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Application no:

Date received:

Date accepted:

Ministry for the Environment
Manatū Mō Te Taiao

Resource Management (National Environmental Standards for Air Quality) Regulations 2004 – Regulation 16A Exceptional Circumstances

APPLICATION FORM

Before completing this form please read section 3.8 of the 2011 User's Guide to the revised National Environmental Standards for Air Quality.

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1 Applicant details

Name of regional council	Auckland Council
Contact person	Louis Boamponsem
Position	Air Quality Scientist
Email address	Louis.boamponsem@aucklandcouncil.govt.nz
Telephone number	0272025907
Mobile number	0272025907
Postal address	Auckland Council, Level 23, 135 Albert Street, Private Bag 92300, Auckland 1142

2 Details of exceedance event

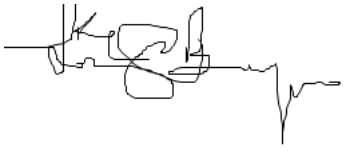
Containment	Particulate matter (PM_{10}), and nitrogen dioxide (NO_2)

Date of exceedance (*application must be received within 3 months from date of the exceedance*)	A. 19 August 2022 for PM_{10} exceedance at Queen Street site B. 24 August 2022 for NO_2 exceedance at Khyber Pass Road site
Relevant airshed	Auckland Urban Airshed
Monitoring station and technical specifications of monitor	A. Queen Street PM_{10} monitoring station: Make: Teledyne Advanced Pollution Instrumentation Model: T640 PM Mass Monitor Age : 5 years Serial: 85 *Queen Street Site metadata are provided in Appendix A of Attachment 1.* B. Khyber Pass Road NO_2 monitoring station: Make: Teledyne Advanced Pollution Instrumentation Model: 200E Age : 17 years Serial: 714 *Khyber Pass Road Site metadata are provided in Appendix A of Attachment 2.*
Summary of monitoring reading showing exceedance event	A. The Auckland Council ambient air quality monitoring site Queen Street experienced one exceedance of the National Environmental Standards for Air Quality (NESAQ) for PM_{10} (24-hour average) on 19th August 2022. The PM_{10} exceedance was 52.06 µg/m³. B. The Auckland Council ambient air quality monitoring site Khyber Pass Road experienced one exceedance of the National Environmental Standards for Air Quality (NESAQ) for NO_2 (1-hour average) on 24th August 2022. The NO_2 exceedance was 261.03 µg/m³.
Analysis of baseline data	A. PM_{10}: An analysis of baseline data at the Queen Street site shows that PM_{10} levels met the national standard from 2014 to 2022, except for the exceedance on 19 August 2022. The exceedance on 23 October 2019 was due to a fire at the New Zealand International Convention Centre (NZICC) construction site was exempted by the Minister. B. NO_2: An analysis of baseline data at the Khyber Pass Road site indicates that NO_2 levels met the national standard from 2015 to 2022, except for the exceedance on 24 August 2022. Air quality monitoring at this site was paused on May 2015 for redevelopment and restarted in August 2017 (No data between March 2015 and August 2019) See Attachment 1 and 2 for details.
Source speciation or other analysis	For PM_{10} exceedance at Queen Street Site see Attachment 3 (GNS Science source apportionment report)

Explanation of any previous exceedance event/s from this monitoring station in the past 5 years	A. There has been one exceedance of PM_{10} at the Queen Street site in the past five years. This exceedance was due to an exceptional event near the site – a fire at the New Zealand International Convention Centre. See section 4 of Attachment 1 for details. B. There has not been any NO_2 exceedance at the Khyber Pass Road site in the past five years. This is the first time the NESAQ permissible excess per year has been breached. See section 4 of Attachment 2 for details (No NO_2 data available in 2018)	
Monitoring readings covering exceedance event	☒ Attached	☐ Not attached

3 Details of exceptional circumstances

Exceptional circumstances leading to exceedance	☑ Localised impact on a monitor **[NO_2]**	☐ Anthropogenic extreme event	☑ Natural disaster or natural extreme event **[PM_{10}]**	☐ Other
Explanation of circumstances leading to exceedance event	A. A regional weather event (from 17th to 19th August) resulted in high sea state and onshore easterly wind conditions causing spikes in PM_{10}. B. The activity of a tag graffiti artist who intruded the air quality monitoring station. The exceedance was the result of emissions from the intruder's stationary running vehicle and spray paint fumes.			
Reasons why these circumstances were beyond the reasonable control of the regional council	A. **PM_{10} exceedance at Queen Street Site**: Natural events are beyond the reasonable control of Auckland Council and it is believed the exceedance was the result of an exceptional amount of sea salt in onshore winds during a period of high seas. B. **NO_2 exceedance at Khyber Pass Road Site:** The activity of a graffiti artist intruder was a temporary point source of NO_2, over which Auckland Council had no ability to control.			
Supporting evidence (eg, *meteorological report*)	☑ Attached	☐ Not attached		



4/11/2022

Date

Signed

17 November 2022

Hon David Parker

Minister for the Environment

Tēnā koe Minister

Re: Application under National Environmental Standards for Air Quality – regulation 16A Exceptional Circumstances

On 18th and 19th August 2022, the National Air Quality Standard for 24-hour PM_{10} was exceeded in the Auckland Urban airshed (Queen Street site). Also, on 24th August 2022, the National Air Quality Standard for 1-hour NO_2 was exceeded in the Auckland Urban airshed (Khyber Pass Road site). Consequently, Auckland Council is seeking a determination that these exceedances were caused by exceptional circumstances, namely, marine aerosol for the PM_{10} exceedances, and in the case of the NO_2 exceedance, a combination of emission from a running stationary vehicle and spray paint fumes by an intruder of the monitoring station. The information in support of this application is attached.

If further information is required regarding this application, please contact Dr Louis Boamponsem in the Research and Evaluation Unit (RIMU) on 0272025907 or louis.boamponsem@aucklandcouncil.govt.nz .

Thank you for your consideration in this matter.

Ngā mihi

Dr Jonathan Benge

Head of Research, Evaluation and Monitoring

Research and Evaluation Unit (RIMU)

Auckland Plan, Strategy and Research

Auckland Council

Cc: Jacqueline Lawrence-Sansbury - Team Manager Air, Land & Biodiversity

Resource Management (National Environmental Standards for Air Quality) Regulations 2004 – Regulation 16A Exceptional Circumstances

Application for exceptional circumstances consideration:

Queen Street particulate matter (PM_{10}) (24-hour Average)

Attachment 1

Louis Boamponsem

November 2022

This report has been prepared to support the application for exceptional circumstances consideration: Queen Street particulate matter (PM_{10}) (24-hour average) (1 exceedance)
Date: 2 November 2022

Executive summary

The Auckland Council ambient air quality monitoring site Queen Street recorded two exceedances of the National Environmental Standard for Air Quality (NESAQ) for particulate matter (PM_{10}) (24-hour average) on 18/08/2022 and 19/08/2022. This means the second exceedance on 19th August has breached the NESAQ standard.

Our investigation into this breach showed it was due to marine aerosol (sea salt). This was a regional weather event (from 17th to 19th August) resulting in high sea state and onshore easterly wind conditions causing spikes in PM_{10} levels across all our monitoring sites. Weather maps for the period 17th to 19th August indicated a large north-easterly oceanic fetch for the air mass approaching Auckland. It is believed this natural event caused the Queen Street site to record the two PM_{10} exceedances. It is important to note that this weather pattern also caused elevated PM_{10} levels in air quality monitors located at Northland, Bay of Plenty and Hawkes Bay. The result from a GNS Science laboratory analysis of filter samples collected from some monitoring sites has confirmed sea salt as the cause of the exceedances.

The Auckland Urban Airshed has been performing well (for PM_{10} exceedances) in recent years, with no unpermitted exceedances in many years. We believe the exceedances meet the five criteria that define exceedances caused by exceptional or natural events:

1. The exceedance was caused by the events assessed,
2. The circumstances were beyond the reasonable control of the Council,
3. The circumstances could not be planned for,
4. The event was unusual,
5. Determining that the circumstances were exceptional is consistent with the purpose of the Resource Management Act.

This application uses monitoring data and source apportionment outcome to show that the two exceedances were caused by a natural weather event, and accordingly should be considered for exceptional circumstances exemption.

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Glossary of terms, acronyms, and abbreviations

Term	Meaning
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 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)
Exceedance	An exceedance defines a period of time during which the concentration of a pollutant is greater than the appropriate air quality criteria.
MfE	Ministry for the Environment
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
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of 2.5 micrometres or less; a type of air pollutant.
Stats NZ	Statistics New Zealand
$\mu g/m^3$	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 Council is required under the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 to report any breach of the air quality standard. The ambient standards are the minimum requirements that outdoor air quality should meet to guarantee a set level of protection for human health and the environment.

An ambient air quality concentration limit of 50 µg/m³ (24-hour average) for particulate matter (PM_{10}) must be met for all but one each year. The Auckland Urban Airshed has breached this standard on one occasion in August 2022 at the Queen Street air quality monitoring site.

Auckland Council has been carrying out ambient air quality monitoring at Queen Street site since 1998. The site's location is shown in Figure 1. Site metadata are provided in Appendix A. The site is located in the Auckland urban airshed and the main air pollution anthropogenic sources are motor vehicles, shipping emissions and home heating (during winter). The site monitors fine particulate matter (PM_{10} and $PM_{2.5}$) and oxides of nitrogen (NOx, NO, NO_2). Meteorological parameters are also measured at this site. The site is operated in accordance with the MfE Good Practice Guide (MfE, 2014) and complies with AS/NZS 3580.1.1:2007 (site location). The particulate matter sensor at the Queen Street site operates in accordance with AS/NZS standards.

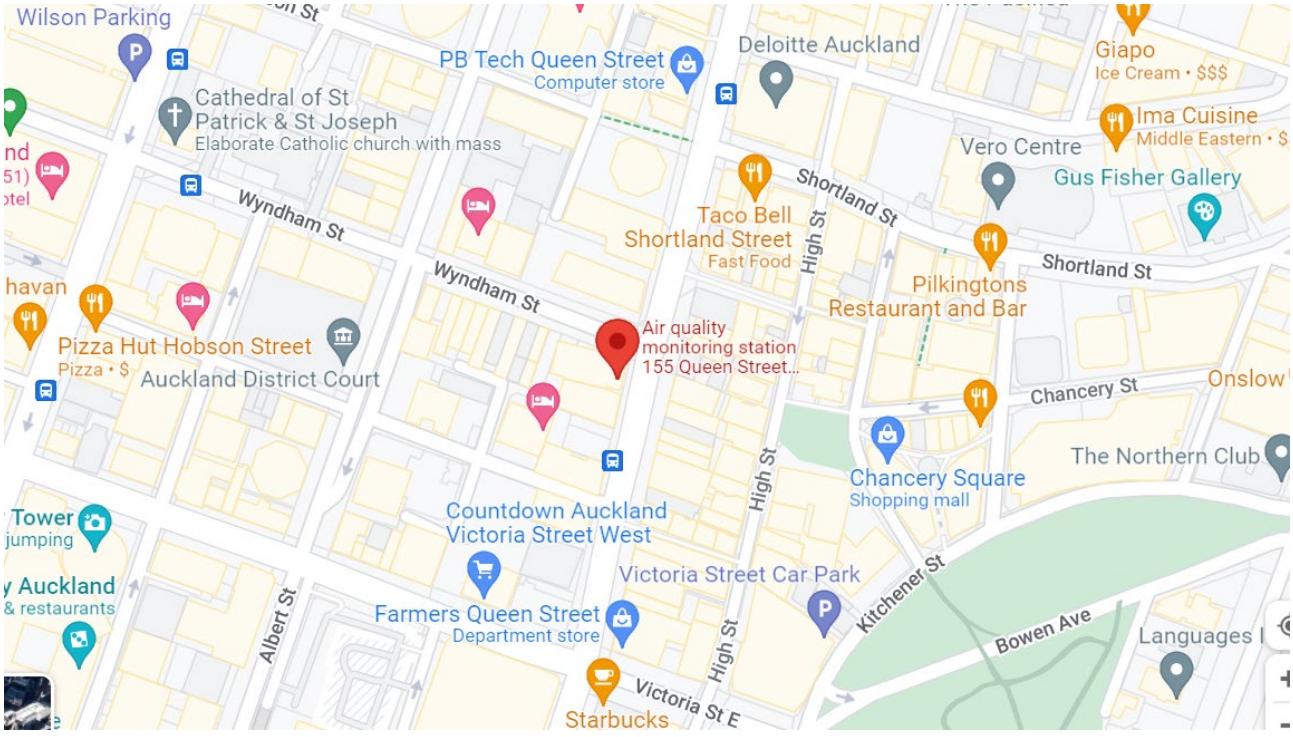

Figure 1. Location of the Queen Street air quality monitoring site (Source: Google maps)

The Queen Street site experienced two exceedances of the National Environmental Standards for Air Quality (MfE, 2014) (NESAQ) for PM_{10} (24-hour average) on 18/08/2022 and 19/08/2022.

The unusual nature of these results led to an investigation, which indicated that these exceedances were due to an exceptional circumstance. This application uses monitoring data and investigation results to demonstrate that the two exceedances were caused by marine aerosol (sea salt) following a high sea state and onshore easterly wind conditions.

This regional weather event (from 17th to 19th August 2022) resulting in high sea state and onshore easterly wind conditions, caused spikes in PM_{10} levels across all our monitoring sites (see Figure 2 below). It is important to note that this weather pattern also caused elevated PM_{10} levels in air quality monitoring stations located in Northland, Bay of Plenty and Hawkes Bay (See Appendix C). The wind direction of this weather event was consistent with the wind and pollution roses of the Queen Street site (see Figure 3).

The results from a GNS Science laboratory analysis of filter samples collected from some monitoring sites has confirmed sea salt as the cause of the PM_{10} exceedances at the Queen Street site (See Attachment 3). Natural weather events are out of the control of Auckland Council, and therefore, these exceedances should be considered for exceptional circumstances exemption.

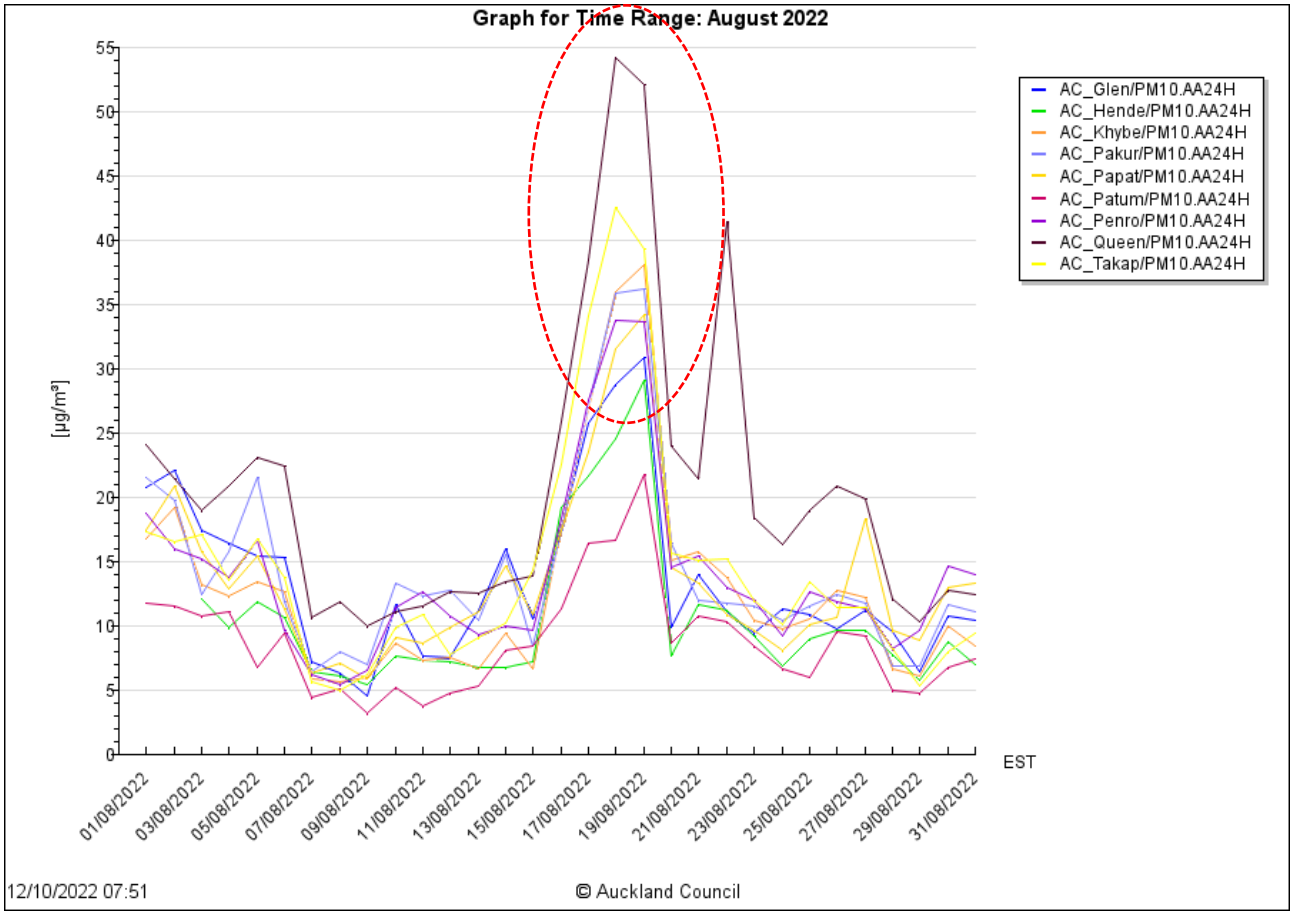

Figure 2. NO_2 1-hour average concentrations showing spikes across all sites on 18th and 19th August.

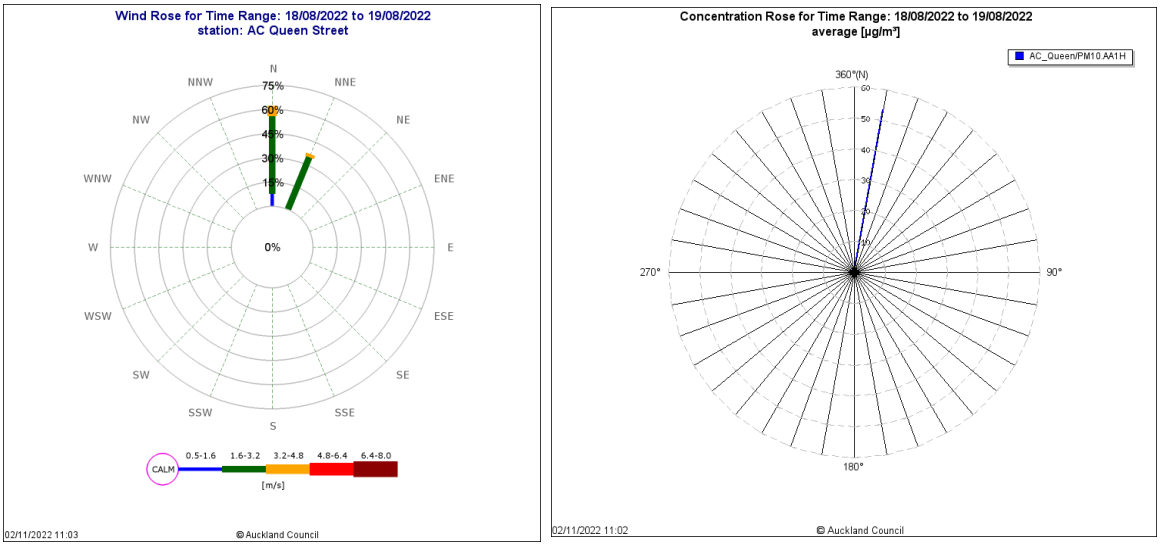

Figure 3. Queen Street site wind and pollution roses on 18th and 19th August 2022.

The Auckland Airsheds have not recorded exceedances of the NESAQ for PM_{10} in 2020 and 2021 and has not been in breach of the NESAQ for PM_{10} between 2014 -2021 (see Table 1).

Table 1. Historical PM_{10} exceedances in the Auckland Airshed (January 2005 – 30 September 2022)

Year	Number of PM_{10} exceedances
2005	7
2006	6
2007	6
2008	3
2009	5*
2010	1
2011	0
2012	1
2013	3
2014	0
2015	0
2016	0
2017	0
2018	0
2019	4**
2020	0
2021	0
2022	2 (reported in this application)

*All monitoring sites exceeded PM_{10} standard: caused by Australian dust storms

**Caused by New Zealand International Convention Centre fires, and Australian dust storms and bush fires

2 Summary of monitoring readings showing exceedance event

The Auckland Council ambient air quality monitoring site Queen Street experienced two exceedances of the National Environmental Standards for Air Quality (NESAQ) for PM_{10} (24-hour average) on 18/08/2022 and 19/08/2022. The PM_{10} exceedances on 18th and 19th August 2022 were 54.2 µg/m³ and 52.1 µg/m³, respectively.

The monitoring site PM_{10} concentrations started spiking above the background levels on the 17th August. The PM_{10} concentrations returned to usual readings as soon as the weather conditions returned to normal (See Figure 4). The PM_{10} exceedances can be considered as unusual and from a temporary source rather than a meaningful change in baseline concentrations. The average source contributions estimated by receptor modelling indicate that marine aerosol (sea salt) normally contributes 41 % of total PM_{10} concentrations recorded at Queen Street site (Davy et al. 2017)

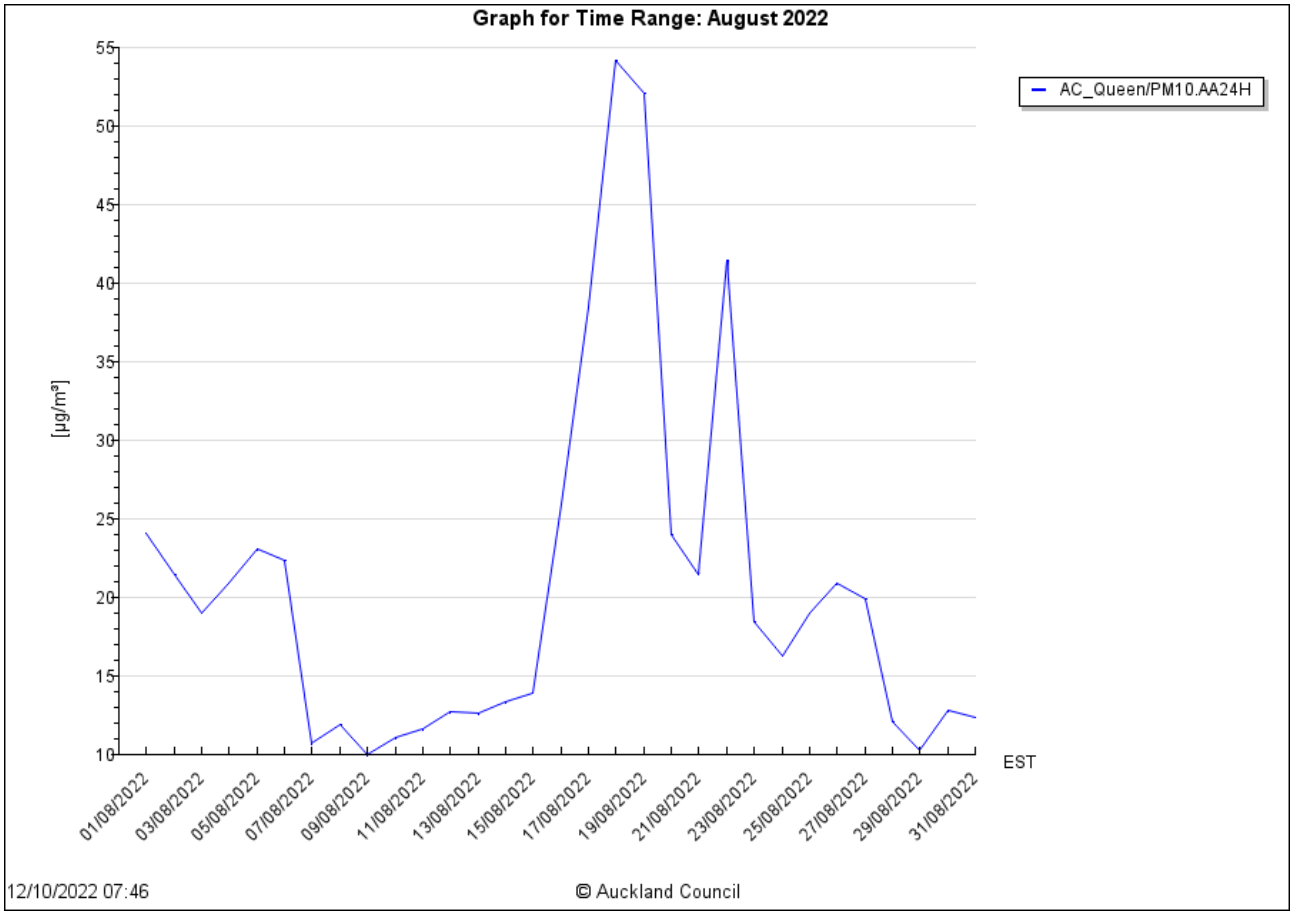

Figure 4. Queen Street NO_2 1-hour average concentrations showing spikes during the weather event.

3 Analysis of baseline and historical data

Overall, Queen Street one-hour average PM_{10} concentration is 30 % more than Auckland's average (see Figure 5). The average PM_{10} 1-hour mean per month ranges from 15.8 µg/m^3 to 17.9 µg/m^3. Table 2 presents the average annual and maximum 24-hour PM_{10} concentrations at Queen Street, from 2017 to 2022.

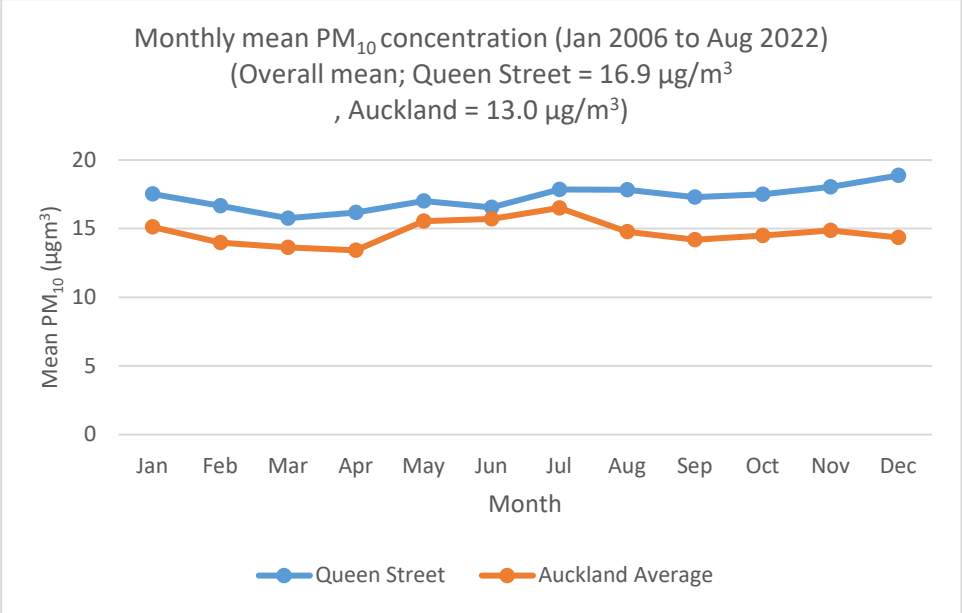

Figure 5. Temporal variation in monthly PM_{10} concentrations – Queen Street compared to Auckland's average.

Table 3. Average annual and maximum 24-hour PM_{10} concentrations at Queen Street: 2017 to 2022.

Year	2017	2018	2019	2020	2021	2022[a]
Annual average (µg/m³)	15.4	16.7	16.8	16.1	19	19.5
Maximum (24-hour) (µg/m³)	30.3	34.9	45.8[b]	33.2	47	54.2[c]
Percent valid data	78%	95%	98%	97%	100%	95%

[a]Data to 31/08/2022 [b]excluding the exceptional event (convention centre fires): 99.4 µg/m³

[c]**Allowable exceedance**

Deseasonalised trend analysis results show there is a downward trend in PM_{10} average concentrations (See Figure 6). Wind and pollution roses of the Queen Street site show that the normal prevailing wind is from southeast (see Figure 7).

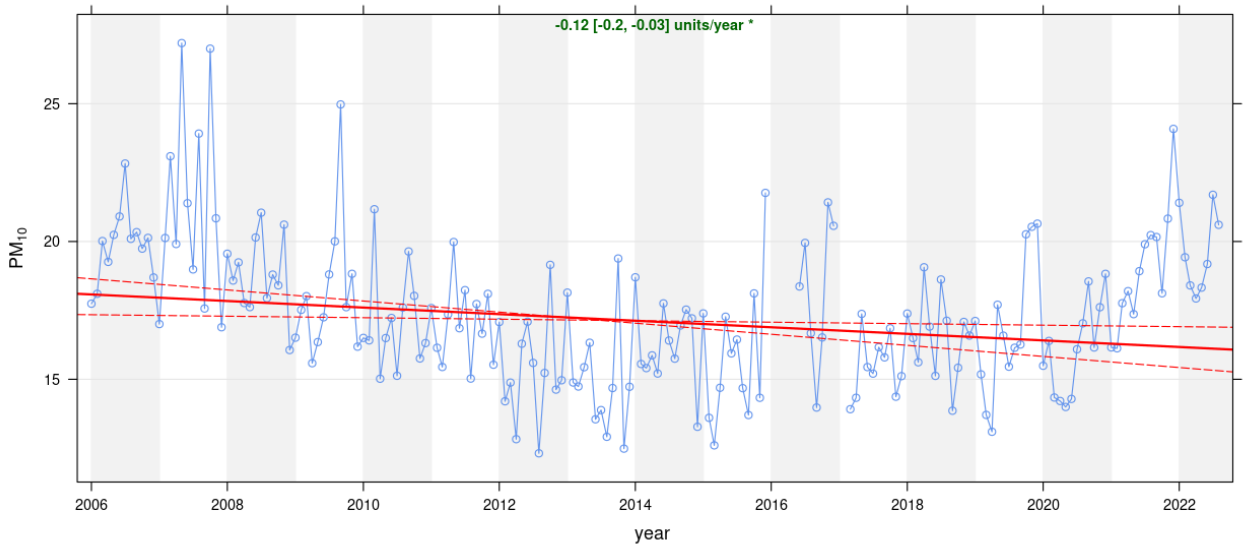

Figure 6. Trends in PM_{10} at Queen Street site. The plot shows the deseasonalised monthly mean concentrations of PM_{10}. The solid red line shows the trend estimate and the dashed red lines show the 95% confidence intervals for the trend based on resampling methods. The overall trend is shown at the top-left as – 0.12 ($\mu g/m^3$) per year and the 95% confidence intervals in the slope from -0.2 – (- 0.03) $\mu g/m^3$ /year. The '***' show that the trend is significant to the 0.001 level.

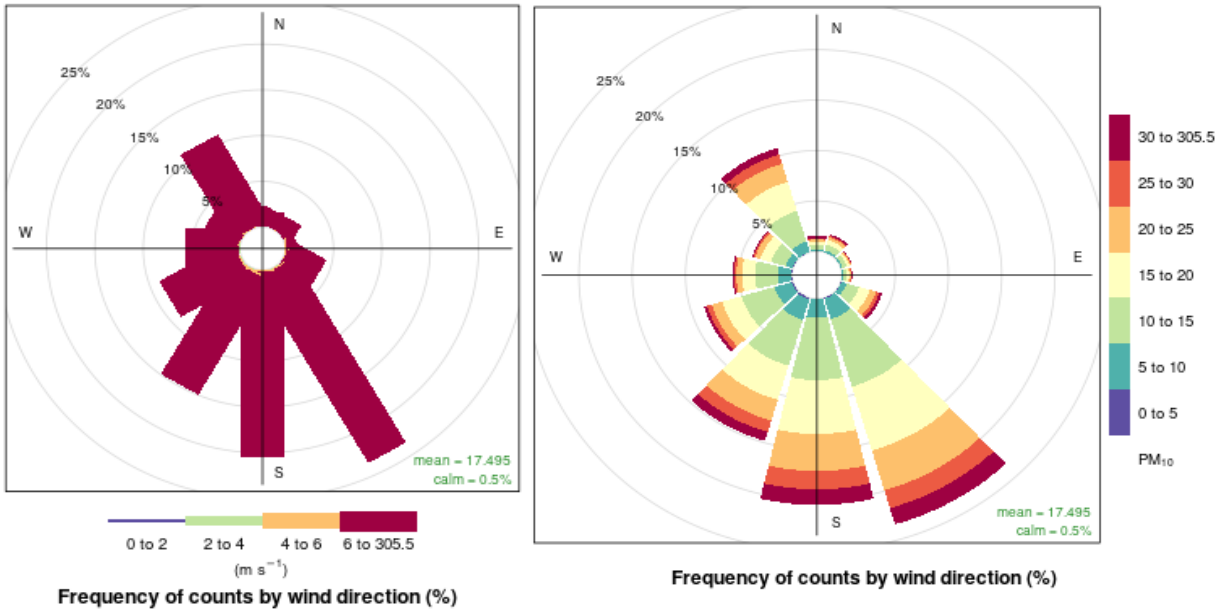

Figure 7. Wind and pollution roses for Queen Street. The predominant wind direction at Queen Street is from the south-easterly quarter (2017- September 2022 data)

4 Previous exceedances at Queen Street site

There have been four NESAQ permissible exceedances of PM_{10} concentrations since 2005. Table 3 presents details of the previous permissible PM_{10} exceedances and their source attribution.

Table 4. 24-hour PM_{10} exceedances of the NESAQ at the Queen Street site since 2005.

Date	**Concentration (µg/m³)**	**Likely caused by**
2/05/2007	54.4	Unknown
25/09/2009	130.0	Australian dust storm
23/10/2019	99.0	Accidental fire
18/08/2022	54.2	Sea salt

5 Exceptional circumstances

The NESAQ standard breach at the Queen Street site occurred during a natural weather event. The exceedances of the PM_{10} standard have ceased to occur again after the weather event passed. PM_{10} concentrations at the site are back to normal ranges below the threshold concentration of 50 µg/m³. This application demonstrates that the exceedance values were caused by marine aerosol (sea salt). The natural weather event in the region represents a temporary source, over which Auckland Council had no ability to control.

These exceedances should be considered for exemption under Regulation 16A, for four reasons:

1. The emissions from marine aerosol represent a strong impact of a regional weather event on the monitoring site and are not representative of the wider emissions profile generally monitored by the Queen Street Site.
2. Auckland Council could not have prevented the exceedances.
3. The Auckland Airsheds have been performing well (for PM_{10} exceedances) with no unpermitted exceedances for many years. If these unusual results were to be included in the overall exceedance total, then the Auckland Airsheds would be in breach of the National Environmental Standard based on the exceedances from an unusual source over which Auckland Council has no control. PM_{10} exceedances are not typical of the Auckland Airsheds.
4. The five requirements outlined by the MfE good practice guide (MfE, 2014) are all met by these exceedances.

5.1 Cause of exceptional circumstances

The PM_{10} NESAQ standard breach at the Queen Street site is the result of a natural weather event. Detailed information on the source apportionment analysis by GNS Science can be found on Attachment 3.

5.2 Justification of exceptional events

The occurrence of the natural weather event was beyond the reasonable control of Auckland Council.

The Users' Guide to the revised NESAQ (MfE, 2014) lays out 5 conditions which must be met for an event to be considered exceptional:

1. Causation – whether the exceedance was caused by the events being assessed
2. Control –the circumstances must be beyond the reasonable control of the regional council
3. Foreseeability – an assessment of whether the circumstances were able to be reasonably predicted
   and/or planned for
4. Frequency and likelihood of reoccurrence – an assessment of how unusual the events were

5. Purpose of the RMA – whether a determination that circumstances were exceptional is consistent with the purpose of the RMA.

This application meets all five of the requirements outlined by MfE (2014) as detailed below:

a. Causation

As described earlier in this section, we are confident that the exceedances described in this application were caused by a natural weather event, which has temporarily elevated concentrations of PM_{10} across all the nine monitoring sites. In contrast, the monitoring site typically records PM_{10} 24-hour average concentrations typically 41% of the NESAQ threshold level. The additional point source temporarily elevated concentrations and is not representative of ambient concentrations. In addition, the exceedances were only recorded during the unusual natural weather system. Owing to this, and the analysis in *Attachment 3*, it is considered that the cause of the exceedances is clearly marine aerosol.

b. Control

The circumstances which led to these exceedances were beyond the reasonable control of Auckland Council. Auckland Council has little ability to restrict this kind of natural event.

c. Foreseeability

There was little that Auckland Council could have done to foresee this event.

d. Frequency and likelihood of reoccurrence

The event detailed in this application are unusual. The Auckland Urban airshed has not been in breach of the NESAQ for PM_{10} between November 2019 and July 2022. The cause of the exceedances is unusual, in that they were caused by a temporary additional source.

e. Purpose of the RMA

The purpose of the RMA is to promote sustainable management of resources, whilst allowing responsible use of natural resources. In this case, the exceedances are consistent with the purpose of the RMA, as it allows for a certain degree of use of resources. In addition, the regulations (NESAQ) are designed to manage poor air quality from representative sites and emissions profiles. As this application has shown, the exceedances recorded at the Queen Street site are not representative of the ambient pollutant profile at the site and are due to the impact of a natural regional weather system. Accordingly, this application is consistent with the purpose of the RMA.

6 Conclusion

The technical investigations outcome shows that the PM_{10} exceedances recorded on the 18th and 19th of August 2022 at the Queen Street air quality monitoring station were caused by elevated levels of sea salt as a results of a natural weather pattern and resulting in a sea state and wind conditions. Auckland Council therefore requests that these exceedances be excluded as an exceptional circumstance under the NESAQ.

7 References

Davy, P. K., Ancelet, T., Trompetter, W. J and Markwitz, A (2017). Source apportionment and trend analysis of air particulate matter in the Auckland region. Prepared by the Institute of Geological and Nuclear Sciences Ltd, GNS Science for Auckland Council. Auckland Council technical report, TR2017/001

Ministry for the Environment (2011). 2011 Users' Guide to the revised National Environmental Standards for Air Quality: Updated 2014. Wellington: Ministry for the Environment.

Appendix A: Queen Street site metadata

<table>
<tr><td colspan="4">Site name: Queen Street</td><td rowspan="5">  </td></tr>
<tr><td>Address</td><td colspan="3">155 Queen St Auckland</td></tr>
<tr><td>Monitoring commenced</td><td colspan="3">1998</td></tr>
<tr><td rowspan="3">Coordinates</td><td>Easting</td><td>Northing</td><td>Elevation</td></tr>
<tr><td>NZMG 2667850</td><td>NZMG 6482270</td><td>15</td></tr>
<tr><td>NZTM 1757414</td><td>NZTM 5920573</td><td></td></tr>
<tr><td>AS2922 compliant?</td><td colspan="3">No</td></tr>
<tr><td>Site description and area characteristics</td><td colspan="4">Queen Street monitoring station is located on a canopy 1st floor roof top. The key emission source measured at this site is combustion from vehicle exhausts. This site is one of our most central site providing information on possible personal exposure in one of the most densely populated areas of Auckland.</td></tr>
<tr><td>Distance from road and other major sources</td><td colspan="4">2m from Queen Street</td></tr>
<tr><td>Pollutants monitored</td><td colspan="4">PM10 – T640 Teledyne PM Mass Monitor
PM2.5 - T640 Teledyne PM Mass Monitor
NOx – API 200E Gas Analyser
PM10 (Speciation) – Thermo 2000H Partisol, 1 in 6 days sampling</td></tr>
<tr><td>Meteorological parameters measured on site</td><td colspan="4">Wind speed, wind direction, ambient temperature, and relative humidity.</td></tr>
<tr><td>Mast height</td><td colspan="4">Est. 6m (at top of housing above Queen Street)</td></tr>
<tr><td>Inlet height (m)</td><td colspan="4">5m</td></tr>
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Appendix B: Spikes in PM_{10} concentrations at air quality monitoring sites located in Bay of Plenty, Hawks Bay and Northland

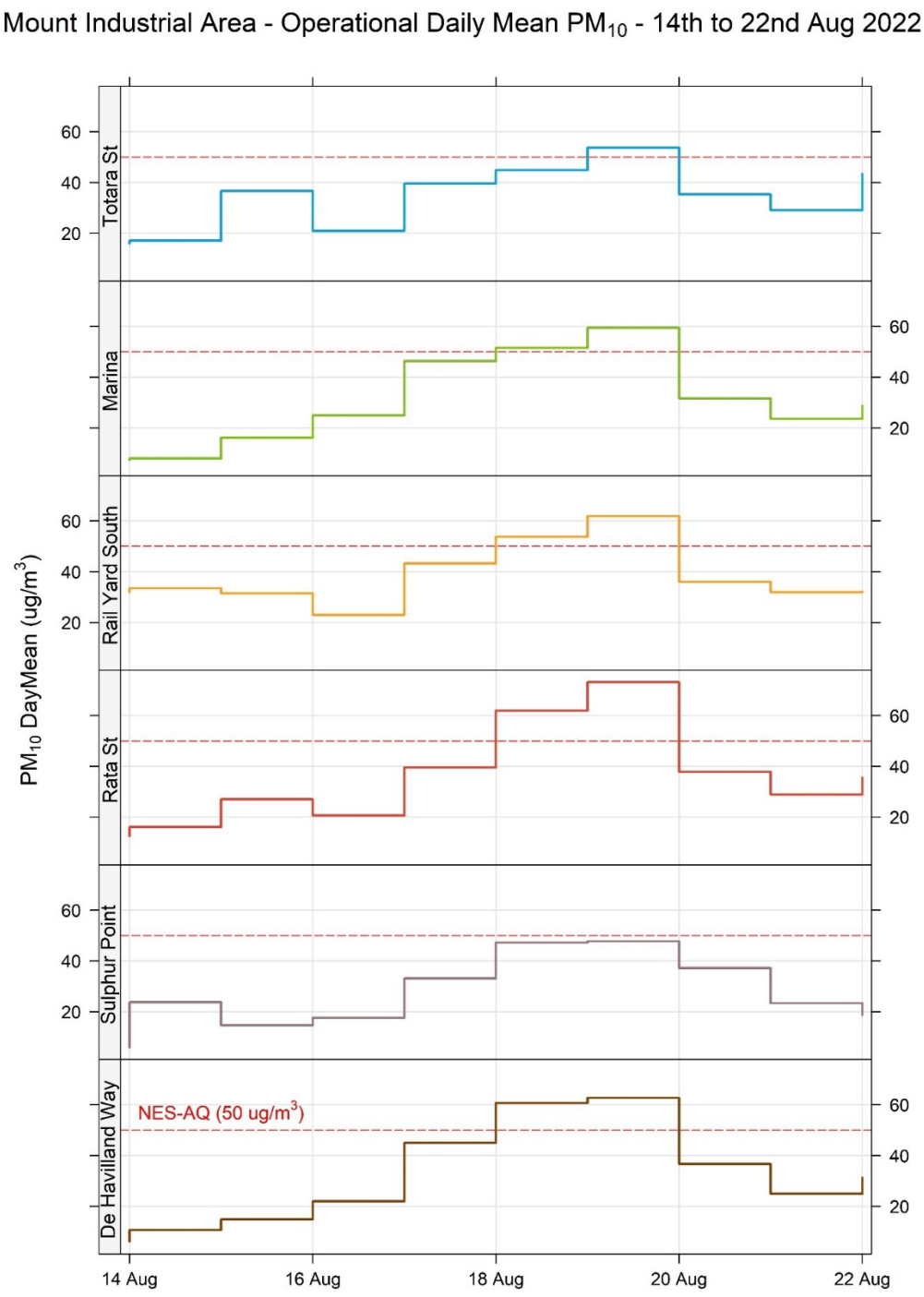

Figure A. PM_{10} levels at some Bay of Plenty air quality monitoring sites: Source: Shane Iremonger, Team Leader Science, Bay of Plenty Regional Council

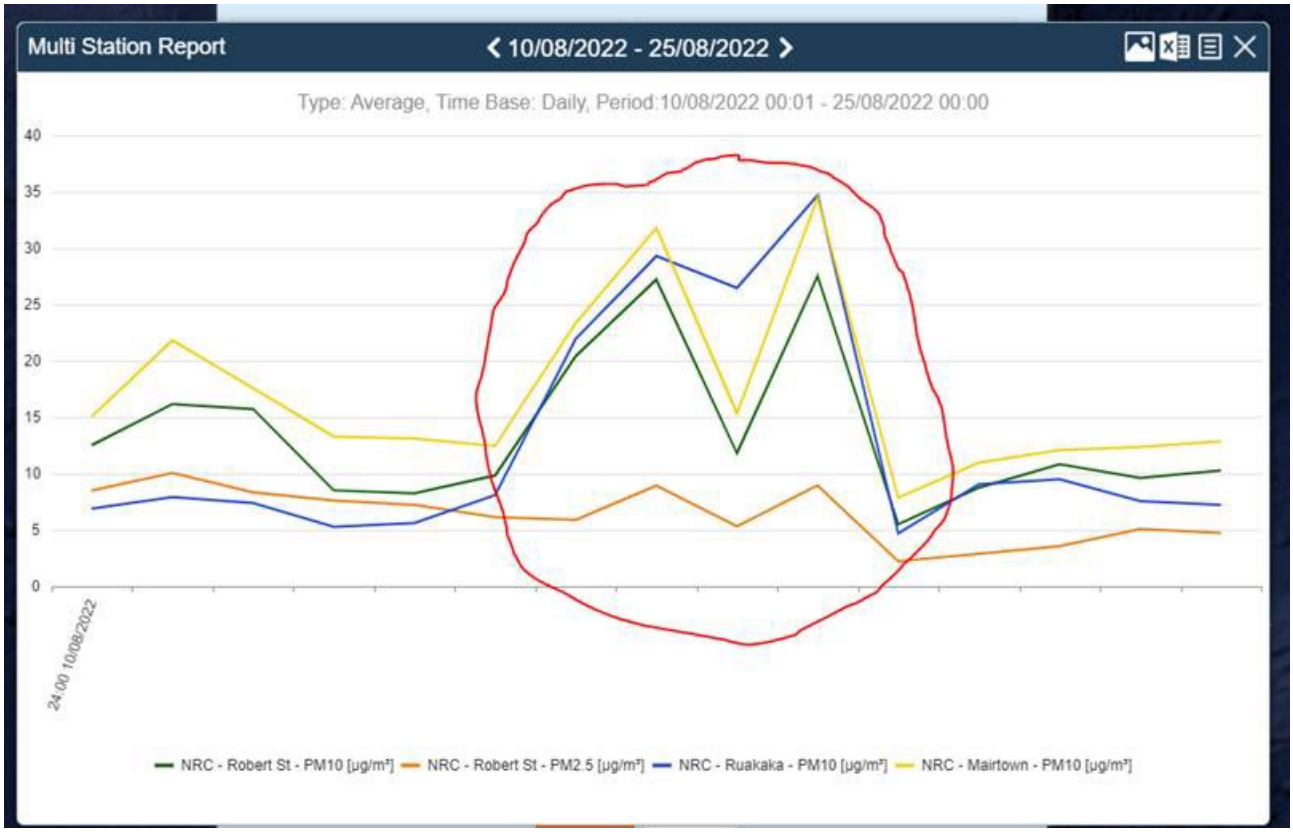

Figure B. PM_{10} and $PM_{2.5}$ levels at Northland air quality monitoring sites: Source: Dr Obi Khanal, Resource Scientist – Air, Northland Regional Council

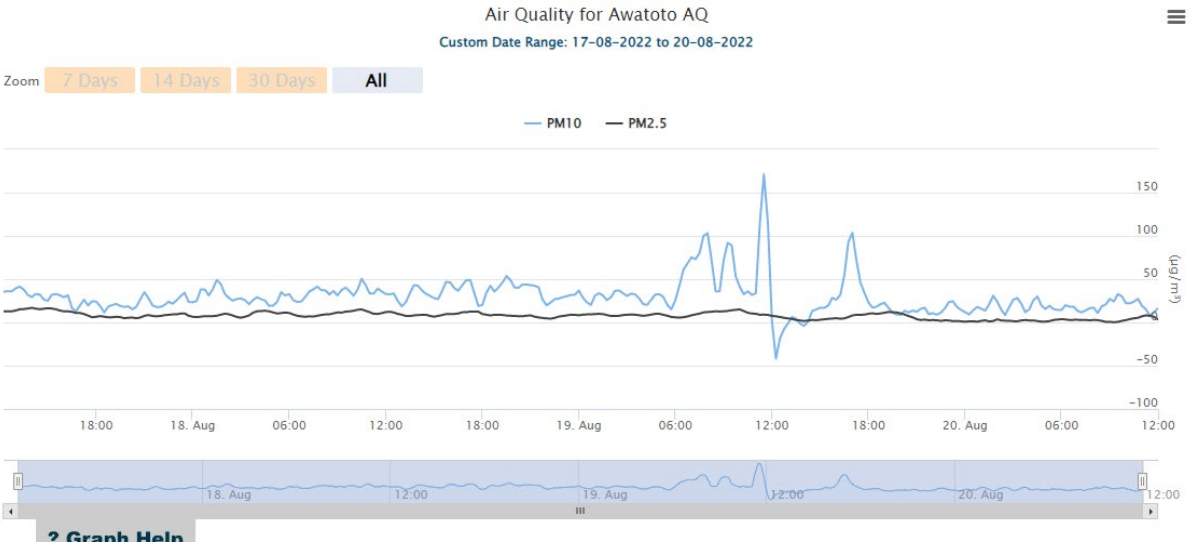

Figure C. PM_{10} and $PM_{2.5}$ levels at Hawkes Bay air quality monitoring sites: Source: Dr Kathleen Kozyniak, Team Leader Marine Air and Land Science, Hawkes Bay Regional Council

Find out more:
Louis.boamponsem@aucklandcouncil.govt.nz
or visit knowledgeauckland.org.nz

Resource Management (National Environmental Standards for Air Quality) Regulations 2004 – Regulation 16A Exceptional Circumstances

Application for exceptional circumstances consideration:

Khyber Pass Road nitrogen dioxide (NO_2) (1-hour Average)

Attachment 2

Louis Boamponsem

November 2022

This report has been prepared to support the application for exceptional circumstances consideration: Khyber Pass Road air quality monitoring site: nitrogen dioxide (NO_2) (1-hour average) (1 exceedance)
Date: 4 November 2022

Executive summary

On 24th August 2022, the Auckland Council ambient air quality monitoring site Khyber Pass Road recorded one exceedance of the National Environmental Standard for Air Quality (NESAQ) for nitrogen dioxide (NO_2) (1-hour average). The unusual nature of this exceedance led to an investigation which has revealed that it was caused by the activity of a tag graffiti artist who intruded the air quality monitoring station. Specifically, the exceedance was the result of emissions from a temporary stationary running vehicle and spray paint fumes. The emissions from the graffiti artist's vehicle and spray paint fumes represent a strong localised impact on the Khyber Pass Road monitoring site and are not representative of the wider emissions profile in the area generally monitored by this site.

The Auckland Urban Airshed has been performing well (for NO_2 exceedances) in recent years, with no unpermitted exceedances in many years. The activity of the intruder of the site is a temporary point source, additional to the 'baseline' concentrations recorded at the monitoring site, and this addition elevated concentrations to the point of exceeding the NESAQ threshold.

This exceedance should be considered for exemption under Regulation 16A, for four reasons:

1. The emissions from the graffiti artist represent a strong localised impact on the monitoring site and are not representative of the wider emissions profile generally monitored by the Khyber Pass Rd Site.
2. Auckland Council could not have prevented the exceedance – the monitoring site is located on private property, and although the monitoring equipment is housed and secure, the area it is located in, despite being private property, has open public access.
3. The Auckland Airshed has been performing well (for NO_2 exceedances) with no unpermitted exceedances for many years. If this unusual result was to be included in the overall exceedance total, then the Auckland Airshed would be in breach of the National Environmental Standard based on the exceedance from an unusual point source over which the Auckland Council has no control. NO_2 exceedances are not typical of the Auckland Airshed.
4. The five requirements outlined by the MfE good practice guide (MfE, 2014) are all met by this exceedance.

This application uses monitoring data and investigation outcome to show that the one exceedance was caused by the activity of a graffiti artist, and accordingly should be considered for exceptional circumstances exemption.

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Glossary of terms, acronyms, and abbreviations

Term	Meaning
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 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)
Exceedance	An exceedance defines a period of time during which the concentration of a pollutant is greater than the appropriate air quality criteria.
MfE	Ministry for the Environment
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.
NOx	Oxides of nitrogen. NOx is principally formed by the oxidation of nitrogen contained in air at high combustion temperatures.
Stats NZ	Statistics New Zealand
µg/m³	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 Council is required under the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 to report any breach of the air quality standard. The ambient standards are the minimum requirements that outdoor air quality should meet to guarantee a set level of protection for human health and the environment.

An ambient air quality concentration limit of 200 µg/m³ (one hour average) for nitrogen dioxide (NO_2) must be met for all but nine hours each year. The Auckland Urban Airshed has breached this standard on one occasion in August 2022 at the Khyber Pass Road air quality monitoring site.

Auckland Council has been carrying out ambient air quality monitoring at Khyber Pass Road site since October 1995. The site's location is shown in Figure 1. The site metadata are provided in Appendix A. The site is classed as urban peak (traffic) site and the main air pollution sources are motor vehicles, home heating (during winter), construction activities and/or road dust. The site monitors particulate matter (PM_{10}), oxides of nitrogen (NO_x, NO, NO_2), and carbon monoxide (CO). The site is operated in accordance with the MfE Good Practice Guide (MfE, 2014) and complies with AS/NZS 3580.1.1:2007 (site location). The NO_x sensor at this site operates in accordance with relevant AS/NZS standards.

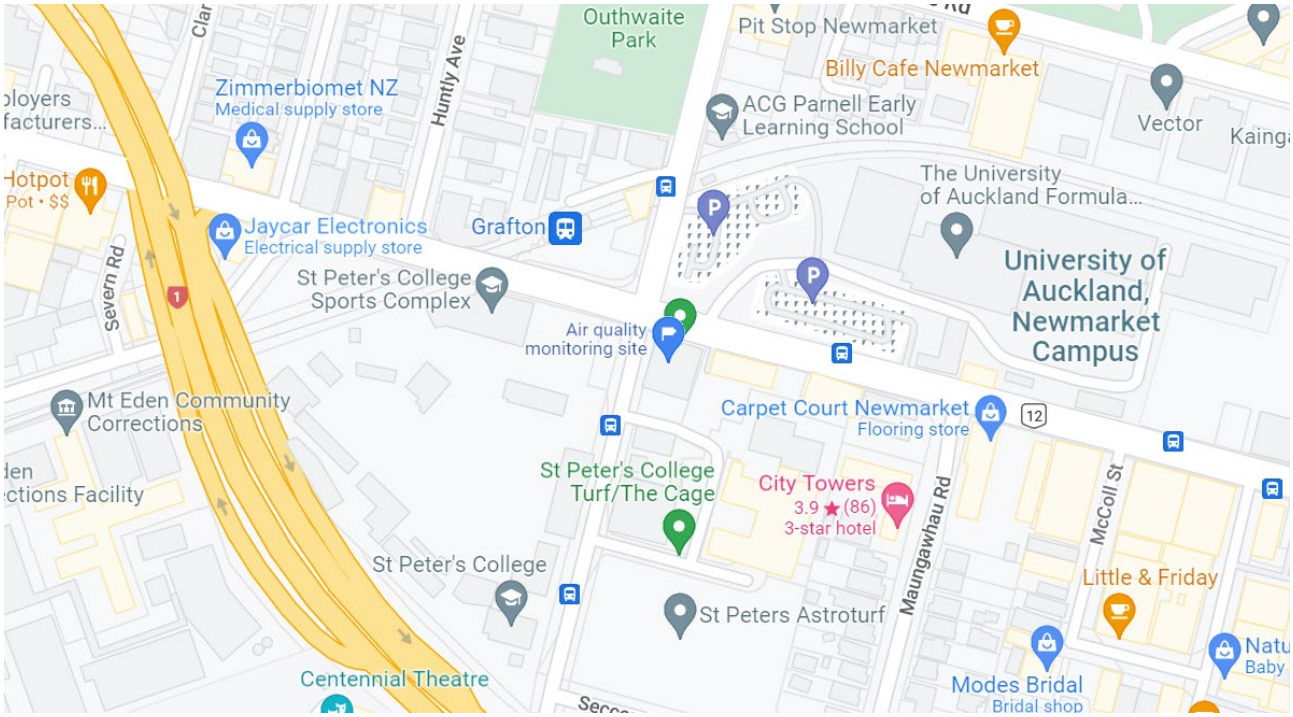

Figure 1. Location of the Khyber Pass Rd air quality monitoring site ( ) Source: Google maps

On 24th August 2022, the Khyber Pass Road site experienced one exceedance of the National Environmental Standards for Air Quality (MfE, 2014) (NESAQ) for NO_2 (1-hour average). The

unusual nature of this result led to an investigation, which showed that this exceedance was due to an exceptional circumstance. This application uses monitoring data and laboratory investigation results to demonstrate that the one exceedance was caused by a graffiti vandalism event on the shed and a nearby wall (see Figure 2).

The circumstances that led to a tag graffiti writer intruding the monitoring site were out of the control of Auckland Council, and accordingly, this exceedance should be considered for exceptional circumstances exemption.

A staff member of the Les Mills Fitness Centre (Newmarket branch, landowner of the premises of the monitoring shed) reported to their manager that on 24th August 2022, between 9 pm and 10 pm the air quality monitoring shed and a nearby wall were defaced with graffiti tags. It is understood that someone parked a car near the monitoring station and left their vehicle running while they defaced the building. This coincides with the time of the time of the elevated NO_2 levels.

High NO_2 levels are normally recorded during peak traffic hours as motor vehicles are the primary source. When a point source of NO_2 is close enough to the inlet of a monitoring instrument, elevated concentrations are likely to be recorded. In addition, gases in paint sprays can spike NO_2 levels when they are closed enough to the inlet of a sensor, as was the case in this event.

Auckland Council requested Watercare Ltd air quality team to conduct a laboratory experiment to ascertain whether gaseous constituents from paint spray can elevate NO_2 concentration. The results from this experiment showed that spray paint fumes near the sample line (inlet) of a NOx analyser can increase ambient NO_2 concentration up to 514 % (See Appendix B).

Figure 2. A picture showing graffiti tags on the Khyber Pass Road air monitoring shed and a nearby wall.

The Auckland Airsheds have not recorded exceedances of the NESAQ for NO_2 between October 2020 – May 2022, and has not been in breach of the NESAQ for NO_2 between 2015 – May 2022 (see Table 1).

Table 1. Historical NO_2 exceedances in the Auckland Airsheds (January 2005 – September 2022)

Year	**Number of NO_2 exceedances**
2005	18
2006	1
2007	11
2008	0
2009	1
2010	None
2011	1
2012	2
2013	None
2014	13[a]
2015	None
2016	None
2017	None
2018	None
2019	None
2020	5
2021	None
2022	94[b] (excluding the one reported in this application)

[a]Breach caused by an exceptional circumstance (diesel power generator) – The minister approved this application (Nick, 2014).

[b]Breach of caused by an exceptional circumstance (diesel power generator) – awaiting the minister's decision on the exceptional circumstance application (June 2022).

2 Summary of monitoring readings showing exceedance event

On 24th August 2022, the Auckland Council ambient air quality monitoring site, Khyber Pass Road, experienced one exceedance of the National Environmental Standards for Air Quality (NESAQ) for NO_2 (1-hour average). The NO_2 exceedance was 261.0 µg/m³.

The monitoring site NO_2 concentrations started spiking above the NESAQ acceptable threshold between 9 pm and 10 pm (see Figure 3). The NO_2 exceedance can be considered as the result of an unusual temporary point source rather than a meaningful change in baseline concentrations. Nitrogen dioxide (NO_2) is a gas primarily generated by the burning of fossil fuels (MfE & Stats NZ, 2021). As shown by the brief experiment (Appendix B), spray paints used by Graffiti artists can contribute to ambient NO_2 concentration.

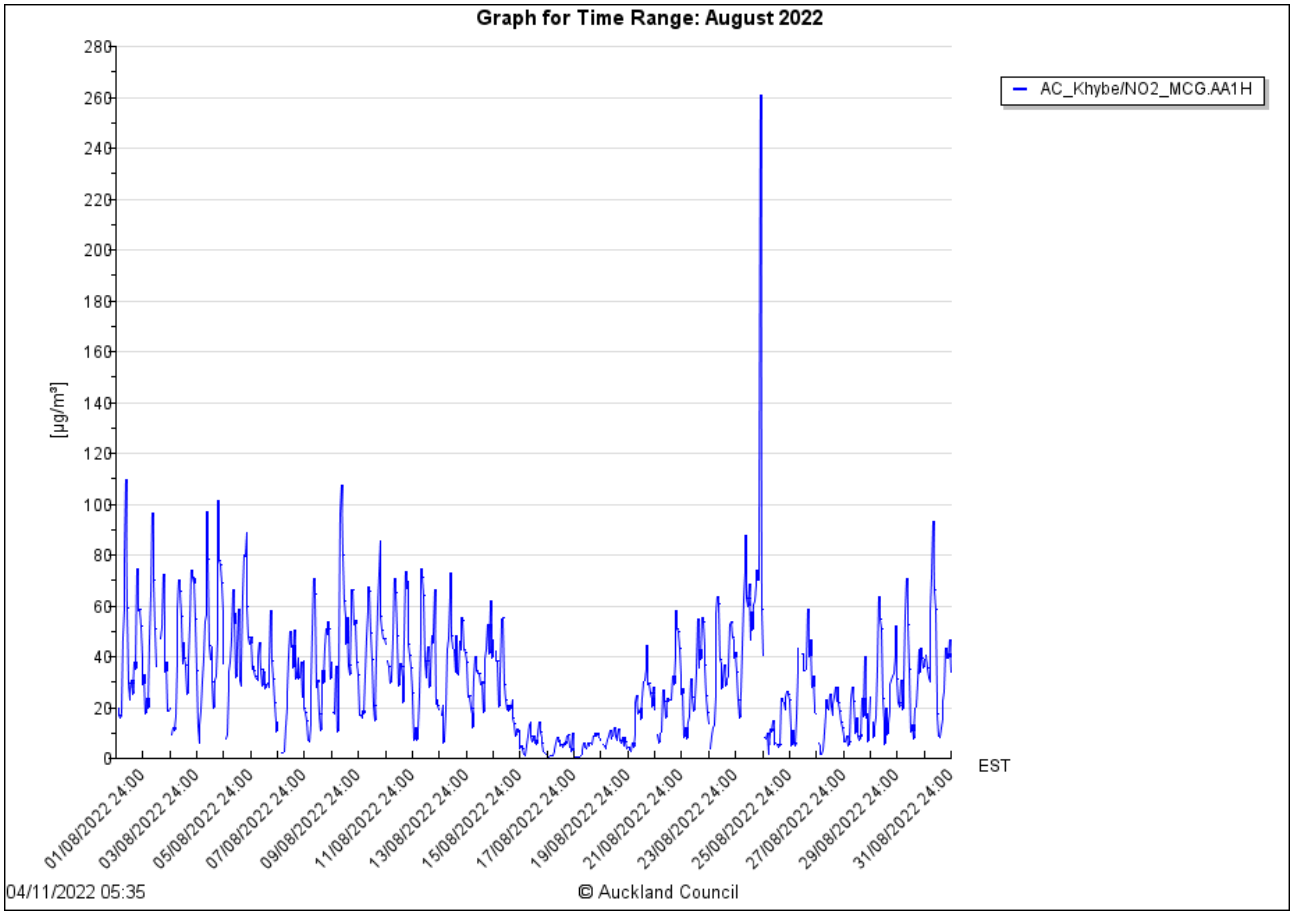

Figure 3. Khyber Pass Rd Site NO_2 1-hour average concentrations showing spikes on 24th August 2022.

3 Analysis of baseline and historical data

Historically, Khyber Pass Rd site average NO_2 concentration is 46% more than Auckland's average and 12 % higher than Queen Street site (the nearest monitoring site). The average NO_2 1-hour mean per month ranges from 23.6 µg/m^3 to 42.8 µg/m^3. The highest NO_2 concentrations are typically recorded in winter (see Figure 4). The pattern of historical NO_2 variations at the Khyber Pass Rd site is similar to Queen Street, the closest air quality monitoring site. Since commissioning of the site, the annual average 1-hour and maximum NO_2 concentrations have been declining (see Figure 5).

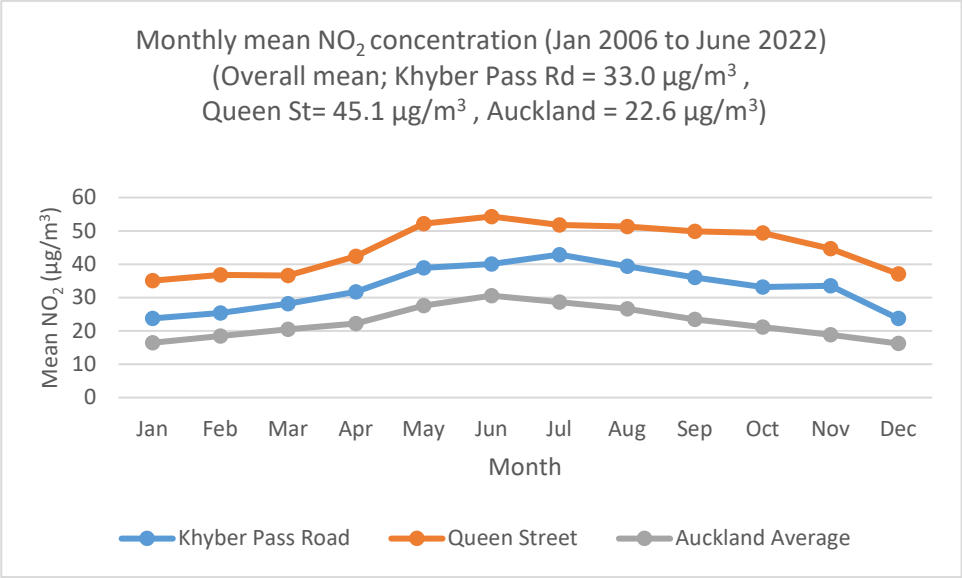

Figure 4. Temporal variation in monthly NO_2 concentrations – Khyber Pass Road compared to Queen Street (nearby site) and Auckland average (No data for Khyber Pass Road site; between March 2015 and August 2019)

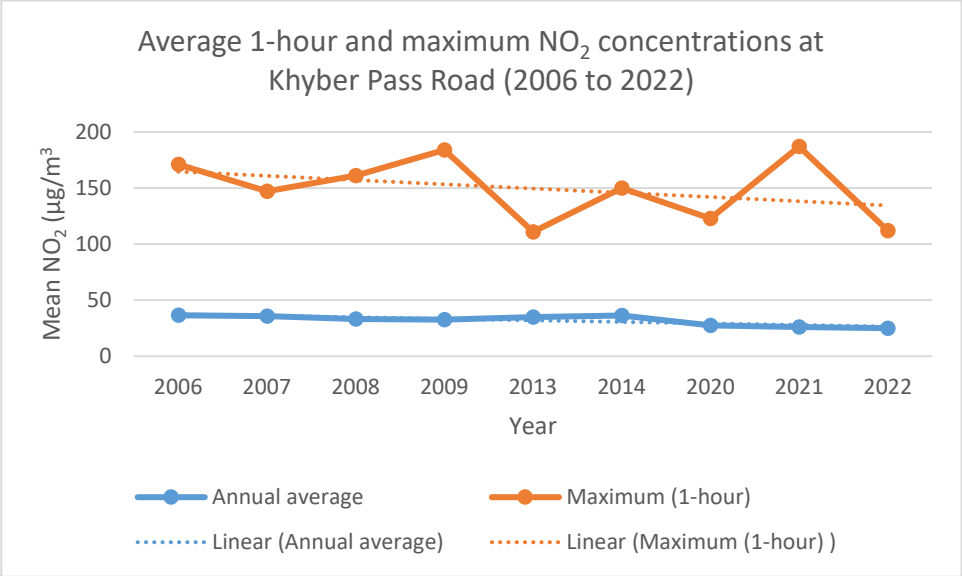

Figure 5. Average 1-hour and maximum NO_2 concentrations at Khyber Pass Rd Jan 2006 to Aug 2022 (No data between March 2015 and August 2019)

Deseasonalised trend analysis results show there is a downward trend in NO_2 average concentrations (See Figure 6).

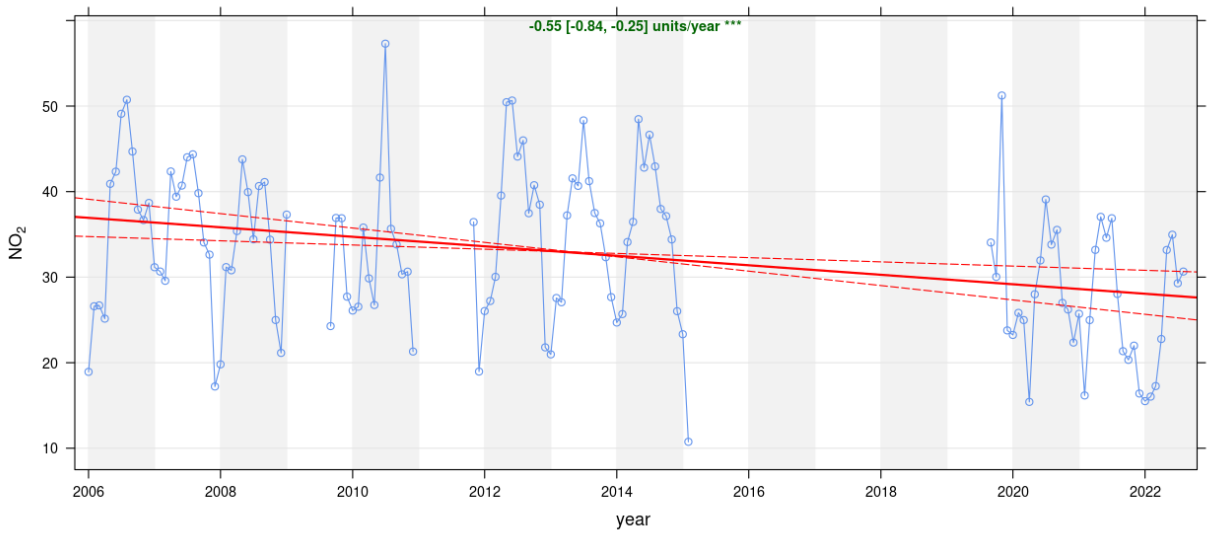

Figure 6. Trends in NO_2 at Khyber Pass Road. The plot shows the deseasonalised monthly mean concentrations of NO_2. The solid red line shows the trend estimate and the dashed red lines show the 95% confidence intervals for the trend based on resampling methods. The overall trend is shown at the top-left as – 0.55 ($\mu g/m^3$) per year and the 95% confidence intervals in the slope from -0.84 – (- 0.25) $\mu g/m^3$ /year. The '***' show that the trend is significant to the 0.001 level (No data between March 2015 and August 2019)

Importantly, the exceedances recorded at the Khyber Pass Rd site on 24th August 2022 is not accompanied by elevated ambient concentrations at Queen Street, indicating the likely presence of a local source at the Khyber Pass Rd site (see Figure 7).

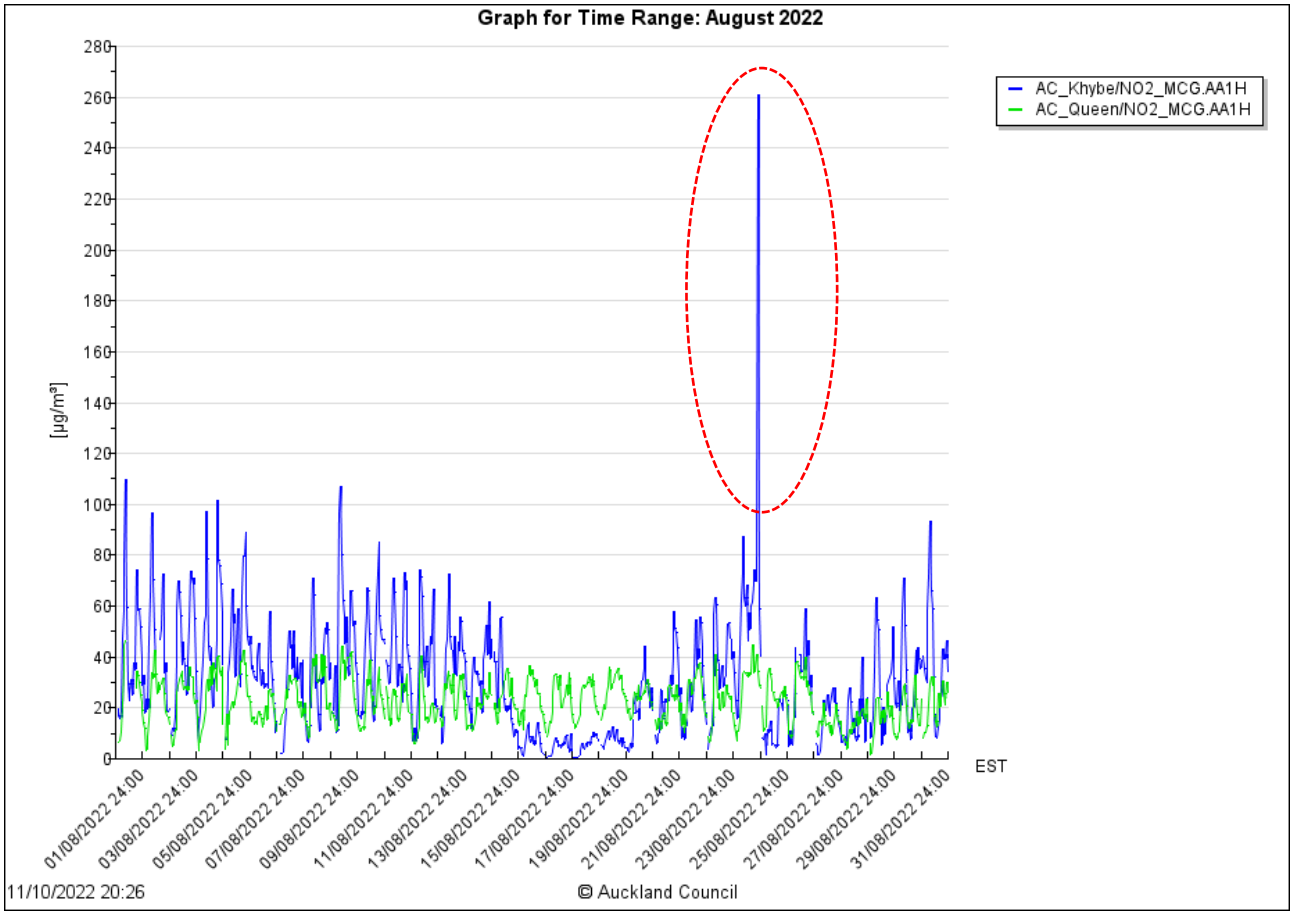

Figure 7. Time series plot for Khyber Pass Rd and Queen Street sites indication similar NO_2 patterns except on the day of the exceedance.

4 Previous exceedances at Khyber Pass Road site

Khyber Pass Rd air quality monitoring site has recorded 15 NESAQ permissible exceedances of NO_2 concentrations since 2005. Table 3 presents details of the previous NO_2 exceedances and their source attribution.

Table 2. Hourly NO_2 exceedances of the NESAQ at the Khyber Pass Rd site since 2005 (No data between March 2015 and August 2019)

Date	Time	Concentration (µg/m³)	Likely caused by
15-Apr-05	17:00	204.1	Motor vehicles (Traffic)
9-May-05	18:00	218.1	Motor vehicles (Traffic)
8-Jun-05	9:00	229.2	Motor vehicles (Traffic)
10-Jun-05	9:00	224.0	Motor vehicles (Traffic)
14-Jun-05	9:00	206.8	Motor vehicles (Traffic)
24-Jun-05	18:00	229.1	Motor vehicles (Traffic)
27-Jun-05	9:00	212.5	Motor vehicles (Traffic)
27-Jun-05	17:00	263.9	Motor vehicles (Traffic)
30-Jun-05	18:00	208.0	Motor vehicles (Traffic)
1-Jul-05	9:00	202.2	Motor vehicles (Traffic)
13-Jul-05	18:00	249.2	Motor vehicles (Traffic)
20-Jul-05	8:00	210.9	Motor vehicles (Traffic)
29-Jul-05	18:00	205.0	Motor vehicles (Traffic)
2-Aug-05	9:00	242.8	Motor vehicles (Traffic)
4-Aug-05	9:00	220.1	Motor vehicles (Traffic)

5 Exceptional circumstances

The NESAQ standard breach at the Khyber Pass Rd site occurred during the unusual activity of an intruder. NO_2 concentrations at the site are back to normal ranges below the threshold concentration of 200 µg/m³. This application demonstrates that the exceedance was caused by the combination of emission from the stationary running vehicle and spray paint fumes. The activity of the graffiti artist was a temporary point source of NO_2, over which Auckland Council had no ability to control.

This exceedance should be considered for exemption under Regulation 16A, for four reasons:

1. The emissions from the graffiti artist represent a strong localised impact on the monitoring site and are not representative of the wider emissions profile generally monitored by the Khyber Pass Rd Site.
2. Auckland Council could not have prevented the exceedances.
3. The Auckland Airsheds have been performing well (for NO_2 exceedances) with no unpermitted exceedances for many years. If this unusual result was to be included in the overall exceedance total, then the Auckland Airsheds would be in breach of the National Environmental Standard based on the exceedances from an unusual point source over which the Auckland Council has no control. NO_2 exceedances are not typical of the Auckland Airsheds.
4. The five requirements outlined by the MfE good practice guide (MfE, 2014) are all met by this exceedance.

6 Conclusion

The Auckland Urban Airshed has been performing well (for NO_2 exceedances) in recent years, with no unpermitted exceedances in many years. The intrusion of the air quality monitoring station by the graffiti tag artist was unforeseen. The Khyber Pass Rd site air quality monitoring data and investigations outcome show that this exceedance was caused by vehicle emissions and spray paint fumes as a result of the activity of a graffiti artist, and accordingly should be considered for exceptional circumstances exemption.

7 References

MfE and Stats NZ (2021). New Zealand's Environmental Reporting Series: Our air 2021. Available at www.environment.govt.nz , (Accessed: 18 January 2022)

Ministry for the Environment (2011). 2011 Users' Guide to the revised National Environmental Standards for Air Quality: Updated 2014. Wellington: Ministry for the Environment.

Nick, R (2014). Application for exceptional circumstances consideration: Auckland Waterfront Nitrogen Dioxide (1-hour Average) (13 Exceedances). Auckland Council. Available on: https://environment.govt.nz/acts-and-regulations/regulations/national-environmental-standards-for-air-quality/applying-to-have-a-breach-of-an-air-quality-standard-excluded/

Appendix A: Site metadata – Khyber Pass Road

<table>
<tr><td colspan="4">Site name: Khyber Pass Road</td><td rowspan="3"> 

Partisol & Passive inlets</td></tr>
<tr><td>Address</td><td colspan="3">Between 269 and 289 Khyber Pass Road, Newmarket</td></tr>
<tr><td>Monitoring commenced</td><td colspan="3">29th October 1995
Paused May 2015, restarted August 2017</td></tr>
<tr><td rowspan="3">Coordinates</td><td>Easting</td><td>Northing</td><td>Elevation</td><td></td></tr>
<tr><td>NZMG
2668305</td><td>NZMG
6480185</td><td rowspan="2">82</td><td></td></tr>
<tr><td>NZTM
1757874</td><td>NZTM
5918488</td><td></td></tr>
<tr><td>AS2922 compliant?</td><td colspan="3">Yes (for gases)
No (for PM_{10})</td><td></td></tr>
<tr><td>Site description and area characteristics</td><td colspan="4">Site description and area characteristics
Khyber Pass slopes down to the east and Newmarket shopping centre (700m E). The Southern Motorway is approximately 250m W-SW from the site. Mixed residential to NW, older houses -approximately 60% with chimneys/commercial/light industry. Newmarket shopping precinct <1km E; Auckland Domain is 250m to North. In 2008 the site was moved 20m SE along Khyber Pass Rd. Les Mills bought 269 Khyber Pass Road in 2014 and the site was decommissioned. A new cabinet was installed between 269-289 Khyber Pass Road.</td></tr>
<tr><td>Distance from road and other major sources</td><td colspan="4">4m N to Khyber Pass Rd</td></tr>
<tr><td>Pollutants monitored</td><td colspan="4">PM_{10} – Thermo FH62C14 Beta Attenuation Monitor
CO - API 300E Gas Analyser
NOx – API 200E Gas Analyser
BTEX – Passive Samplers, Monthly sampling (here and at Crowhurst St)</td></tr>
<tr><td>Meteorological parameters measured on site</td><td colspan="4">NA</td></tr>
<tr><td>Mast height</td><td colspan="4">NA</td></tr>
<tr><td>Inlet height (m)</td><td colspan="4">5m</td></tr>
</table>

Appendix B: Synopsis of paint spray experiment

Aim: To find out whether NO/NO_2/NOX ambient concentration would increase in the presence of spray paint fumes.

Method:

Three random brands of spray paints were purchased for this experiment. NOx analyser model (TAPI T200 Chemiluminescence NO/NO2/NOX Analyzer (sn 7323) same as the version running at the Khyber Pass Rd was set up in the Watercare Laboratory Services air quality lab (see Figure a below). The sample line of the NOx analyser was placed above a cardboard box. The ambient (normal) concentrations of NO/NO2/NOx were recorded. Three different spray paint brand samples were sprayed for three seconds into the box allowing the NOx analyser to sample the paint fumes. The analyser was allowed to return to "normal" levels between each paint sample.

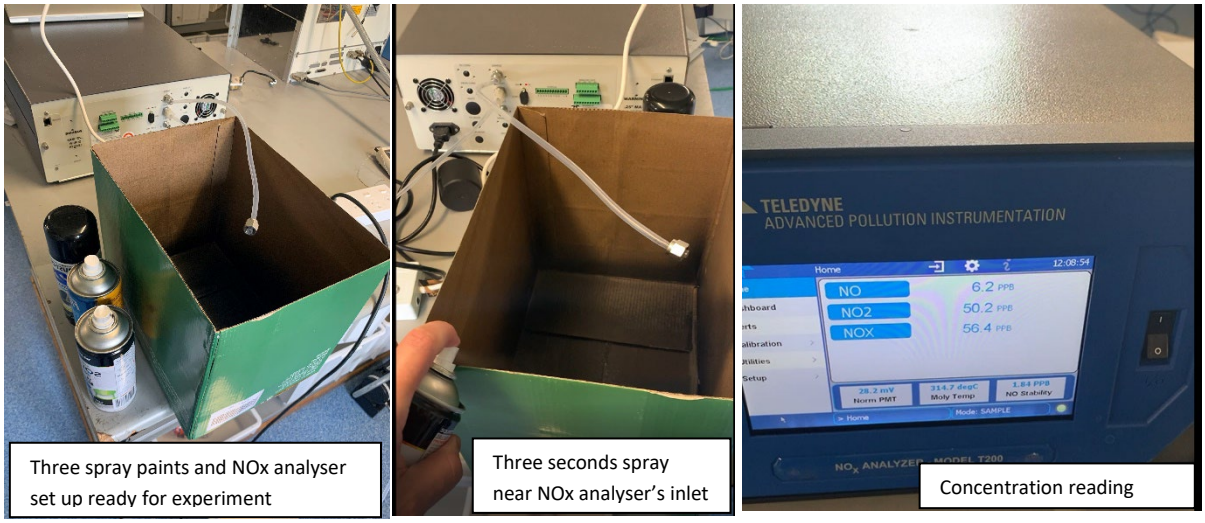

Figure a. Experiment set up at the Watercare Laboratory Services air quality lab

Results:

The average NO_2 concentrations of the spray paints ranged from 36.4 ppb to 53.6 ppb (see Table a. The overall average NO_2 concentration of 31.1 ± 19.6 ppb was statistically significantly higher than the ambient concentration ($p<0.05$).

Table a. Average NO, NO_2 and NOx concentrations with and without spray paint fumes

	NO (ppb)	NO_2 (ppb)	NOx (ppb)	What percentage higher is the NO_2 level after spraying

				compared to the ambient?
Ambient (no spray paint fumes)	0.1	6.5	6.6	N/A
Spray paint brand 1	2.4	36.4	38.8	469 %
Spray paint brand 2	3.6	27.8	31.4	334 %
Spray paint brand 3	6.3	53.6	59.8	738 %
Average (± standard deviation)	4.1 ± 2.0	39.3 ± 13.1	43.3 ± 14.7	514 % ± 206%

Conclusion:

The results from this experiment indicate that spray paint fumes near NOx analyser sample line can significantly increase ambient NO_2 concentration. It is hard to find scientific literature on the chemical mechanism involved in the released of NO, NO_2 and NOx from spray paints. More research is needed to increase our understanding in this area of science.

Find out more:
Louis.boamponsem@aucklandcouncil.govt.nz
or visit knowledgeauckland.org.nz

Analysis of airborne particulate matter associated with Auckland Council Queen Street NESAQ PM_{10} exceedance on 18 and 19 August 2022

PK Davy WJ Trompetter

GNS Science Consultancy Report 2022/118
November 2022

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Use of Data:

Date that GNS Science can use associated data: November 2022

BIBLIOGRAPHIC REFERENCE

Davy PK, Trompetter WJ. 2022. Analysis of airborne particulate matter associated with Auckland Council Queen Street NESAQ PM_{10} exceedance on 18 and 19 August 2022. Lower Hutt (NZ): GNS Science. 17 p. Consultancy Report 2022/118.

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EXECUTIVE SUMMARY

On 18 and 19 August 2022, the Auckland Council air quality monitoring site at Queen Street in the Auckland central business district recorded elevated concentrations of airborne particulate matter that exceeded the PM_{10} (24-hour average) National Environmental Standards for Air Quality (NESAQ) of 50 μg m^{-3}. All other Auckland Council air quality monitoring sites registered similar increases in particulate matter concentrations but did not exceed the NESAQ. Compositional analysis of particulate matter samples collected over the period, along with meteorological factors and air mass-transport mechanisms, have been used to identify the source(s) responsible for the NESAQ exceedance.

The pan-Auckland rise in air particulate matter concentrations indicated that this was a regional event and unlikely to be due to local particulate emission sources, particularly considering that the rural background site at Patumahoe was affected similarly to the more urbanised monitoring stations. Monitoring data showed that PM_{10} concentrations were significantly higher than $PM_{2.5}$, indicating that the primary driver was most likely a coarse particle ($PM_{10–2.5}$) source. The compositional analysis of filter-based samples of particulate matter collected at the Queen Street, Takapuna and Henderson air quality monitoring sites immediately before, during and after the particulate-matter event indicated that the particulate matter was largely composed (>66%) of sea salt. These data, coupled with the analysis of meteorological and air mass-transport mechanisms and reference to previously recorded incursions, have identified that the PM_{10} exceedances on 18 and 19 August 2022 at the Queen Street air quality monitoring site were primarily the result of a marine aerosol (sea salt) natural-source event.

1.0 INTRODUCTION

On 18 and 19 August 2022, the Auckland Council air quality monitoring site at Queen Street registered PM_{10} concentration (24-hour average) exceedances of the National Environmental Standards for Air Quality (NESAQ) of 50 µg m^{-3}. The *Resource Management (National Environmental Standards for Air Quality) Regulations 2004* require mandatory reporting of such breaches of the NESAQ, along with appropriate air-quality management interventions.

However, under clause 16A *Exceptional circumstances causing breach of standard*:

> *(1) The Minister may, on written application by a regional council, decide that an exceedance of a contaminant in an airshed in the region of the council was caused by exceptional circumstances.*

This report outlines the results from an investigation to determine what caused the NESAQ exceedance. The elemental composition of airborne particulate matter samples collected onto filters has been analysed to determine the primary source(s) responsible for the high PM_{10} concentrations. In addition, the meteorological factors that may have contributed to the event have also been assessed. The following sections of this report present a description of the samples and sampling sites, the analytical methodology and the results, along with a conclusion describing the source(s) contributing to the PM_{10} NESAQ exceedance.

1.1 Auckland Council Air Quality Monitoring Sites and Particulate Matter Concentrations

The Auckland Council air quality monitoring network (Figure 1.1) consists of multiple sites located across the Auckland region. Particulate matter samples of $PM_{2.5}$ (includes all particles less than 2.5 micrometres in diameter) and PM_{10} (includes all particles less than 10 micrometres in diameter)[1] have been collected onto polytetrafluoroethylene (PTFE) filters at a subset of the air quality monitoring sites for compositional analysis since mid-2004 (Davy and Trompetter 2021). The Auckland air quality monitoring network is operated for Auckland Council by Watercare Services Limited as part of the Council's ambient air quality monitoring programme.

1 By definition, $PM_{2.5}$ is a subset of PM_{10}.

Figure 1.1 Auckland Council air particulate matter sampling sites (○) with PM_{10} National Environmental Standards for Air Quality exceedances recorded at Queen Street (●) on 18 and 19 August 2022 (Map source: Auckland Council).

Particulate matter concentrations measured at Auckland Council sites during the PM_{10} exceedance events at the Queen Street site on 18 and 19 August show that PM_{10} concentrations were significantly higher than $PM_{2.5}$ concentrations (Figure 1.2) and were highly correlated across all sites (Figure 1.3), including the background site at Patumahoe (near Pukekohe), 40 km southwest of the Auckland central business district (CBD). Only the Auckland Council Queen Street site exceeded the PM_{10} (24-hour average) NESAQ (50 µm m^{-3}). However, the degree of correlation between sites suggests that particulate matter concentrations were reasonably homogeneous in the air mass across the entire region, indicating that sources localised to each monitoring site were unlikely to be responsible for the pan-Auckland event. This is especially the case, as the event also included the Patumahoe site, which is classified as a rural-background air quality monitoring station and is not subject to the same particulate matter source pressures (e.g. motor vehicle, domestic and industrial emissions) experienced by the more urban sites (Davy et al. 2020a). It was notable that $PM_{2.5}$ concentrations only contributed about 40% of total PM_{10} mass at the Queen Street site for the exceedance day, as this suggests that a primarily coarse particle ($PM_{10–2.5}$) source may have been responsible for the high PM_{10} concentrations. This observation was consistent for all sites where both $PM_{2.5}$ and PM_{10} were monitored.

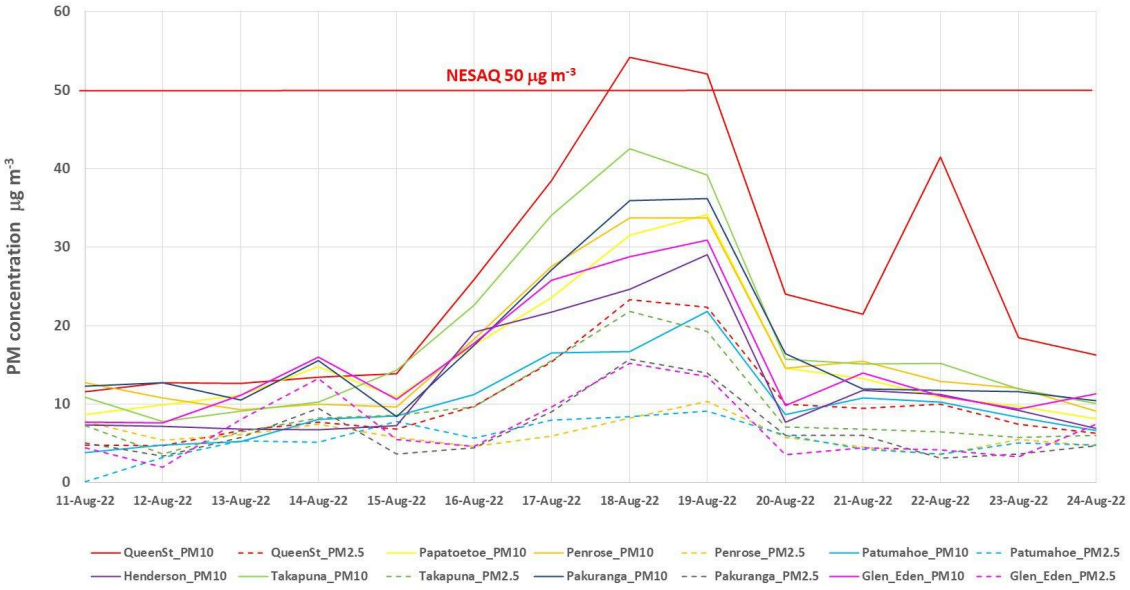

Figure 1.2 PM_{10} and $PM_{2.5}$ at Auckland Council air particulate matter sampling sites from 11 to 24 August 2022.

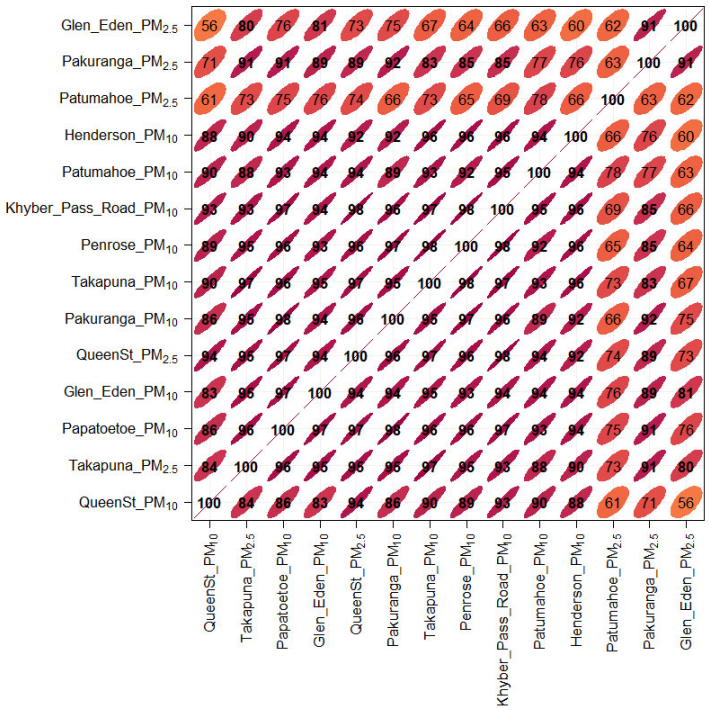

Figure 1.3 Highly correlated PM_{10} and $PM_{2.5}$ concentrations at Auckland Council air particulate matter monitoring sites from 11 to 24 August 2022.

1.2 Particulate Matter Samples Collected for Compositional Analysis

Compositional analysis of particulate matter collected on filters provides information on the sources or source types contributing to total particulate matter concentrations, a valuable tool for air quality management. As there were no routine particulate matter speciation samples collected during the Queen Street PM_{10} exceedance event on 18 and 19 August 2022, we have analysed the composition of particulate matter collected onto the glass-fibre filter tapes used by the Beta Attenuation Monitor (BAM) systems for routine continuous

particulate matter monitoring available from the Takapuna and Henderson monitoring sites (there was no BAM system at the Queen Street site). Samples of BAM PM_{10} glass-fibre filter tape from the Takapuna and Henderson monitoring sites were provided by Watercare Limited. Additionally, we have analysed the Auckland Council speciation samples that were taken on 17 and 23 August 2022 at the Queen Street, Takapuna and Henderson sites to demonstrate comparative analytical equivalence for key indicator elements. Table 1.1 presents the details for the samples that were analysed.

Table 1.1 Auckland air particulate matter sample details. AQMS = air quality monitoring station, PM = particulate matter.

AQMS Site	Sampling Dates	Number of Samples	Sample Period	Sampler Type	PM Size Fraction	Filter Type
Queen Street	17 and 23 August 2022	2	24-hours	Partisol	PM_{10}	PTFE
Takapuna	17 and 23 August 2022	2	24-hours	Partisol	PM_{10}	PTFE
	17–23 August 2022	7	24-hours	BAM	PM_{10}	Glass fibre (BAM tape)
Henderson	17 and 23 August 2022	2	24-hours	Partisol	PM_{10}	PTFE
	17–23 August 2022	7	24-hours	BAM	PM_{10}	Glass fibre (BAM tape)

2.0 ANALYTICAL METHODOLOGY AND RESULTS

Black carbon (BC) concentrations were measured in the particulate matter samples at GNS Science using the light reflectance method. X-ray fluorescence spectroscopy (XRF) was used to measure elemental concentrations in the particulate matter samples. The XRF measurements in this study were carried out at the GNS Science XRF facility, and the spectrometer used was a PANalytical Epsilon 5 (PANalytical, the Netherlands). XRF is a non-destructive and relatively rapid method for the elemental analysis of air particulate matter samples. For quality assurance purposes, elemental calibration standards were used for all reported elemental concentrations (Hyslop et al. 2019). Further details of the BC and XRF analytical methodologies are provided in Davy and Trompetter (2021). Table 2.1 presents the results for BC and elemental concentrations that were above the analytical limits of detection in the PM_{10} samples.

Note that the elemental concentration data have been blank subtracted. A key limitation in the use of glass-fibre filter media for compositional analysis of collected particulate matter is that the filters are relatively thick (200–500 µm) and have a high elemental background of silicon and alkali-earth metals (Na, Mg, Ca, K) and Zn associated with the filter composition, which can preclude the extraction of any useful data for these elements. The thickness of the glass-fibre filter also results in attenuation (internal absorption) of X-rays, particularly those associated with the lighter elements. However, despite these limitations, which significantly increases the limit of detection (LOD), useful particulate matter compositional data has been extracted from glass-fibre filters for elevated ambient particulate matter concentrations in New Zealand studies (Davy and Ancelet 2014; Davy and Trompetter 2020a) and overseas (Watson et al. 2012; Raja et al. 2017).

Table 2.1 Concentrations of key elemental components of PM_{10} air particulate matter collected on filter material from the Queen Street, Takapuna and Henderson air quality monitoring stations 17–23 August 2022. N/A = data not available.

		PTFE Filters (6 Samples)		Takapuna BAM Tape (7 Samples)		Henderson BAM Tape (7 Samples)	
	Unit	Average	Maximum	Average	Maximum	Average	Maximum
PM_{10}	µg m^{-3}	22.3	38.5	24.8	42.6	16.5	29.1
BC	ng m^{-3}	962	1506	569	993	452	633
Na	ng m^{-3}	4901	8752	1425	2282	313	545
Mg	ng m^{-3}	344	534	70	103	50	73
Al	ng m^{-3}	209	349	N/A	N/A	N/A	N/A
Si	ng m^{-3}	129	154	N/A	N/A	N/A	N/A
S	ng m^{-3}	247	1482	N/A	N/A	N/A	N/A
Cl	ng m^{-3}	6348	13850	3073	5141	1707	2999
K	ng m^{-3}	50	206	N/A	N/A	N/A	N/A
Ca	ng m^{-3}	216	358	N/A	N/A	N/A	N/A
Ti	ng m^{-3}	12	28	N/A	N/A	N/A	N/A
Fe	ng m^{-3}	138	321	119	239	42	87
Cu	ng m^{-3}	8	20	6	14	2	3
Zn	ng m^{-3}	7	13	N/A	N/A	N/A	N/A

It is clear from the data in Table 2.1 that Na and Cl were the dominant elemental species in the samples. In order to compare the relationship between the range of analytes measured in the BAM tape samples and routine PTFE speciation samples and the total particulate matter mass, a mass reconstruction approach was used based on geochemical principles (Cahill et al. 1989; Cohen 1999; Malm et al. 1994) with methodological details provided in Davy et al. (2017).

The key point for the mass comparison is that measured elemental mass should correlate with total particulate matter mass to confirm that the measured components are sufficient to describe the system. Figure 2.1 presents the mass comparison between measured elemental mass and the PM_{10} mass for the BAM tape samples and PTFE filters, respectively.

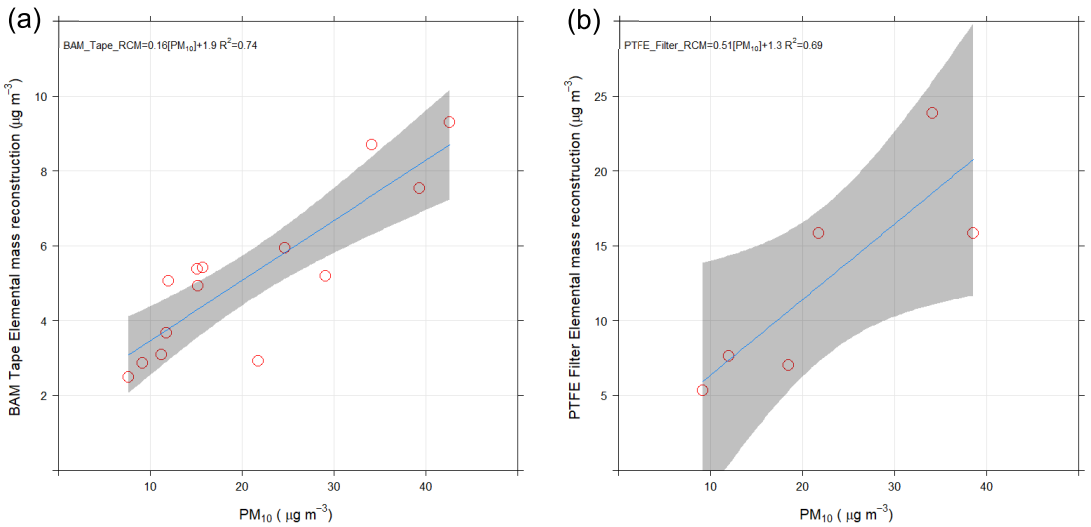

Figure 2.1 Elemental mass composition of air particulate matter samples compared to PM_{10} mass for (a) BAM filter tape samples and (b) PTFE speciation samples. The shaded areas are the 95% confidence intervals in the calculated slope.

Measured elemental mass and PM_{10} mass concentrations were found to be reasonably well correlated for the BAM tape and PTFE samples and therefore for the use of key elemental species to indicate the primary contributing sources to each sample. When the elemental concentrations measured in the BAM tape samples were compared with the PTFE speciation filters (17 and 23 August 2022 samples), it was found that individual elements were highly correlated between the two types of filter media (Figure 2.2).

Having established that the relative elemental concentrations in the BAM filter samples were representative of the mass contributions to PM_{10}, the data were compared. It was found that two specific groupings were evident, as shown in the clustered correlation plot (Figure 2.3). The two groupings were the association of PM_{10}, Na, Mg and Cl, representing a marine aerosol component (sea salt) and the other grouping of BC, Fe and Cu concentrations representing combustion sources (BC) and crustal matter (Fe, Cu). These source components and their origins are described in Davy et al. (2020b). It is clear that the sea-salt components were a likely driver of PM_{10} concentrations over that period (17–23 August 2022) at the Henderson and Takapuna sites.

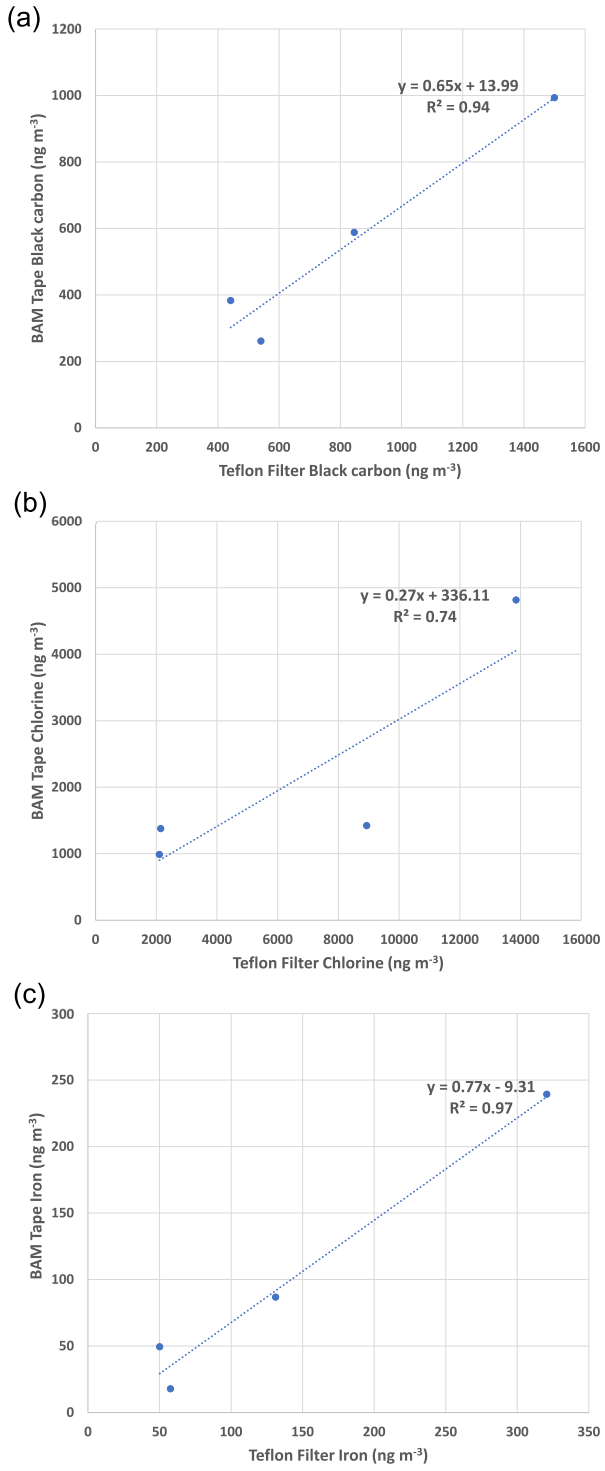

Figure 2.2 Comparison between key elemental species measured on the BAM tape samples and PTFE speciation filters at the Henderson and Takapuna sites showing acceptable correlations in relative concentrations.

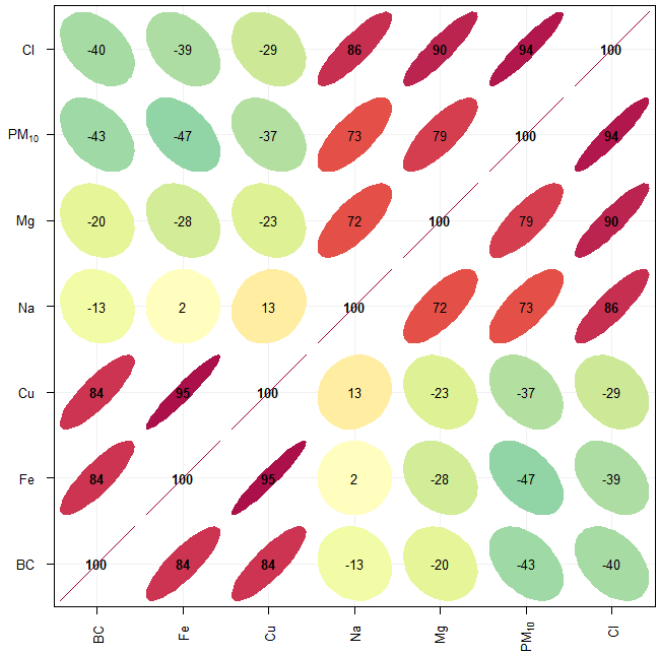

Figure 2.3 Clustered correlation plot for key components of PM_{10} BAM tape air particulate matter samples. The percentage correlation (r^2) is provided by the numerical values, while highly positively correlated variables are marked as red ellipsoids and strongly anti-correlated variables are highlighted as green ellipsoids.

3.0 DISCUSSION

As shown in Figure 1.2, continuous $PM_{2.5}$ and PM_{10} monitoring data from the Auckland Council air quality monitoring indicates that particulate matter concentrations began rising on 15 August 2022 at all stations and culminated in peak concentrations on 18 and 19 August 2022, with NESAQ PM_{10} exceedances at the Queen Street site that decreased to what would be considered normal concentrations in the days thereafter. The elemental concentration (24-hour average) data for Takapuna and Henderson, graphed alongside PM_{10} concentrations (Figure 3.1), shows how each of the components varied over time. Chlorine concentrations, (representing sea salt) peaked on 18 and 19 August 2022 at both sites, whereas Fe (representing crustal matter) and BC (representing anthropogenic combustion sources) remained relatively low over the entire period.

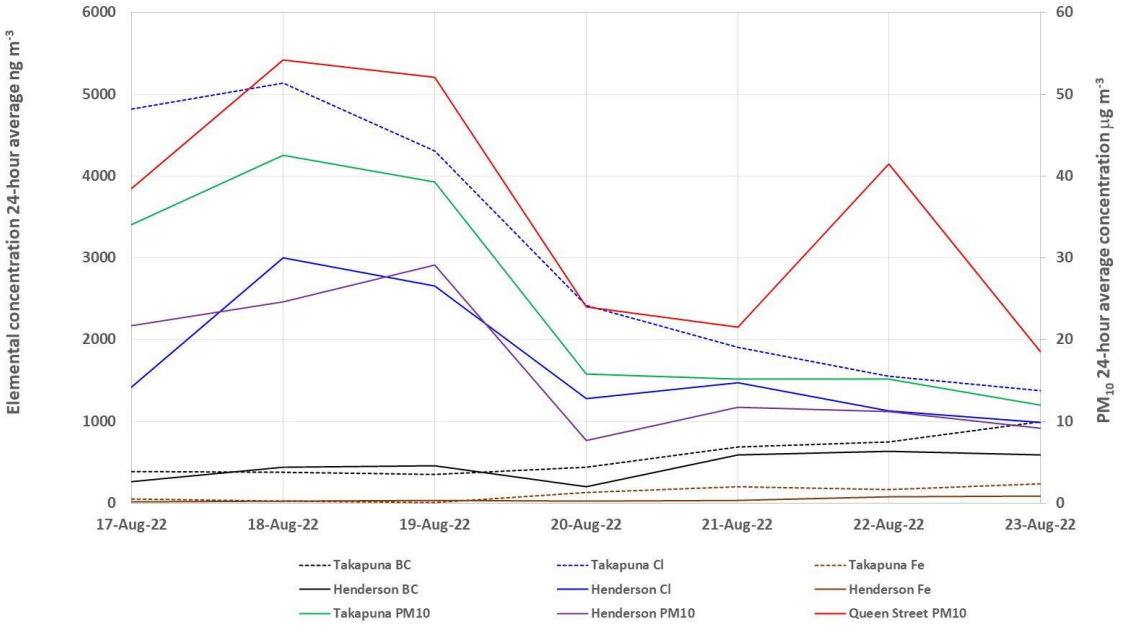

Figure 3.1 PM_{10} concentrations (Queen Street, Takapuna and Henderson) and key elemental components on the BAM tape samples from the Takapuna and Henderson monitoring sites.

3.1 Meteorological Influences

Meteorological data for the Takapuna and Henderson Queen Street sites (unavailable for Queen Street) shows that local winds were moderate and blowing from the northeast sector on 18 and 19 August 2022, as presented in Figure 3.2. Air temperature records indicate that it was a mild 16°C on both days.

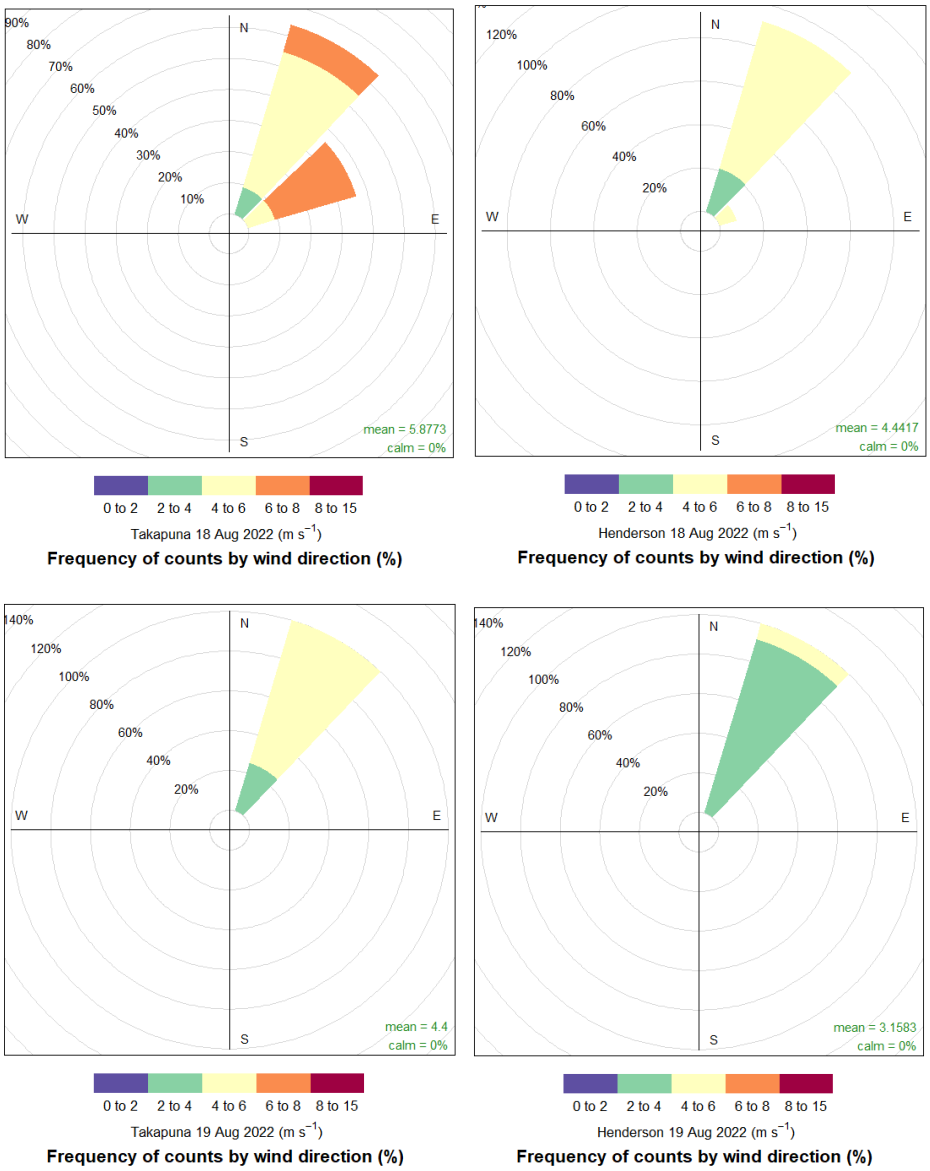

Figure 3.2 Wind roses showing wind speed and direction on 18 August 2022 (top) and 19 August 2022 (bottom) for the Takapuna and Henderson monitoring sites.

The moderate wind speeds and mild temperatures over the two days that the PM_{10} exceedance occurred at the Queen Street site indicate that it was unlikely that combustion sources such as solid fuel fires for domestic space heating (the dominant anthropogenic source in Auckland during winter) or motor vehicles (the dominant anthropogenic source all year in Auckland) were responsible, due to the low BC concentrations; in any case, such emissions would have been rapidly dispersed by the moderate wind speeds. It has been shown that cold and calm conditions are most likely to lead to high concentrations of these combustion sources (Davy and Trompetter 2017).

The synoptic mean sea-level pressure (MSLP) maps (Figure 3.3) over the PM_{10} exceedance period indicate a large area of high pressure to the east of Auckland and a trough of low pressure to the northwest of New Zealand, which generated a north-easterly fetch of several thousand kilometres across the South Pacific for the airmass arriving over Auckland.

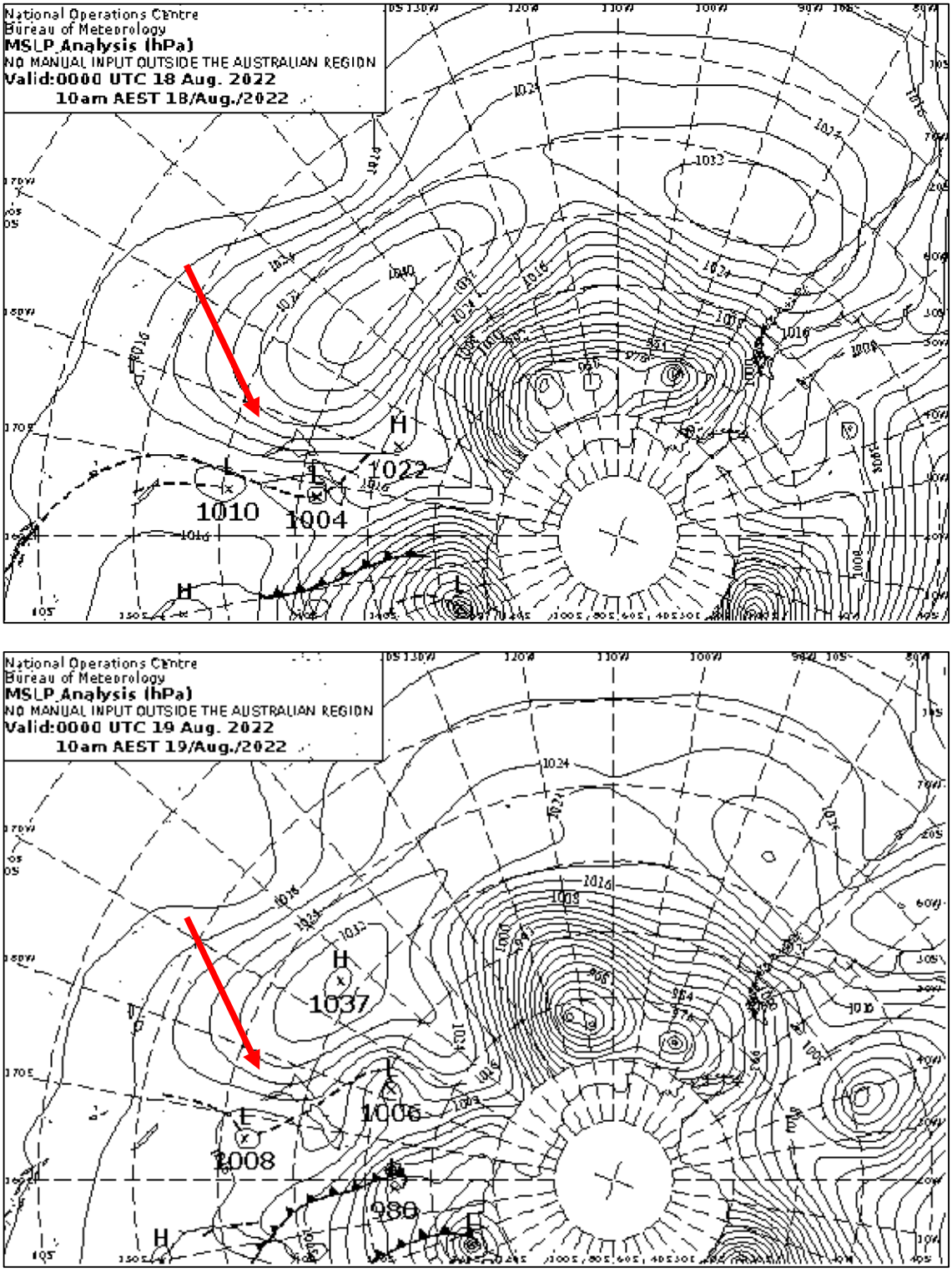

Figure 3.3 Synoptic mean sea-level pressure (MSLP) maps for midday (NZST) 18 August 2022 (top) and 19 August 2022 (bottom). → indicates synoptic wind flow direction (Source: Australian Bureau of Meteorology).

The synoptic meteorology was also generating a high sea state due to the combined action of wind and long-range fetch. Research has shown that the concentration of marine aerosol (sea salt) shows a strong dependence on wind speed across the ocean surface and ranges from about 2 μg m^{-3} to as much as 50 μg m^{3} or more at wind speeds in excess of 15 m s^{-1} (Fitzgerald 1991), and the Auckland data corroborates those potential concentration ranges. Marine aerosol concentrations in New Zealand urban areas are largely influenced by meteorological and long-range transport mechanisms, as shown previously (Davy et al. 2011). Marine aerosol concentrations have been shown to be highly correlated (see Figure 3.4) across the Auckland monitoring sites and dominated by coarse particles (PM_{10} > $PM_{2.5}$), indicating that marine aerosol concentrations were homogeneous in the regional airmass. Indeed, marine aerosol concentrations at the Queen Street site were found to be well correlated with those at the background site at Patumahoe 40 km southwest of the Auckland CBD (Davy et al. 2020b).

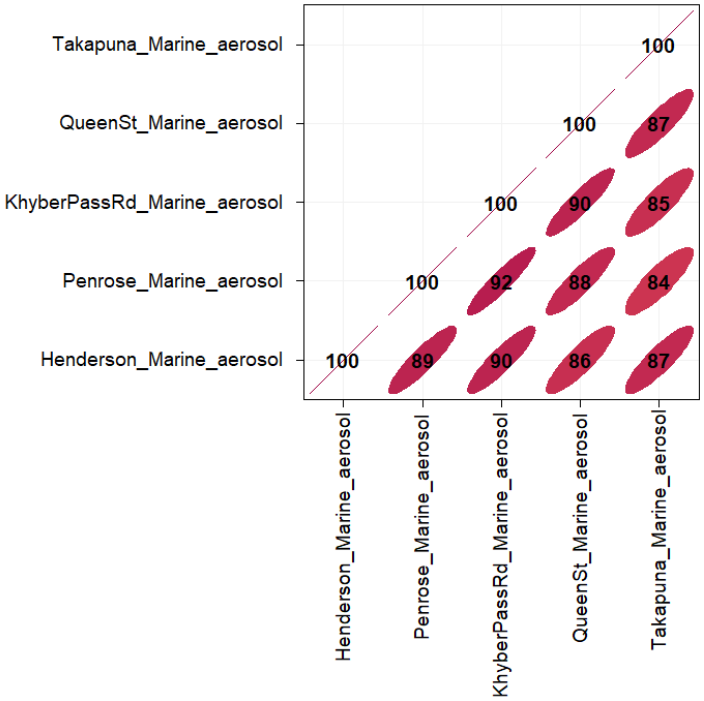

Figure 3.4 Correlation plot for marine aerosol in PM_{10} for all Auckland monitoring sites (Source: Davy et al. 2020b).

The widespread nature of the PM_{10} event was also observed at monitoring sites in other regions, such as Northland and the Bay of Plenty, where those sites closest to the eastern coastline experienced elevated PM_{10} concentrations over the same period (Figure 3.5), with a time lag between regions commensurate with the movement of the salt-laden air mass across each region. NESAQ PM_{10} exceedances also occurred at several Bay of Plenty Regional Council monitoring sites. $PM_{2.5}$ concentrations at these locations were approximately 25–35% of the corresponding PM_{10} concentration, indicating that the event was dominated by a coarse particle ($PM_{10–2.5}$) source.

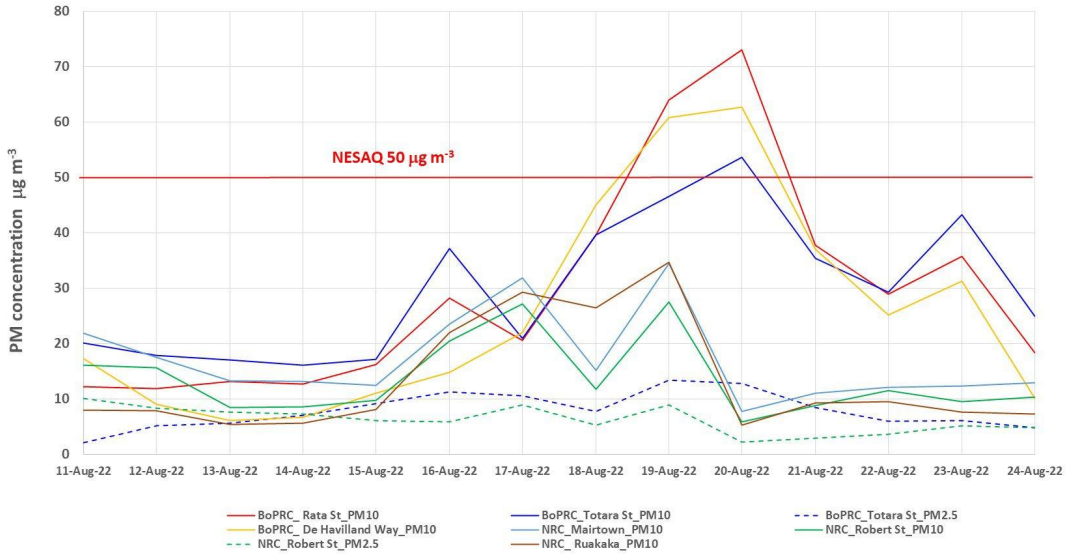

Figure 3.5 PM_{10} and $PM_{2.5}$ concentrations at Bay of Plenty Regional Council (BoPRC) and Northland Regional Council (NRC) air quality monitoring sites. The results show the regional nature of the PM_{10} event that also affected Auckland (Data source: NRC and BoPRC).

3.2 Source Contributions to Particulate Matter Concentrations on 18 and 19 August 2022

It is evident that the PM_{10} exceedances on 18 and 19 August 2022 at the Auckland Council Queen Street air quality monitoring site were likely caused by a regional transboundary particulate-matter event. Synoptic meteorological evidence shows that there was a long north-easterly fetch over the South Pacific Ocean to the air mass arriving at Auckland. The oceanic origin explains the regional rise in Na and Cl concentrations as driven by sea-salt concentrations, which are dominated by coarser particles and hence PM_{10} was much higher than the corresponding $PM_{2.5}$ concentrations during the event. By applying geochemical principles, the relative contribution of source types to PM_{10} concentrations on 18 and 19 August 2022 can be calculated using the analytical results described in Section 2. Figure 3.6 presents the relative source contributions to PM_{10} estimated for Takapuna and Henderson based on the elemental composition data extracted from the BAM tape samples. Note that the unquantified (remainder) amount of PM_{10} has been labelled as 'Other'. It is likely that this remaining PM_{10} was associated with the transboundary event (*cf* the correlation of the measured elemental mass with PM_{10} at Queen Street, Takapuna and Henderson), most probably as organic and secondary organic carbonaceous species of oceanic origin (associated with the sea-salt generation) but not quantified by XRF spectroscopy.

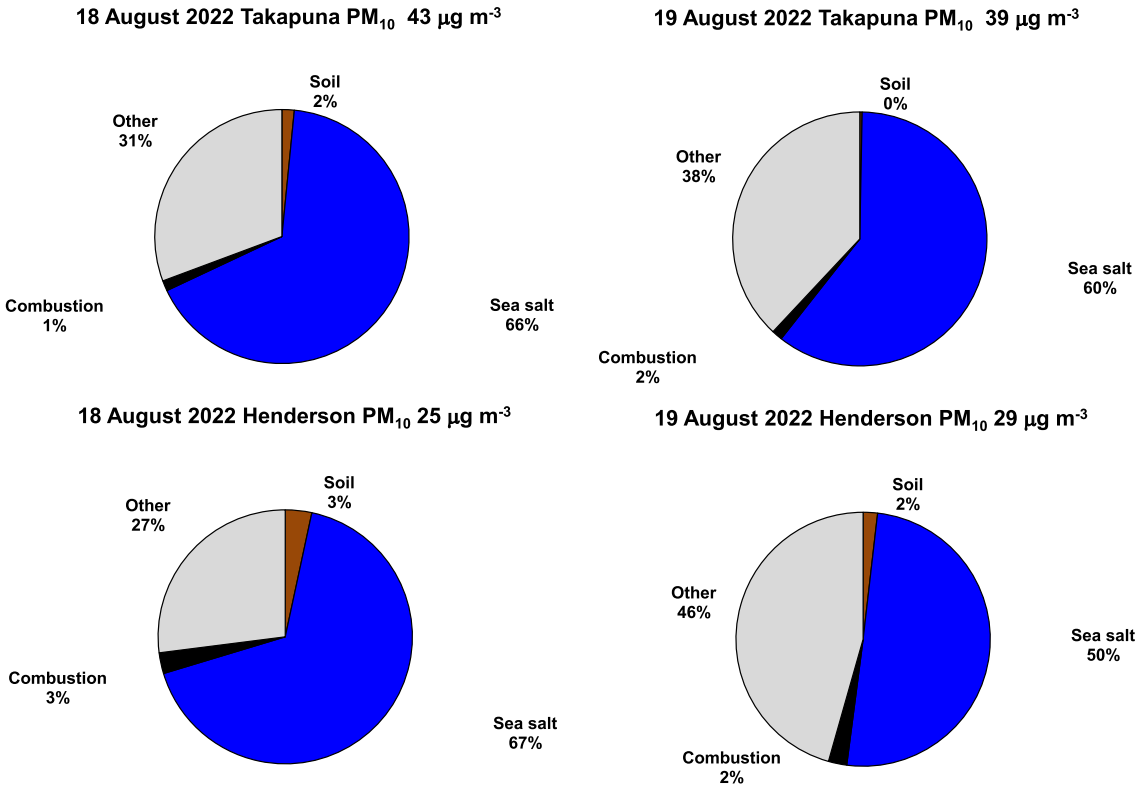

Figure 3.6 Estimated source contributions to PM_{10} at Takapuna and Henderson on 18 and 19 August.

The substantial database available for air particulate matter composition and source apportionment for Auckland shows that marine-aerosol events (contribution to PM_{10} >30 µg m^{-3}) for the Auckland region occur every few years (Davy and Trompetter 2021). Sodium and chlorine are the primary constituents of marine aerosol (or sea salt) and were also significant elemental contributors to both $PM_{2.5}$ and PM_{10} mass at Auckland monitoring sites, along with the more minor components (K, Ca, Mg, S) of sea salt. The Na and Cl were highly correlated (as shown in Figure 3.7) and present in the same ratio at peak concentrations as found in sea salt ([Na] = 0.56[Cl]) (Lide 1992). The long-term data from Auckland Council monitoring sites show that contributions of marine aerosol to $PM_{2.5}$ are 25% of the total contribution to PM_{10}, indicating that the marine aerosol particle size distribution extends into the fine fraction. The analytical results demonstrate the relative influence of this natural aerosol source on urban particulate matter concentrations in New Zealand, even for inland locations, due to the isolated oceanic location of the New Zealand landmass (Davy and Trompetter 2018).

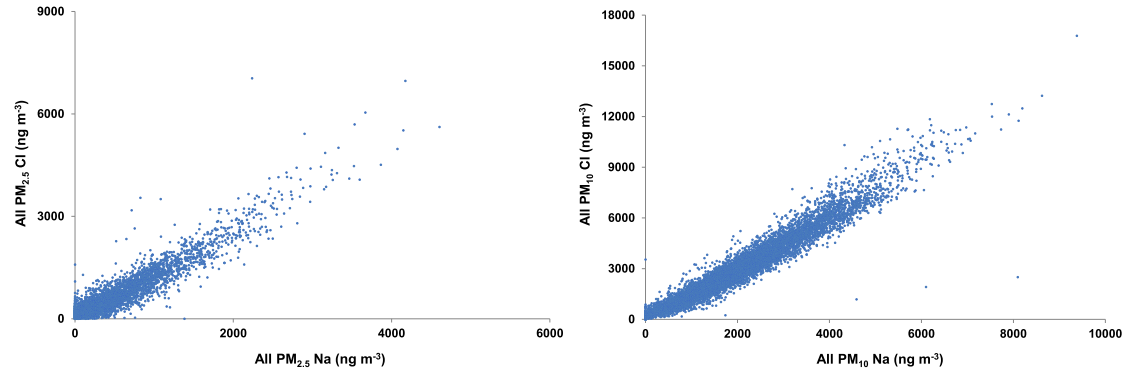

Figure 3.7 Scatterplots for sodium and chlorine in $PM_{2.5}$ (left) and PM_{10} (right) for all Auckland particulate matter samples (2006–2022).

4.0 CONCLUSION

On 18 and 19 August 2022, air quality monitoring stations across Auckland recorded elevated concentrations of airborne particulate matter, with the Queen Street site exceeding the PM_{10} (24-hour average) NESAQ (50 µg m^{-3}). The pan-Auckland impact and observations in neighbouring regions suggested that this was a large-scale regional event and not due to local (anthropogenic) particulate emission sources, particularly considering that the rural background site at Patumahoe was similarly affected to the more urbanised monitoring stations. Monitoring data showed that PM_{10} concentrations were significantly higher than $PM_{2.5}$, indicating that the primary driver was likely to be a primarily coarse particle ($PM_{10–2.5}$) source. The compositional analysis of filter-based samples of particulate matter collected at the Queen Street, Takapuna and Henderson air quality monitoring sites immediately before, during and after the particulate-matter event indicated that the particulate matter was largely composed (>66%) of sea salt. This data, coupled with the analysis of meteorological and air mass-transport mechanisms and reference to previously recorded incursions, has led to the conclusion that the PM_{10} exceedances on 18 and 19 August 2022 at the Queen Street air quality monitoring site were the result of a marine aerosol (sea salt) natural-source event.

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