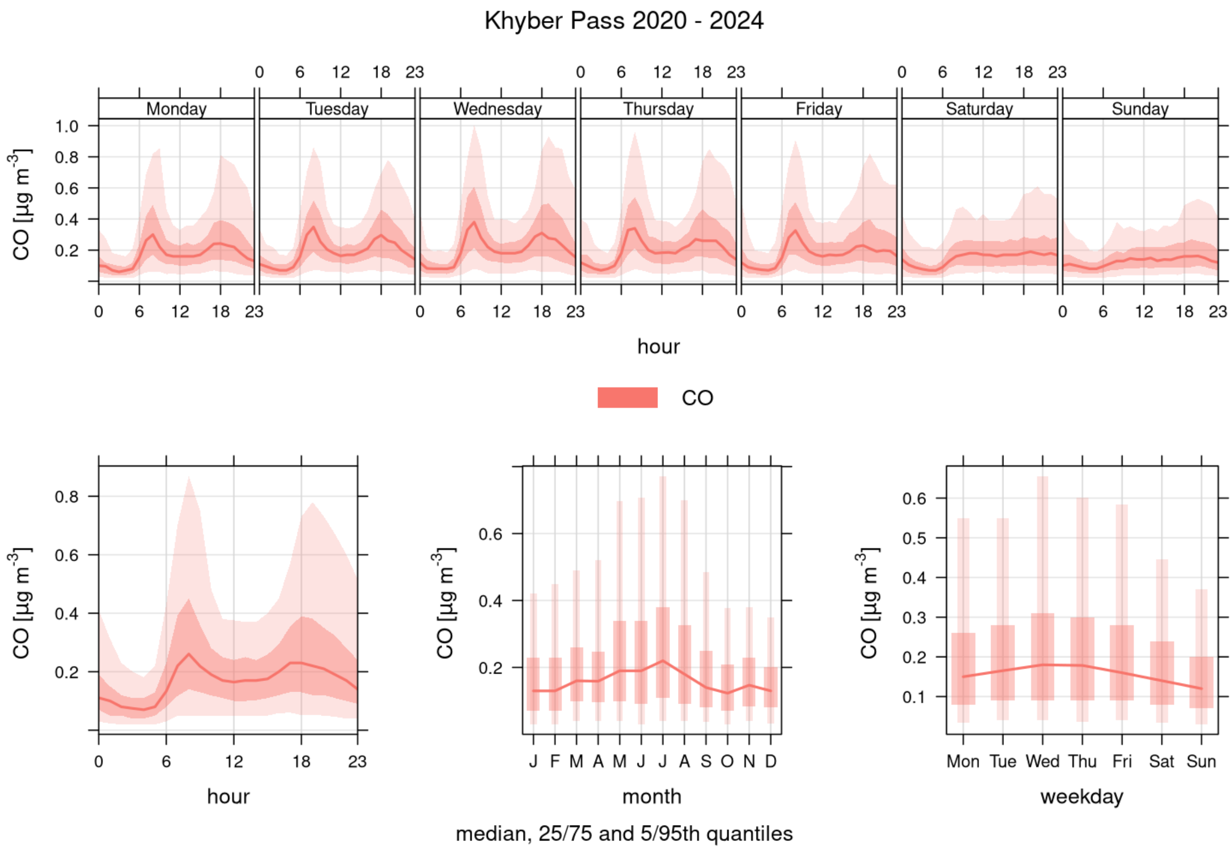


Figure 80. Temporal variability for CO at Khyber Pass Street, including hourly, weekday and monthly plots, 2020-2024.

Papatoetoe

Site description

Located in Milton Park, Papatoetoe, this site is one of the newest sites in the network. It was established in 2018 and it is intended to represent the densely populated area of South Auckland. The main sources of air pollution around the area, apart from the residential sources, are Middlemore Hospital, 800m to the north-east, and the industrial area of Otahuhu 2km to the north of the site. Further afield, Auckland Airport and the Wiri industrial park are expected to have a smaller impact on the site.

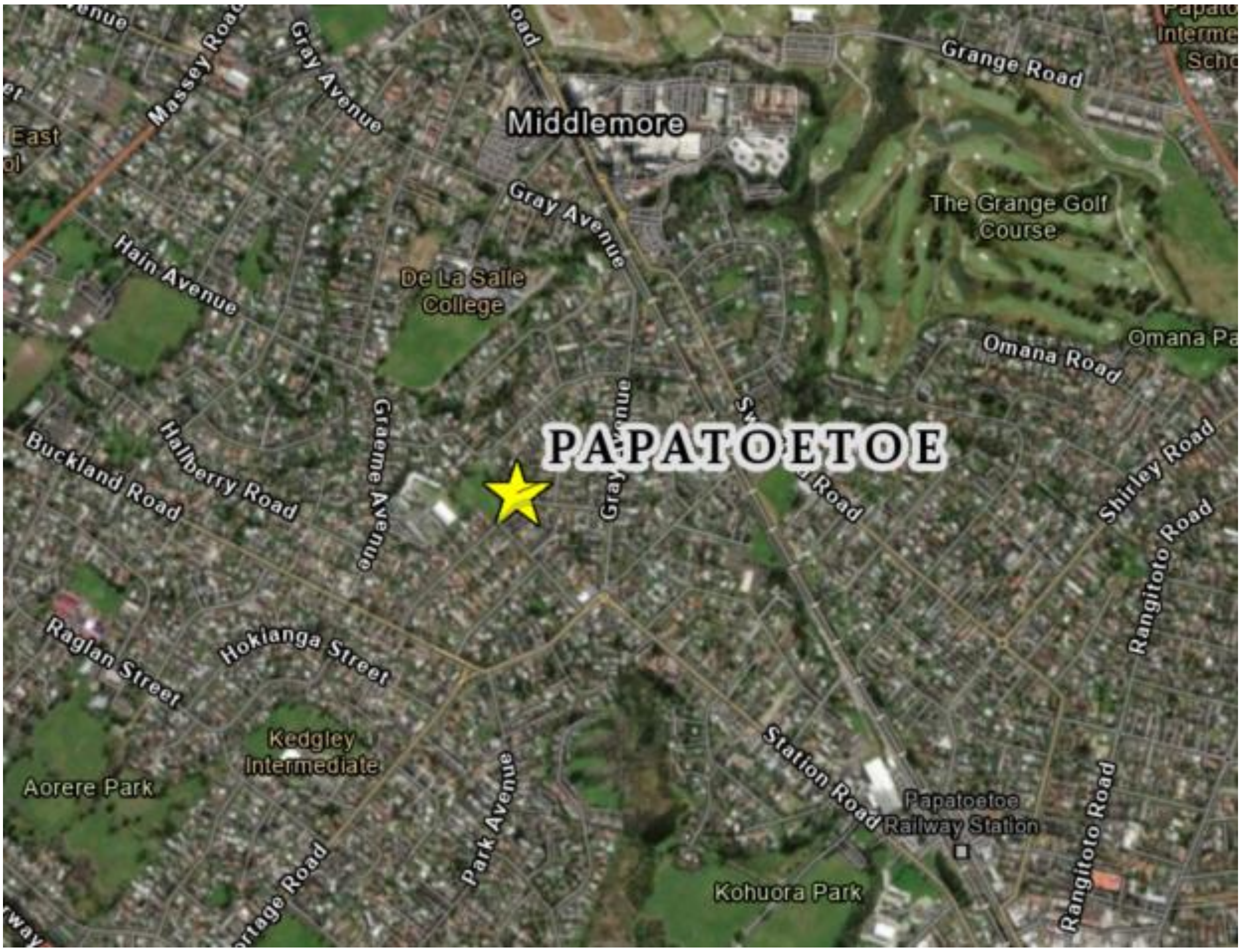


Figure 81. Map of the location of Papatoetoe air quality monitoring site (Google Maps 2018).

PM_{10} trends

Over the past five years, PM_{10} concentrations at the Papatoetoe site have remained relatively constant with no statistically significant year on year change.

The site also presents a very subtle seasonal variation with concentrations in July through to September slightly higher than during the rest of the year. The diurnal variation shows significantly higher concentrations during the middle of the day which is markedly different from other sites and points to sources other than traffic that control PM_{10}. These could be natural or human-generated. Further data is needed to determine this.

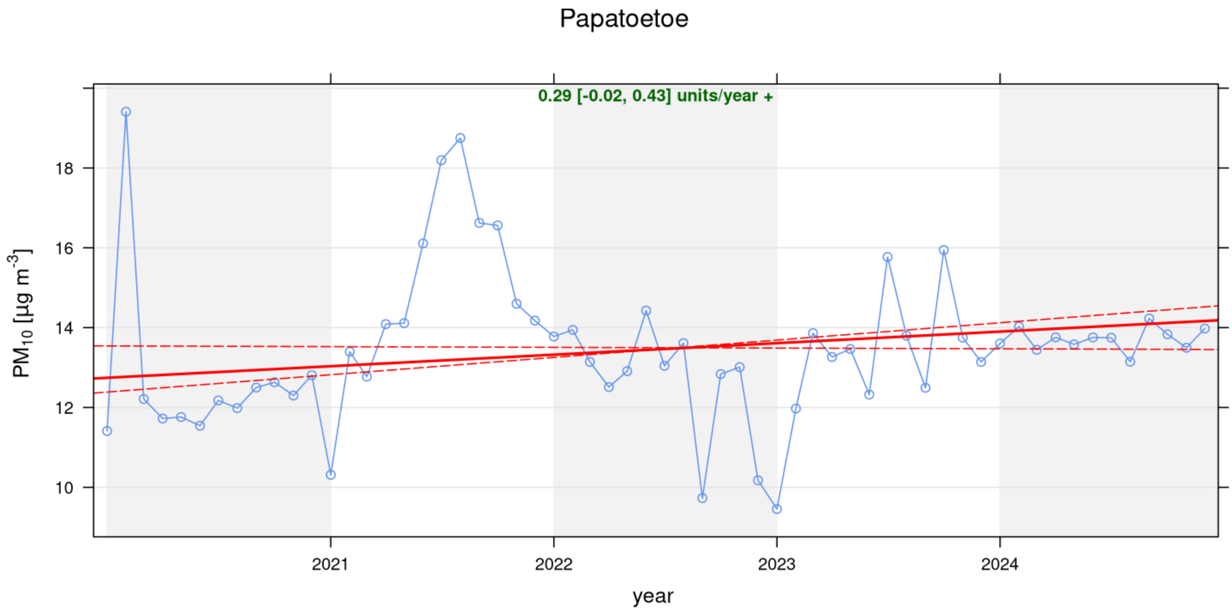


Figure 82. Theil-sen deseasonalised trends for PM_{10} at Papatoetoe, 2020-2024.

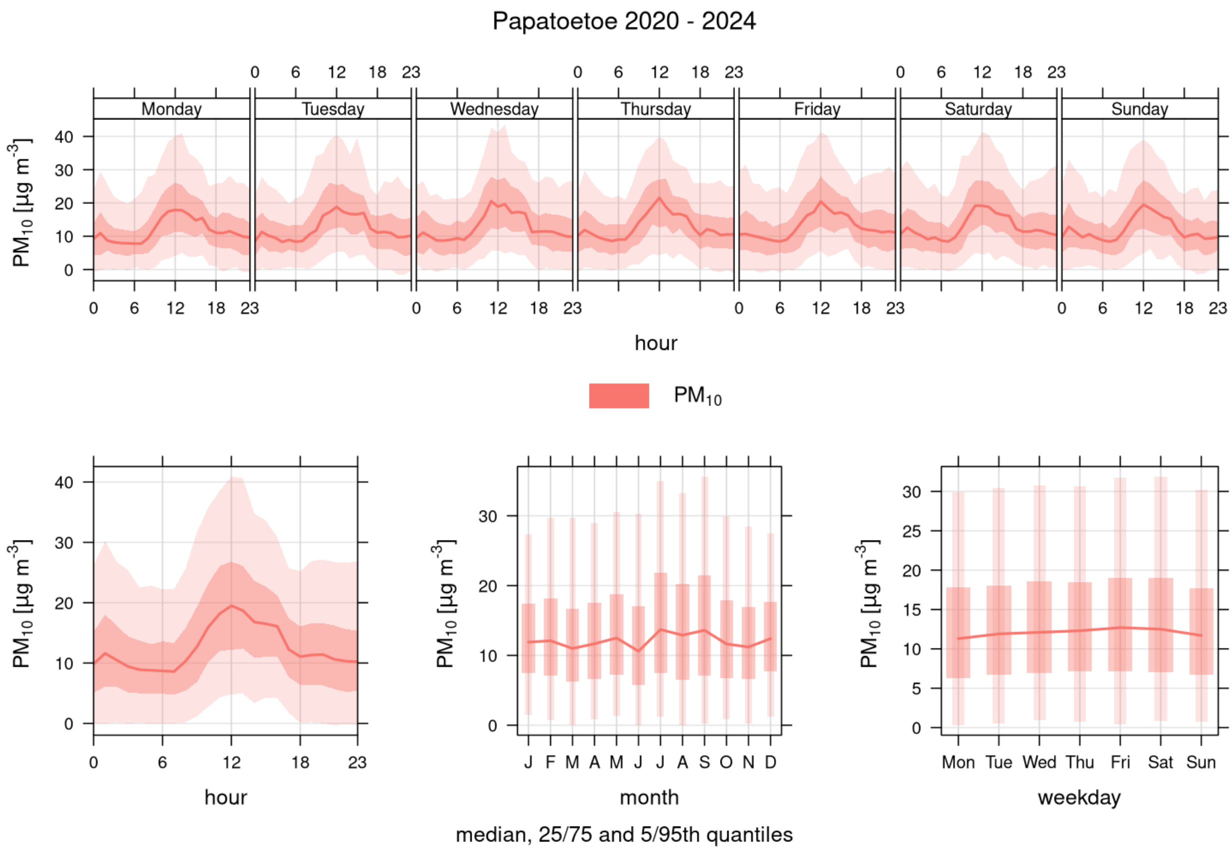


Figure 83. Temporal variability for PM_{10} at Papatoetoe, including hourly, weekday and monthly plots, 2020-2024.

Patumahoe

Site description

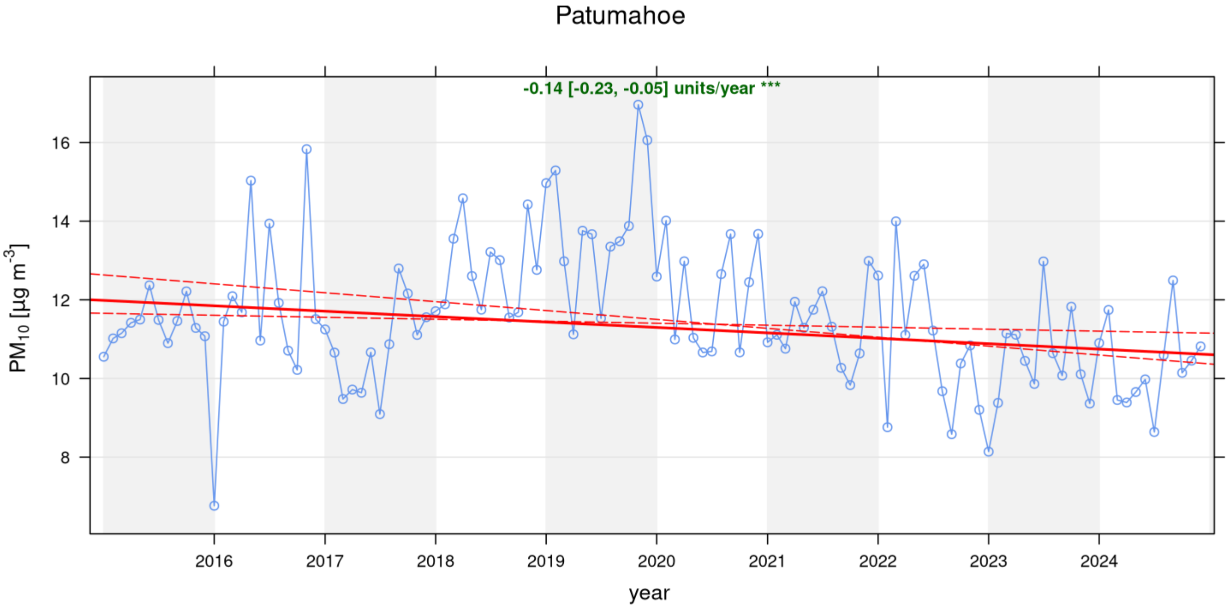
Located within the Crop and Food Research Station at Cronin Road (Figure 84), Patumahoe air quality station provides Auckland with regional background air quality data. The site is located approximately 2.5 km west of the Pukekohe urban area. The surrounding area is predominantly used for horticulture (market gardening) and pastoral agriculture. Occasional spikes in PM_{10} from nearby rural activities such as fertiliser application, crop tilling and green waste burning have been recorded. There are only lightly used roads immediately surrounding the monitoring station.

Figure 84. Map of the location of Patumahoe air quality monitoring site (Google Maps 2018).

PM_{10} trends

The deseasonalised long-term trend show a 0.14 µg/m^3 year on year reduction in PM_{10} since 2015. For the period from 2020, that trend has increased with a year on year reduction of 0.45 µg/m^3 between 2020 and 2024.

The diurnal, annual and weekly variation of PM_{10} concentrations indicate a seasonal variability with lower concentrations during the winter months and higher concentrations from September to March, consistent with rural activities and wind-blown dust being the main sources of PM_{10}. The diurnal cycle shows higher concentrations during daytime, which is again consistent with agricultural activities and wind as the main drivers of PM_{10} concentrations.



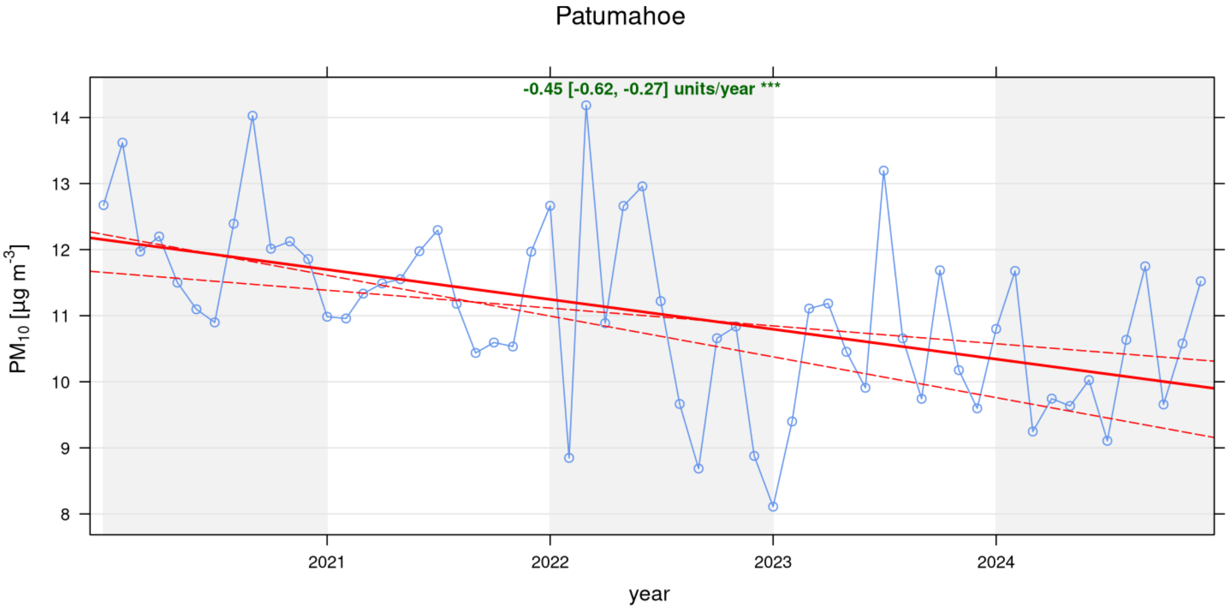


Figure 85. Theil-sen deseasonalised trends for PM_{10} at Patumahoe, 2015-2024 (top) and 2020-2024 (bottom).

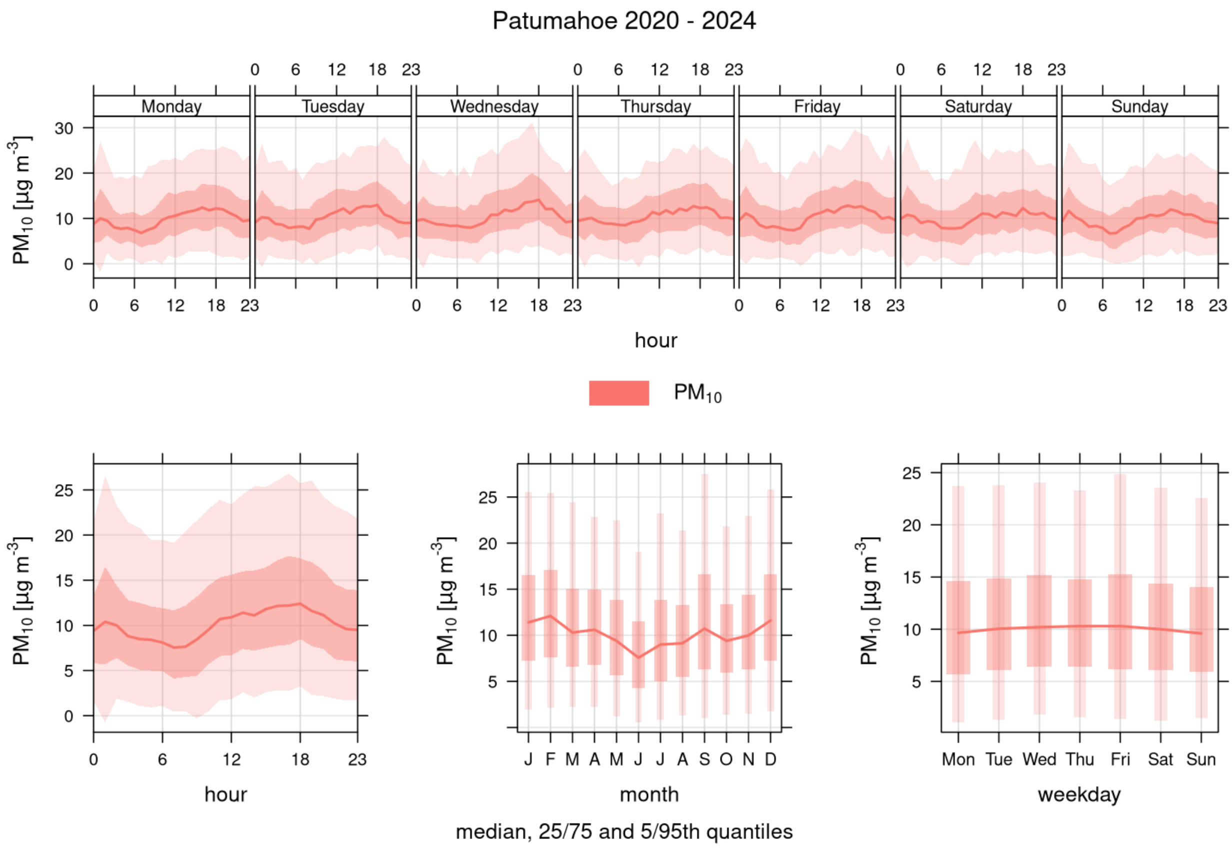
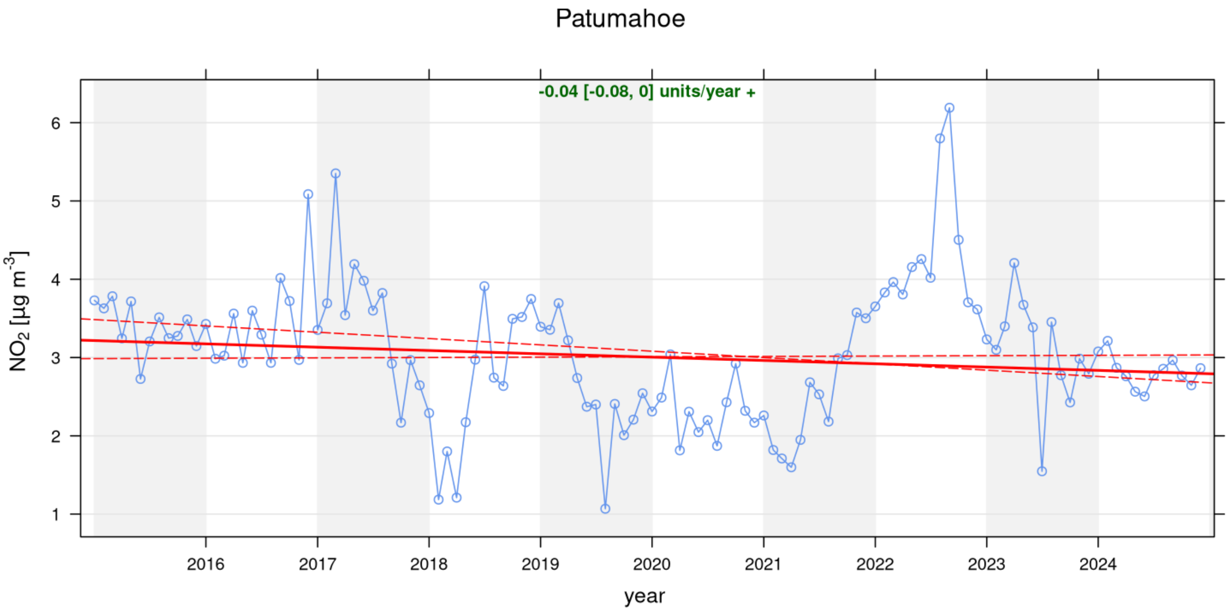


Figure 86. Temporal variability for PM_{10}, at Patumahoe, including hourly, weekday and monthly plots, 2020-2024.

NO_2 trends

The long-term trend shows no statistically significant year on year variation since 2015 and only a slight increasing trend since 2020 of 0.13 µg/m^3 year on year.

The seasonal variation in NO_2 shows a steady increase in concentrations from January to a peak in June and then a steady decrease until December. The diurnal variation shows a morning peak consistent with traffic rush hour but an evening peak later in the evening and wider than other sites, peaking just before midnight.



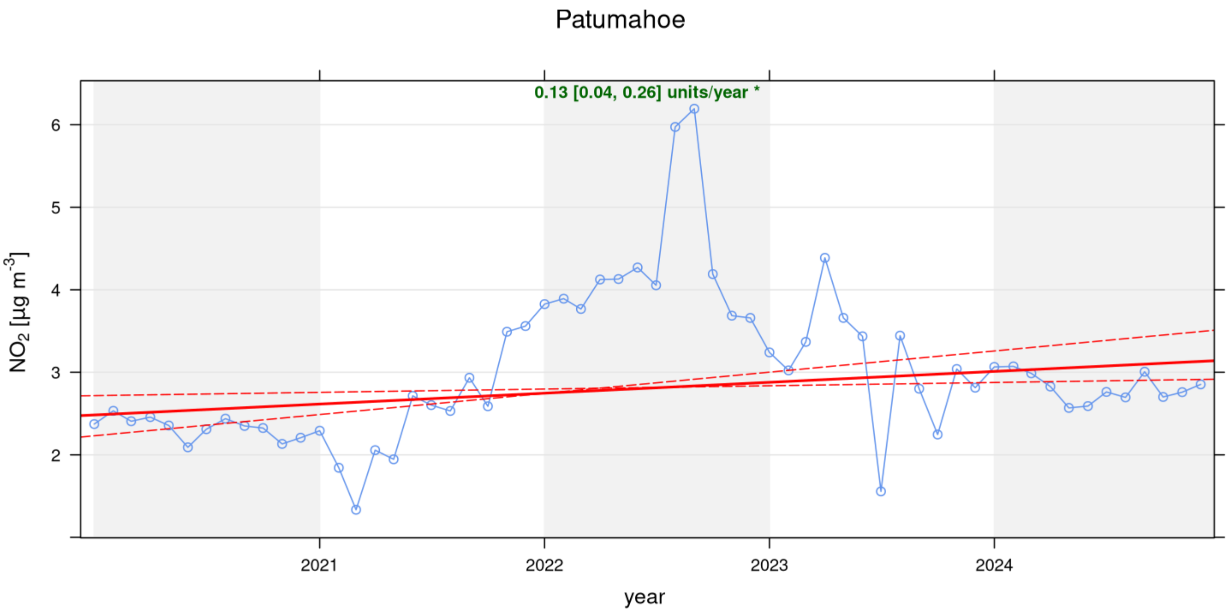


Figure 87. Theil-sen deseasonalised trends for NO_2 at Patumahoe, 2015-2024 (top) and 2020-2024 (bottom).

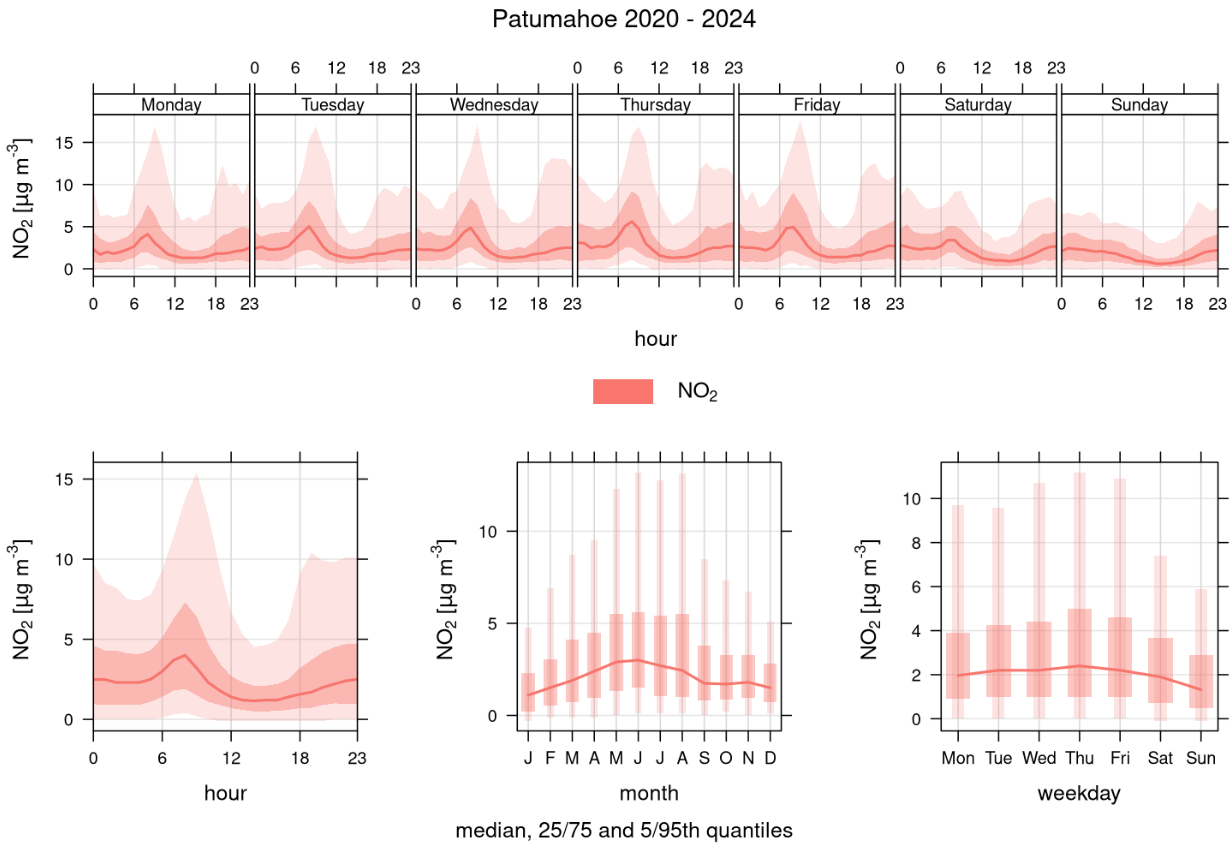
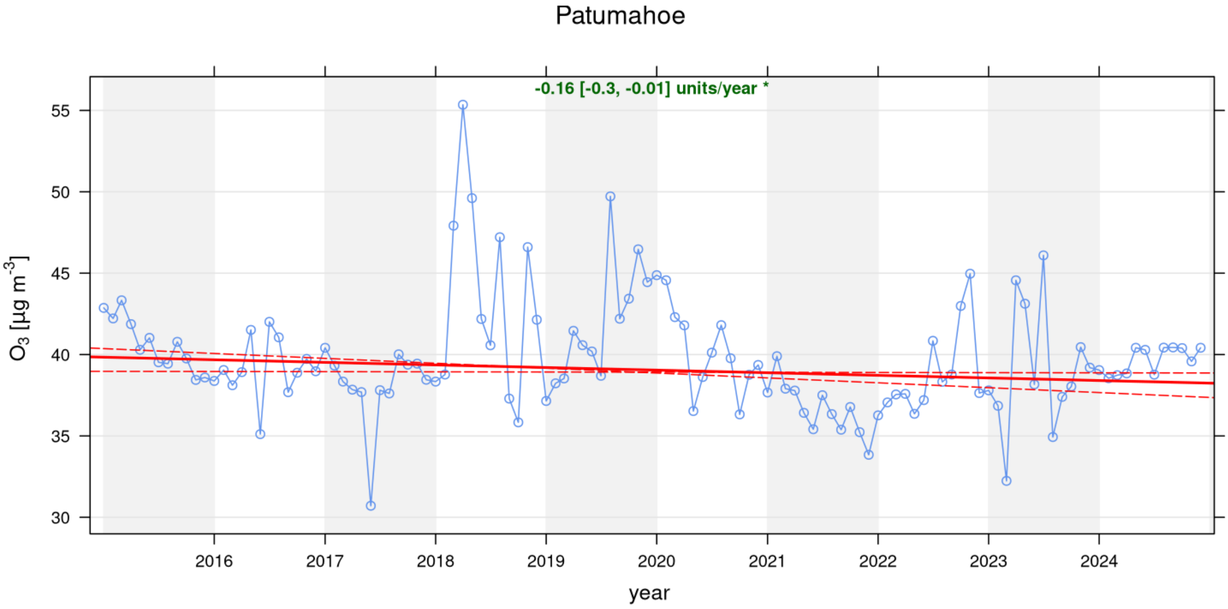


Figure 88. Temporal variability for NO_2 at Patumahoe, including hourly, weekday and monthly plots, 2020-2024.

Ozone trends

The concentrations of Ozone at Patumahoe have slightly decreased in the last 10 years with a year on year decrease of 0.16 µg/m³ since 2015. For the shorter timeframe of 2020 to 2024, the changes in O_3 are not statistically significant.

The seasonal variation shows a steady increase in concentrations from a minimum in January to a maximum in September. This is related to photochemistry of ozone that requires nitrogen oxides as a precursor as well as solar radiation so, in winter, precursor concentrations increase, and so does ozone with concentrations and then in spring time, while precursor concentrations decrease slightly, there is more solar radiation to drive the chemistry. After September, however, nitrogen oxides concentrations have dropped so low that are no longer enough to drive ozone formation and ozone concentrations drop.



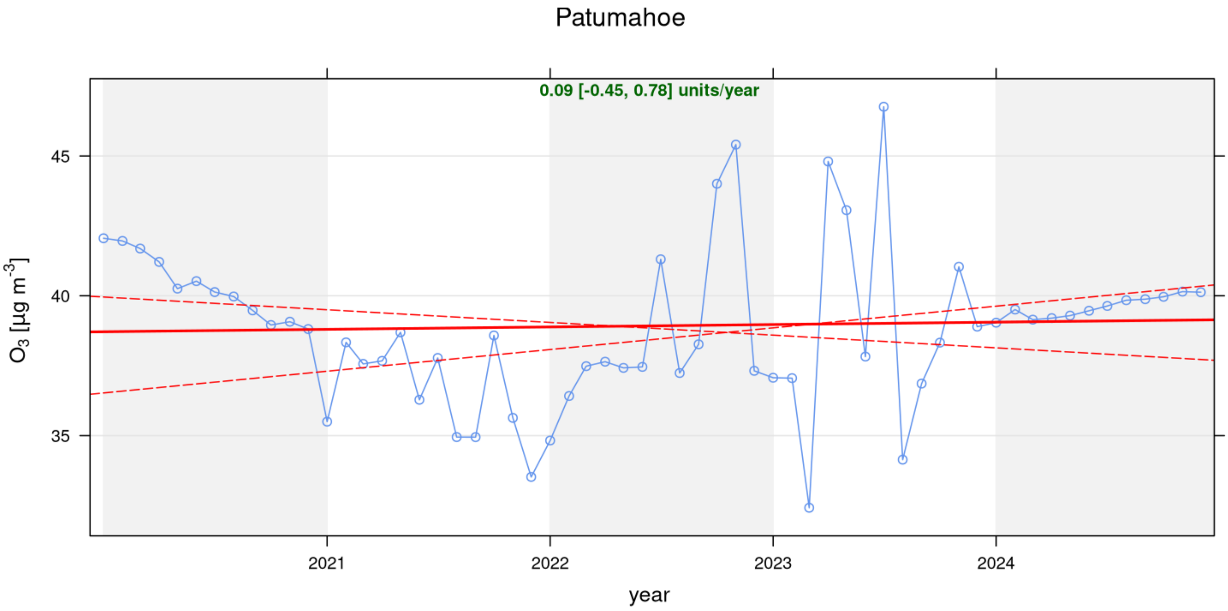


Figure 89. Theil-sen deseasonalised trends for O_3 at Patumahoe, 2006-2017 (top) and 2013-2017 (bottom).

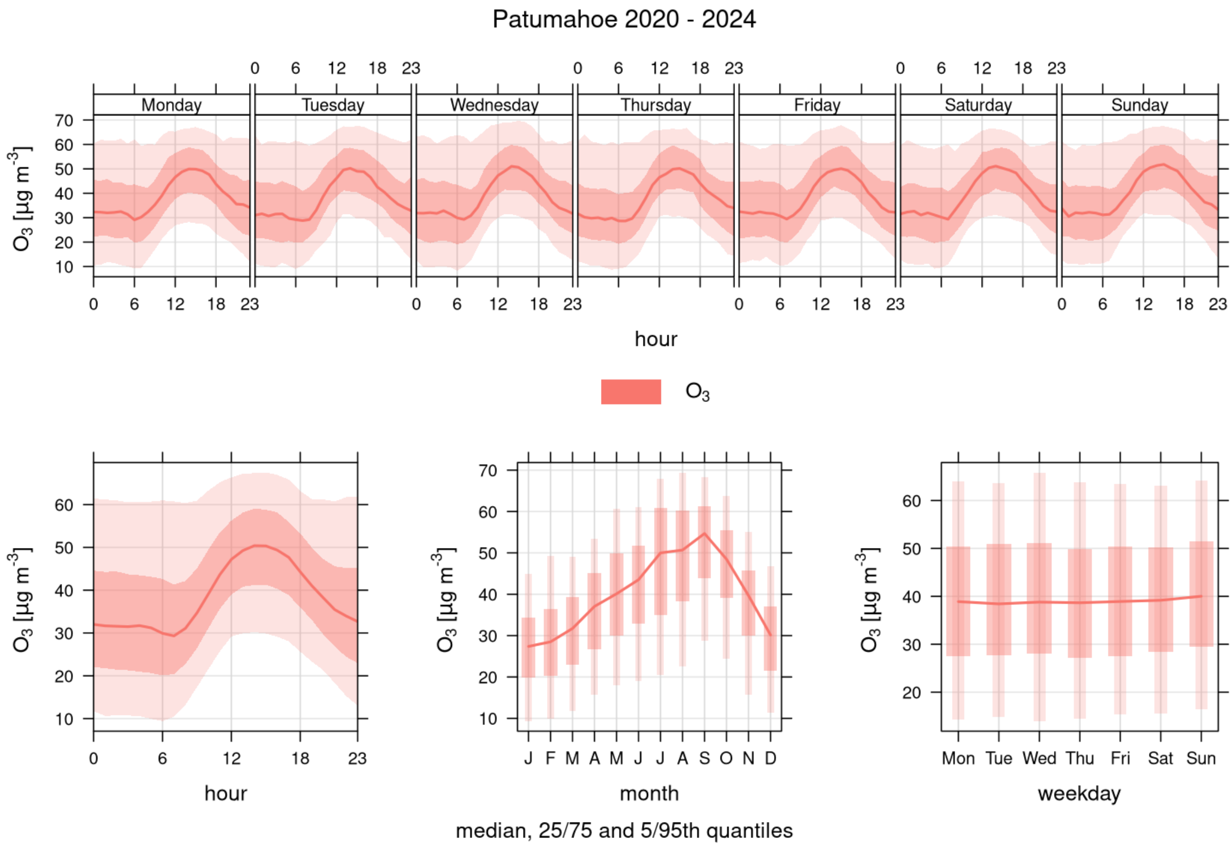


Figure 90. Temporal variability for O_3 at Patumahoe, including hourly, weekday and monthly plots, 2020-2024.

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