Ambient air quality (nitrogen dioxide) monitoring programme

Annual report 2007–2023

September 2024

NZ TRANSPORT AGENCY
WAKA KOTAHI

Te Kāwanatanga o Aotearoa
New Zealand Government

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More information

NZ Transport Agency Waka Kotahi
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If you have further queries, call our contact centre on 0800 699 000 or write to us:

NZ Transport Agency Waka Kotahi
Private Bag 6995
Wellington 6141

This document is available on the NZ Transport Agency Waka Kotahi website at www.nzta.govt.nz

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Introduction

NZ Transport Agency Waka Kotahi (NZTA) started a national nitrogen dioxide (NO_2) monitoring programme, known as the National Air Quality Monitoring Network ('the network'), in 2007.

This report describes the results from the network and reviews data gathered from the beginning of 2007 up to the end of 2023. Results are compared spatially (that is, at different sites) and temporally (year-to-year and seasonally).

The purpose of the monitoring programme is to determine relative levels of vehicle pollution across New Zealand with the aim of seeing a decreasing trend in NO_2 concentrations measured at the sites over time.

NO_2 concentrations are recorded monthly using diffusion tubes (a type of passive sampler). The results from passive samplers are less accurate than continuous monitoring but, because they are relatively cheaper, the monitoring network can cover a large number of sites.

Passive sampling is useful as a screening method and can be used to identify hotspots and look at trends in longer-term average NO_2 concentrations. Comparison of the triplicate passive sampler results co-located with continuous monitoring in New Zealand confirmed that passive monitoring results are typically higher than the corresponding continuous data.

The World Health Organisation Global Air Quality Guidelines (WHO AQG) were updated in 2021. The update included a reduction in the NO_2 annual average guideline from 40 $\mu g/m^3$ to 10 $\mu g/m^3$. This has not been formally adopted in New Zealand; however, the results of the monitoring programme have been compared with this guideline in the absence of a New Zealand NO_2 annual mean environmental standard. The annual average concentrations are relevant to locations where people are likely to be exposed on a long-term continuous basis such as a residential dwelling, they are not relevant to roadside locations that are not representative of where people live.

This is the second annual report in which NZTA has considered the results against the WHO AQG 2021. For 2023, 15.3 percent of monitoring sites are expected to have met the annual average NO_2 criterion.[1] This is a marginal improvement on last year (14.6 percent of monitoring sites are expected to have met the criterion in 2022). It should be noted that most of the monitoring locations in the network are roadside monitors, where people are only transiently present, and are therefore not locations where annual average criteria would apply. Taking into account overall trends in NO_2 concentrations over the past few years, there continues to be a general decline in NO_2 concentrations (improved air quality) across the monitoring areas.

NZTA is continuing to further refine the network by including new sites and relocating some existing sites to more optimal locations.

[1] The percentage of sites expected to have met the criterion in 2022 was erroneously reported as 18.2 percent. The correct figure for 2022 is 14.6 percent.

1. How do motor vehicles affect air quality?

Good outdoor air quality is fundamental to our well-being. On average, a person inhales about 14,000 litres of air every day, and pollutants in the air can adversely affect peoples' health. People with pre-existing respiratory and heart conditions, the young, and older people are particularly vulnerable to poor air quality. Air and air quality are both a taonga (all things prized or treasured, tangible and intangible) and part of kaitiakitanga (guardianship and stewardship – particularly for the natural environment) for Māori.[2]

Air pollution comes from many sources, including burning of fuels from home heating, vehicle exhausts, industrial processes, volcanoes, and wind-blown dust and pollen. The pollutants emitted from these sources include particles and gases. The level (or concentration) of pollutants in the air at any given time depends on the quantity of pollutants being released into the air (known as emissions), and how these emissions are affected by the weather. They can be dispersed by winds or removed by rain.

Vehicles are the main source of nitrogen dioxide (NO_2) in the air in New Zealand. In 2019, on-road vehicle emissions were the main contributor to nitrogen oxides in our air, producing an estimated 39 percent (45,464 tonnes) of human-generated emissions.[3]

Exposure to NO_2 can irritate the lungs, increasing susceptibility to asthma and lowering resistance to respiratory infections. Long-term exposure to low levels of NO_2 can have severe respiratory effects in children and contribute to respiratory mortality.

This report describes the results from the NZ Transport Agency Waka Kotahi (NZTA) National Air Quality Monitoring Network and reviews data gathered from the beginning of 2007 up to the end of 2023. Results are compared spatially (that is, at different sites) and temporally (year-to-year and seasonally).

2. Why is nitrogen dioxide used as an indicator of air quality?

Motor vehicles produce a complex mix of contaminant emissions, so it is not feasible to monitor all components. Therefore, NZTA uses one pollutant, NO_2, as a proxy for motor vehicle pollutants. This is consistent with the recommendations of the World Health Organisation (WHO), which states:

> *Nitrogen dioxide concentrations closely follow vehicle emissions in many situations, so nitrogen dioxide levels are generally a reasonable marker of exposure to traffic-related emissions. Health risks from nitrogen oxides may potentially result from nitrogen dioxide itself, correlated exhaust components such as ultrafine particles and hydrocarbons, or nitrogen dioxide chemistry products, including ozone and secondary particles.* [4]

NZTA instigated a national NO_2 monitoring programme, known as the National Air Quality Monitoring Network ('the network'), in 2007 with 53 locations across the state highway network throughout New Zealand. In 2009, the network was expanded to include background and local road sites, with a further expansion in 2010 and again in 2016. By the end of 2023, monitoring was being conducted at 173 locations. NZTA's overall aim is to see a decreasing trend in NO_2 concentrations measured at these sites.

The previous reports were prepared to summarise the results from the network were published in 2017, 2019, 2020, 2021, 2022 and 2023, and covered the period from the beginning of 2007 to the end of 2022. This report builds on that earlier work and includes data collected up to the end of 2023.

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[2] Land Air Water Aotearoa (2021) *Factsheet: Why is air quality important?*

[3] Stats NZ Tatauranga Aotearoa (2021) *Air pollutant emissions*.

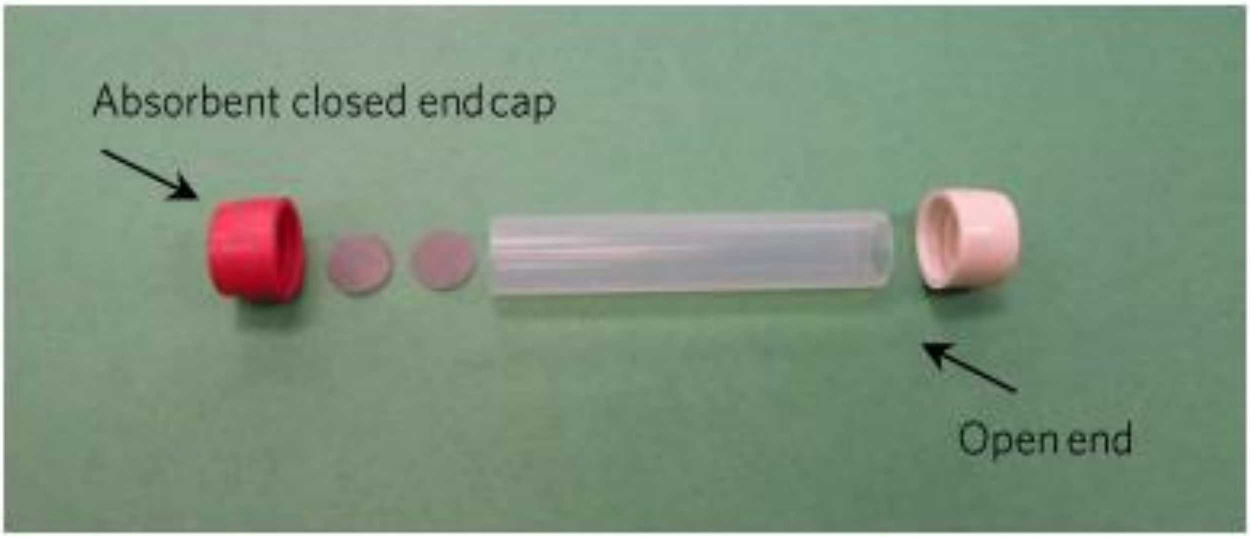
[4] World Health Organization (2005) *Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide, and sulphur dioxide*.

3. How do we monitor NO_2?

Ambient NO_2 concentrations can be measured by continuous analysers or passive samplers. Passive samplers are easy to operate and relatively inexpensive, they can therefore be installed in large numbers over a wide area giving good spatial coverage. However, their results are indicative only and provide longer-term (monthly) rather than daily averages. Comparison of the passive sampler monthly averages, with averages recorded at the regional council continuous monitoring stations over the 2020–23 period, found that the passive monitoring results are typically higher than the corresponding continuous data, particularly for the monitors located in proximity to state highways or local roads (see appendix C). Passive sampling is therefore useful as a screening method and can be used to identify hotspots and look at trends in NO_2 concentrations. It is not a regulatory method, for which continuous analysers are used. Continuous analysers measure instantaneous concentrations and are the regulatory method for assessing compliance against the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (Air Quality NES) and New Zealand Ambient Air Quality Guidelines (AAQG), based on 1-hour and 24-hour averages.

The monitoring programme is operated by Watercare Services Ltd on behalf of NZTA. The programme uses diffusion tubes for passive sampling of NO_2. Passive samplers consist of a small plastic tube, approximately 7 centimetres long. During sampling, one end is open and the other closed. The closed end contains an absorbent for the NO_2. At the end of each month, the exposed tubes are replaced and sent to a laboratory for analysis.

Figure 3.1: Diffusion tube



4. Where are the monitoring sites?

NZTA monitoring zones have been established for each main urban area in New Zealand, as well as for Taupō, Ōtaki, Blenheim, Greymouth and Queenstown. The number of monitoring sites within each zone reflects the risk of being exposed to elevated levels of air pollution arising from vehicles using the state highway network. This is based on the population of urban areas in each zone.

The monitoring programme uses a simple classification scheme in which each monitoring site is designated as either:

- state highway, which are located within 100 metres of the highway being monitored
- local roads, which are located within 50 metres of the road being monitored, or
- urban background sites, which are located more than 100 metres from a state highway and more than 50 metres from a busy local road.

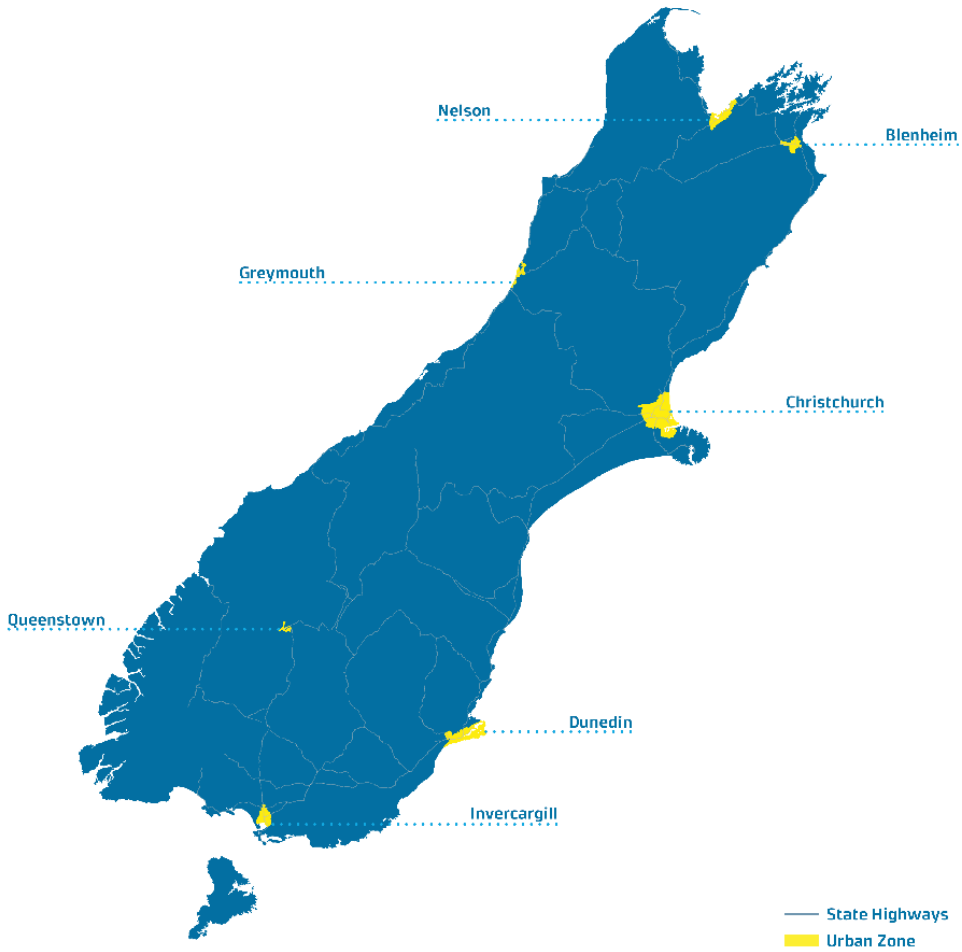
The monitoring sites are spread across each NZTA region and are generally intended to measure exposure to road vehicle emissions at locations:

- that are sensitive to adverse air pollution effects (sites are generally within 50 metres of either a school or residential areas), or
- where elevated concentrations are most likely to occur.

Sites are classified by monitoring zone (refer to figure 4.1), which broadly corresponds to towns or cities with populations greater than approximately 30,000 people, and by site type (highway, local or background, as defined above).

Each site is also allocated a unique site identification (site ID) code. Where sites have been re-located and a new source of elevated NO_2 concentrations have been identified, the unique site identification code has been updated accordingly (for example siteID(a), siteID(b)).

Figure 4.1: NZTA passive monitoring zones



5. How do we interpret the results?

5.1. NO_2 ambient air quality standards and guidelines

The passive monitoring results are expressed as a **monthly average** concentration. A **seasonal average** concentration is calculated if there are at least 2 valid monthly averages for summer and winter (at least 66 percent valid data for the season).

An **annual average** concentration can be calculated where there is a minimum of 75 percent valid data (at least 9 months out of 12 of results), and at least one valid monthly average for winter (a valid average for July, August or September) and summer (a valid average for January, February or March).

In New Zealand, the health-based air quality standards and guidelines for NO_2 are set for short-term exposures – 1-hour and 24-hour average concentrations in the Air Quality NES and the AAQG, respectively. There are no New Zealand health-based guidelines for exposure to NO_2 over time periods longer than 24 hours. In 2021, the WHO reviewed and published updated air quality guidelines. Further discussion of these updated guidelines is set out in section 5.2.

There is also a New Zealand annual average guideline value of 30 $\mu g/m^3$ for protecting the health of ecosystems. These relevant standards and guidelines are shown in table 5.1.

Table 5.1: NO_2 ambient air quality standards and guidelines

Standard or guideline	Averaging period	Concentration
Air Quality NES	1-hour	200 µg/m^3
AAQG	24-hour	100 µg/m^3
AAQG (ecosystems)	Annual	30 µg/m^3

The National Air Quality Monitoring Network measures monthly average NO_2 concentrations, which does not allow a direct comparison with the 1-hour Air Quality NES. A review of regional council continuous NO_2 monitoring data from 2008 to 2023 shows that where the annual average concentration is less than 40 ug/m^3 (the previous WHO guideline) there are no exceedances of the 1-hour average Air Quality NES. This means that, through careful choice of sampling sites and the use of passive samplers as screening devices, locations where the standard is most likely to be exceeded due to motor vehicle emissions can be identified.

The AAQG for ecosystems has been included in table 5.1, though it should be noted that there are no monitors located at sites representative of ecosystems exposure.

5.2. WHO air quality guidelines

The World Health Organization Global Air Quality Guidelines (WHO AQG) are intended to provide guidance for environmental regulatory agencies around the world to inform the development of air quality policy.

Updates to the WHO AQG in 2021[5] included a reduction in the previous annual average NO_2 guideline value from 40 µg/m^3 to 10 µg/m^3. The annual average concentrations are relevant to locations where people are likely to be exposed on a long-term continuous basis such as a residential dwelling; they are not relevant to roadside locations that are not representative of where people live. Further information is provided in section 6 about the limitations when comparing the passive sampler results directly with air quality guidelines.

The WHO AQG 2021 have not been formally considered or adopted in New Zealand. It should be noted that globally, including in many areas within New Zealand, the annual mean concentration of NO_2 is likely to be above 10 µg/m^3. The WHO AQG 2021 include suggested interim targets that may be used in a staged approach to achieve the AQG over time.

Table 5.1: WHO 2021 ambient air quality guidelines for NO_2

Averaging period	Concentration
24-hour	25 µg/m^3
Annual [a]	10 µg/m^3

[a] The previous WHO AQG (2005) was 40 µg/m^3

[5] World Health Organization (2021) *WHO global air quality guidelines: particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*.

6. What do the monitoring results tell us?

6.1. Introductory comment on bias

It is important to note that the passive samplers are known to overstate NO_2 concentrations compared to measurements from reference monitors (see section 7). None of the results presented in this section have been adjusted to account for this bias and the results of the monitoring programme should not be directly compared with ambient air quality standards and guidelines. However, the data can be used to inform our understanding of temporal and spatial trends, and to identify locations where it is more (or less) likely that ambient air quality standards and guidelines are met.

6.2. What range of concentrations have been measured?

Some of the monitoring locations are very close to roadsides, where concentrations may be high but are not representative of air quality that people would be exposed to for extended periods of time. They are therefore not locations where the annual average guidelines would be applied. Table 6.1 summarises the measured concentrations at monitoring locations that are identified as being within 20 metres of a sensitive receptor, such as a dwelling.

Table 6.1: Results at monitoring locations within 20 metres of a sensitive receptor, 2023 data

Site classification	Number of monitoring locations with annual average concentrations in range			
	0–10 µg/m³	10.1–24.9 µg/m³	25–34.9 µg/m³	>35 µg/m³
State highway	1	34	5	0
Local road	4	24	3	0
Urban background	14	2	0	0

6.3. Is NO_2 air quality improving?

The monitoring data for 2023 showed that 15.3 percent of monitoring sites are expected to have met the much lower WHO 2021 AQG (compared with all sites meeting the previous WHO 2005 AQG in 2023). As discussed previously, most monitoring locations are near a roadside and therefore people are very unlikely to be exposed to the measured concentration continuously for an entire year.

Figure 6.1 shows the annual average NO_2 concentrations for the state highway monitoring sites in the three largest cities and the aggregated national results.[6] There has been a gradual decline in median values from 2011[7] to 2023.

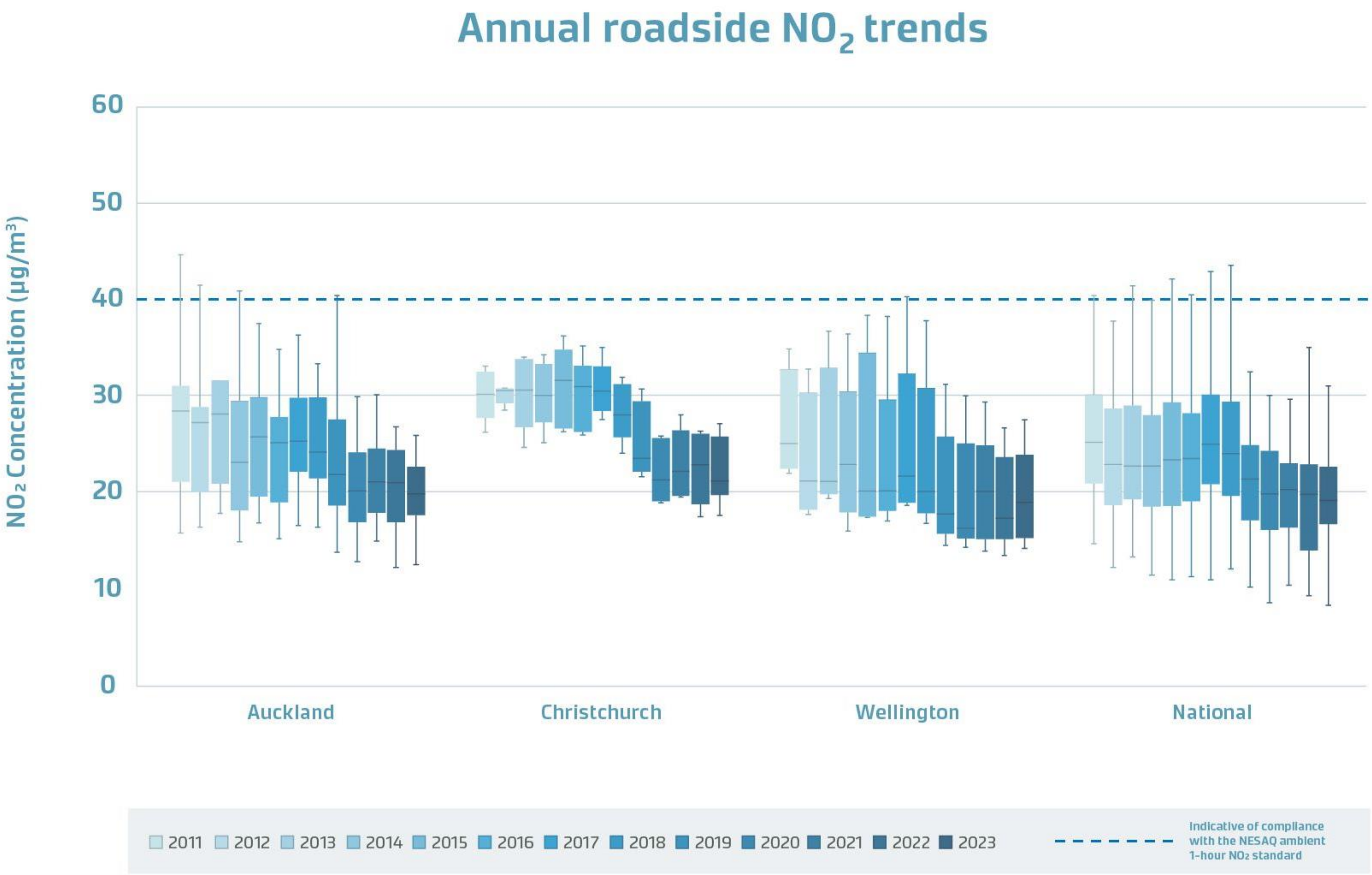
The reasons for this trend of reducing average and median NO_2 concentrations at roadside sites, despite increases in vehicle travel, is likely due to changes in source emissions (such as improvements in the emissions from the vehicle fleet) and/or meteorology (for example emissions may be better dispersed in some years because of weather patterns).

The COVID-19 pandemic may have partially contributed to NO_2 concentration trends in 2020 and 2021. The nationwide lockdowns, and the extended lockdown in the Auckland region resulted in regional travel restrictions, greatly reducing vehicle travel. This also prevented data collection at many of the Auckland sites for the August to December 2021 period, which reduced the availability of valid data for sites in this region. The minimum and maximum NO_2 concentrations indicated a similar trend to previous years and are consistent with measurements recorded in 2022.

[6] All sites from across the country, including those outside of major cities.

[7] 2011 was chosen because this is when the first set of complete data is available for majority of sites.

Figure 6.1: State highway sites and NO_2 concentration levels 2011–2023

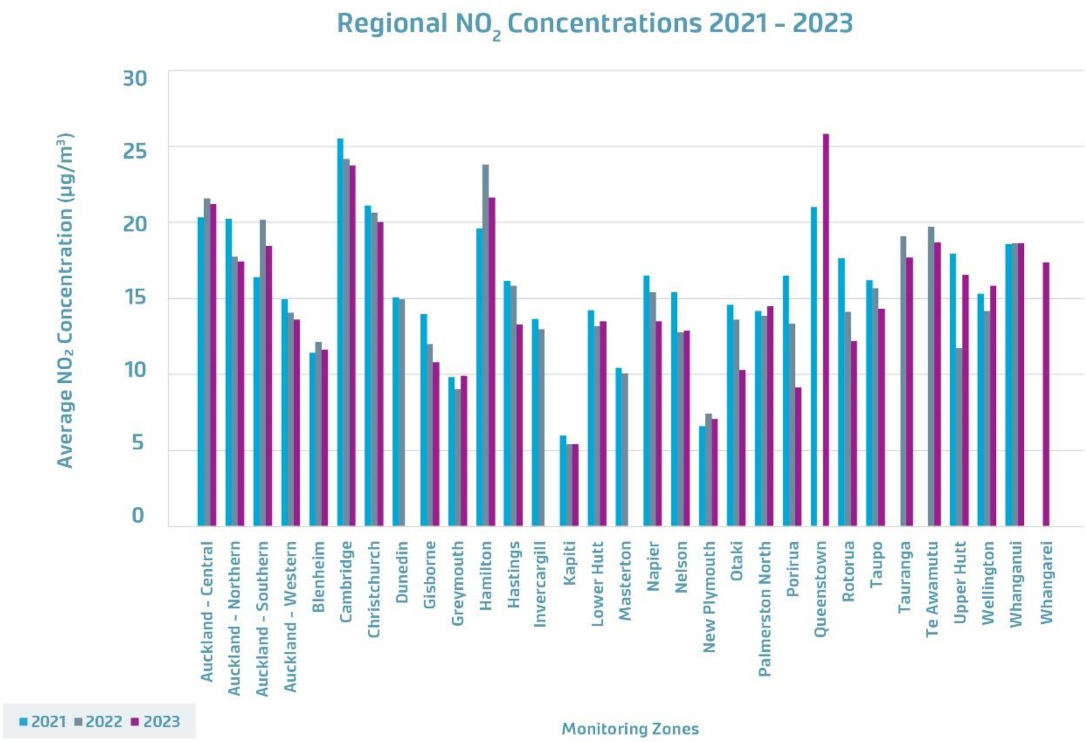


6.4. How do the results differ across New Zealand?

Figure 6.2 shows the annual average NO_2 concentration averaged across the sites in each monitoring zone.[8] It shows that the highest average NO_2 monitoring results in 2023 were recorded in Queenstown, Cambridge, Hamilton, central Auckland, and Christchurch. The lowest average monitoring results in 2023 were recorded in the Kāpiti, New Plymouth and Porirua monitoring zones. The Dunedin, Invercargill and Masterton monitoring zones did not have sufficient valid data in 2023 to produce an annual average.

When we look at the average results over the 3 years, there is a general decline in NO_2 concentrations (improved air quality) across many of the monitoring zones.[9] Of the monitoring zones with 3 valid annual averages for 2021–23, 15 show a decrease in NO_2 concentration and 10 show an indeterminate trend for this short period.

Figure 6.2: Average NO_2 concentrations measured in New Zealand monitoring zones



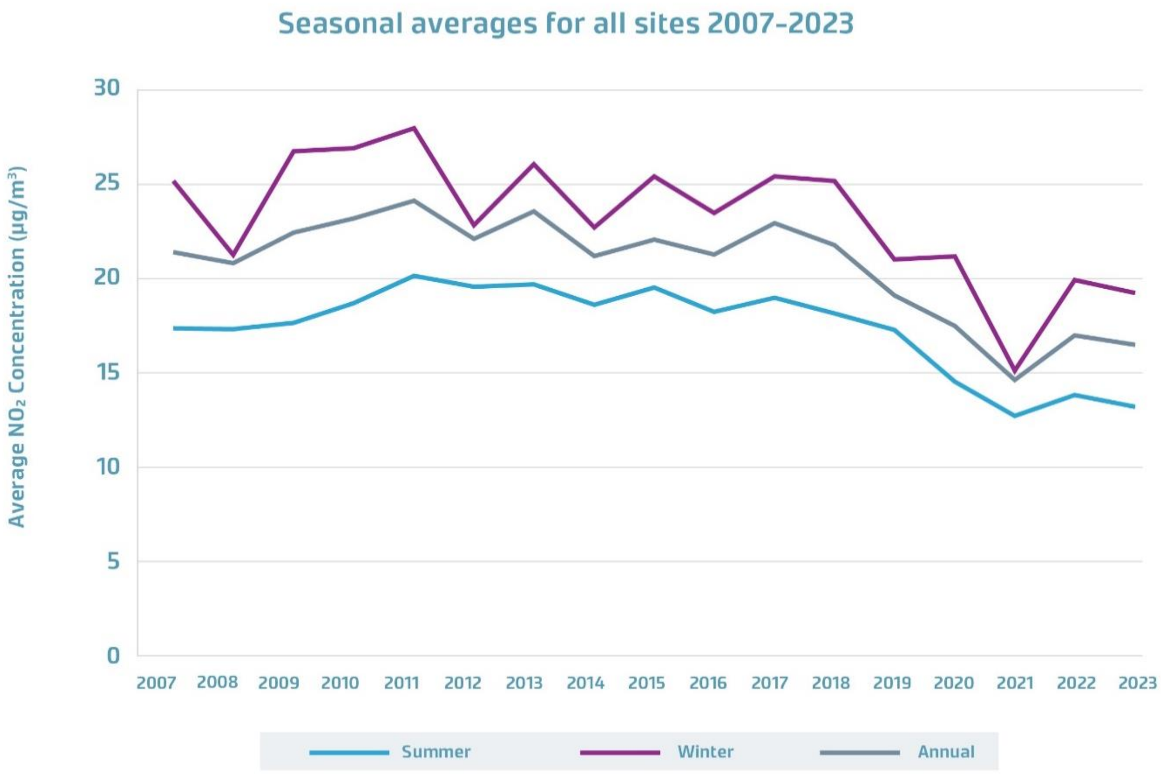
6.5. Are the NO_2 concentrations higher in summer or winter?

Figure 6.3 illustrates that NO_2 concentrations vary seasonally, and further analysis of the data shows that the highest NO_2 concentrations are observed during June and the lowest NO_2 concentrations are observed during December. This seasonal trend in NO_2 concentrations close to roads is likely to be because weather conditions in winter tend to inhibit dispersal of emissions compared to summertime conditions.

[8] This is based on data from all road types, however the number of monitoring sites varies between zones, eg Queenstown only has one monitoring site, whereas Auckland Central has 18 monitoring sites.

[9] Complete data for the 3 years is unavailable for Tauranga, Te Awamutu, Whangārei and Queenstown.

Figure 6.3: Varying NO_2 concentration levels during the seasons[10]



7. How do we know the data is reliable?

At a small number of the monitoring sites, 3 passive samplers (referred to as triplicate samples) are co-located with continuous NO_2 monitors operated by the local regional council to assess the precision and accuracy of results. This was undertaken at 7 monitoring sites in 2023.

7.1. How precise are the passive sampler results?

The precision of the passive sampler results is checked by comparing the variation (coefficient of variation, CV) between the triplicate samples collected each month (presented graphically in appendix B). The CV is calculated according to:

$$\text{CV (\%)} = \frac{\text{standard deviation of the sampler results x 100}}{\text{mean of the sampler results}}$$

The precision of the diffusion tubes is categorised as 'good' or 'poor' as follows:[11]

- Diffusion tubes are considered to have 'good' precision where the CV of duplicates or triplicates based on 8 or more individual periods during the year is less than 20 percent, and the overall average CV of all monitoring periods is less than 10 percent.
- Diffusion tubes are considered to have 'poor' precision where the CV of 4 or more individual periods is greater than 20 percent and/or the overall average CV is greater than 10 percent.

The distinction between 'good' and 'poor' precision is an indicator of how well the same measurement can be reproduced.

[10] Includes data from every site with **either** valid summer, winter or annual values.

[11] UK Department for Environment, Food and Rural Affairs (2022) *Local air quality management, technical guidance LAQM TG(22)*.

For the triplicate sites in the network between 2007 and 2016, the average CV had been less than 8 percent.[12] For the triplicate sites in the network between 2016 and 2023, the overall average of all monthly CVs is calculated to be 5.8 percent. No sites had an average CV above 10 percent.

The CV has been less than 20 percent for 96.6 percent of the triplicate samples during 2016–23. Overall, the precision of the passive samplers is good according to the criteria above.

7.2. How accurate are the passive sampler results?

The continuous monitors operated by regional councils use an approved reference method (chemiluminescence analyser) in accordance with the Resource Management (National Environmental Standards for Air Quality) Regulations 2004. These analysers actively draw sample air through the monitor at a constant flowrate. In comparison, the passive samplers rely on diffusion, which can be influenced by a range of factors including temperature, pressure and the concentration gradient of NO_2. Therefore, the results from the continuous monitors are expected to more accurately represent actual NO_2 concentrations.

'Bias adjustment' is the process of accounting for the variable accuracy of annual mean NO_2 concentrations as measured by diffusion tubes relative to the chemiluminescent reference method. Bias factors have been estimated using guidance prepared by the UK Department of Environment, Food and Rural Affairs (DEFRA).[12] Appendix C details the calculation of annual bias factors based on the co-location data for 2020–23. Separate adjustment factors are presented for each year because the performance of the passive samplers is expected to vary from year to year due to differing meteorological conditions and NO_2 concentrations.

In summary:

- The bias factor for state highway sites is between 0.59 and 0.66, indicating that the concentrations recorded by the continuous monitors are between 34 and 41 percent **lower** than the passive sampler results (that is, the passive samplers are expected to overstate the actual NO_2 concentration).
- The bias factors for local roads and background sites are higher than for the state highways sites – between 0.68 to 0.75 for local road sites and 0.72 to 1.16 for background sites. This suggests that the passive samplers are more accurate in environments with lower ambient NO_2 levels.

These results increase confidence in the reliability of passive sampling as a screening method, and confirms that the passive monitoring results should not be directly compared to guideline values.

8. Are there any future changes to the proposed programme?

National Institute of Water & Atmospheric (NIWA) carried out a review of the National Air Quality Monitoring Network in 2021.[13] This recommended that the monitoring network be split into:

- a regional network of representative sites, and
- local networks covering sites subject to highly local influences.

This will involve maintaining current monitoring sites, establishing new monitoring sites and relocating some existing sites to more optimal locations over time.

In the future, additional monitors could be added to determine how NO_2 concentrations change at varying distances from the road. These transverse monitors could provide insight into how quickly NO_2 concentrations decrease at set distances from a linear source and this transverse data could assist in the geospatial modelling of NO_2.

[12] Waka Kotahi NZ Transport Agency (2017) *Ambient air quality (nitrogen dioxide) monitoring network – annual report 2007–16*.

[13] National Institute of Water & Atmospheric (NIWA) (2021) *Review of the National Air Quality Monitoring Network*.

Additional monitors could also be added to improve coverage in parts of the existing local network – mainly busy city centre streets, but also ports and growth areas (another NIWA recommendation). Sixteen new monitors were installed in the Hawke's Bay region in March 2023, in line with NIWA's recommendations.

Appendix A: Sites that have recorded NO_2 concentrations exceeding the previous WHO AQG 2005 criterion

Table A.1 shows the monitoring locations that previously recorded annual average NO_2 concentrations exceeding the WHO AQG 2005 criteria (40 µg/m^3) since 2014. No exceedances of this criterion were reported in 2023.

Table A.1: Results at monitoring locations within 20 metres of a sensitive receptor, 2023 data

Zone	Site ID	Site type	NZTM easting	NTZM northing	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014
Auckland – Central	AUC009	SH	1756848	5919273	34.5	35.8	39.0	41.8	40.4	43.6	48.2	47.7	-	41
Hamilton	HAM013	SH	1799056	5814544	32.1	34.5	38.0	41.3	42.4	44.3	41.4	40.4	42.2	39.9
Hamilton	HAM003	SH	1800756	5813015	31.5	33.7	36.8	39.1	41.4	42.5	42.9	40.5	41.4	38.7
Wellington	WEL008	SH	1748917	5426328	27.3	26.5	29.2	29.8	31.1	37.8	40.3	38.2	38.3	36.4
Christchurch	CHR017-19	Local	1567570	5180276	26.9	25.4	28.5	30.5	36.0	36.8	38.4	40.8	39.7	36.1
Christchurch	CHR016	Local	1573683	5179994	26.2	24.8	28.1	27.9	31.0	35.0	40.7	32.1	35.1	35.3

Note: The sites are listed in order based on the annual average NO_2 concentrations recorded in 2023. Red indicates an exceedance of criterion.

Appendix B: Co-located monitors

Figures C.1, C.2 and C.3 present the 2023 monitored concentrations recorded for 3 co-located monitors.

Figure C.1: 2023 average monthly NO_2 monitoring for AUC054a-56a

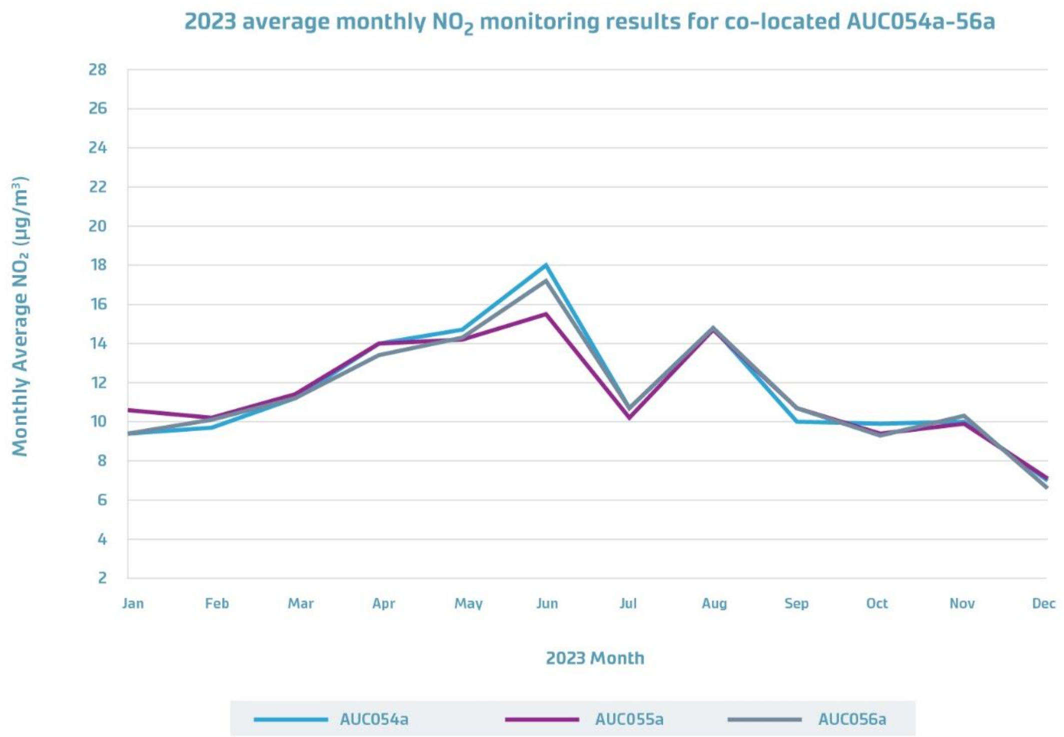


Figure C.2: 2022 average monthly NO_2 monitoring for WEL073-075

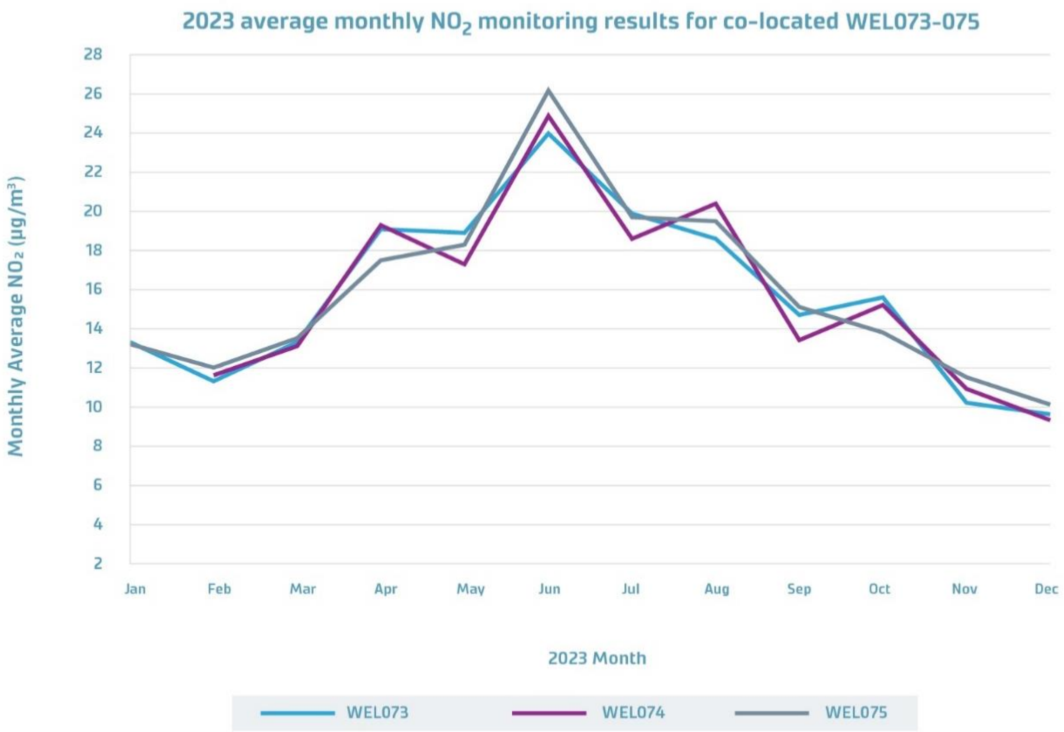
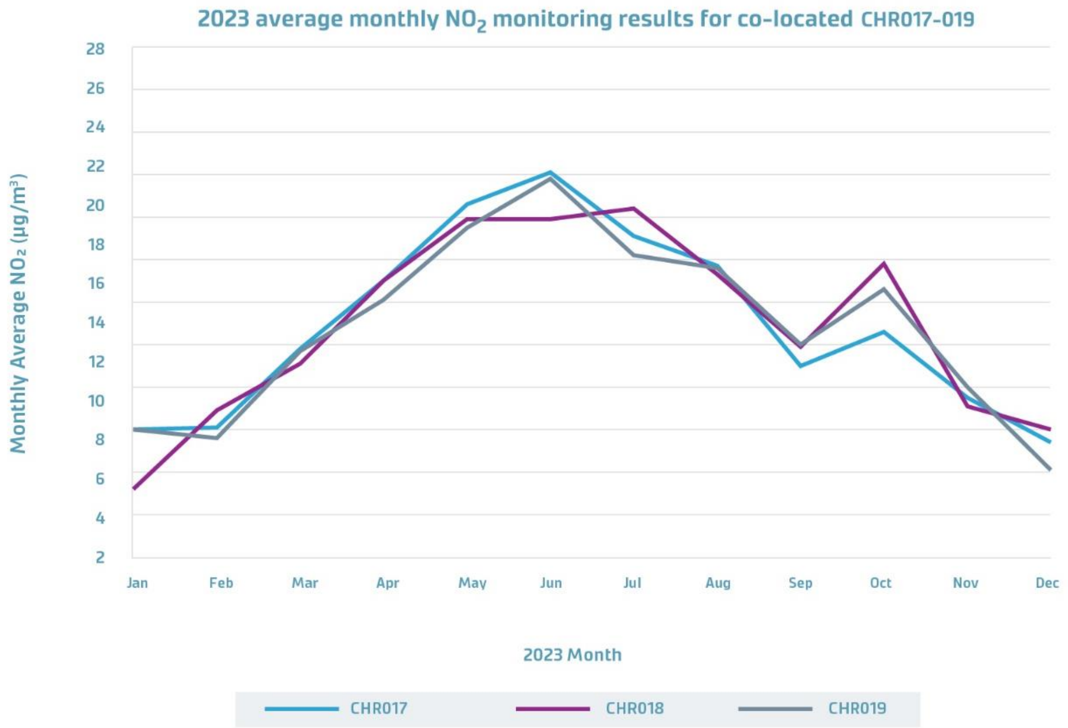


Figure C.3: 2022 average monthly NO_2 monitoring for CHR017-019



Appendix C: Annual bias adjustment factors

There are 7 active triplicate passive sampler sites co-located with a continuous monitoring site operated by a regional council within the network. These sites are identified in table C.1, with comment on the precision of the triplicate passive sampler concentrations and on the data capture at the continuous monitoring reference data for the 2020–23 period.

Table C.1: Co-located NO_2 monitoring and triplicate passive sampler sites

Site ID	Site name	Type[a]	Duration	Triplicate precision[b]	Data capture at the continuous monitoring site
AUC013-015	Auckland – Penrose	SH	2020–23	Good precision	>75% for all years
AUC043-045	Auckland – Takapuna	SH	2020–23	Good precision	>75% for all years
AUC054-056	Auckland – Henderson	Local	2020–23	Good precision	>90% for all years
AUC057-059	Auckland – Glen Eden	Background	2020–23	Good precision	>90% for all years except 2020 (77%)
WEL073-075	Wellington Central – Willis St	SH	2020–23	Good precision	>90% for all years
CHR017-019	Christchurch – Riccarton	Local	2020–23	Good precision	>90% for all years
CHR020-022	Christchurch – St Albans (Coles Pl)	Background	2020–21 Decommissioned in Dec 2021. New site established at English Park (CHR045-047)	Good precision	>75% for all years Council reference monitoring site decommissioned in Nov 2020
CHR045-047	Christchurch – St Albans (English Park)	Background	2022–23	Good precision	Poor data capture in 2022 (62%) >75% data capture in 2023 (88%) Monitoring site commissioned in December 2021

Notes:

[a] The site ‘type’ is defined per the criteria for state highway, local road or urban background sites as set out in section 4 of this report.

[b] Diffusion tubes are considered to have ‘good’ precision where the CV of duplicates or triplicates based on 8 or more individual periods during the year is less than 20%, and the overall average CV of all monitoring periods is less than 10%.

The Local Air Quality Management (LAQM) Diffusion Tube Precision Accuracy and Bias spreadsheet tool[14] was used to calculate bias adjustment factors for each site. The tool excludes data points where the precision of the triplicate passive samplers was low – that is where the coefficient of variation of the triplicate concentrations was above 20 percent. The tool also excludes periods where there is insufficient data capture at the continuous monitoring site, which is classified as below 75 percent for the data period in question.

Each triplicate passive sampler site was compared with the averaged continuous hourly data collected at the co-located monitor over the calendar month. This will introduce some uncertainty as the diffusion tubes are typically collected and changed within 2 days of the first Wednesday of each month and the exact dates will vary between regions. On limited occasions, passive samplers were exposed for 2-month periods, in accordance with section 5.2 of the *Ambient Air Quality (Nitrogen Dioxide) Monitoring Network operating manual 2017–18* published by NZTA, and the concentration in this circumstance applied to both months. For the purpose of the bias adjustment calculation, these results were recorded as one entry and compared with the average concentration recorded at the continuous monitoring site for the same 2-month period.

The overall bias adjustment factors determined for the sites within each region and for each site type are presented in tables C.2 and C.3.

Table C.2: Bias adjustment factors – by region

Year	Auckland	Wellington	Christchurch	National
2020	0.61	0.71	0.80	0.67
2021	0.66	0.65	0.93	0.69
2022	0.77	0.63	0.78	0.74
2023	0.64	0.61	0.80	0.67

Table C.3: Bias adjustment factors – by site type

Year	Background	Local Road	State Highway
2020	0.72	0.68	0.64
2021	0.76	0.71	0.66
2022	1.16	0.75	0.66
2023	0.78	0.73	0.59

The annual average results at each co-located monitoring site are also presented for reference in tables C.4 and C.5.

[14] AEA_DifTPAB_v04.xls, Version 4 February 2011. Published on https://laqm.defra.gov.uk/air-quality/air-quality-assessment/local-bias/, accessed April 2024.

Table C.4: Summary of NO_2 annual averages for co-located continuous monitoring sites operated by regional councils[a]

Site ID[b]	Site name	Type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
AUC013-015	Auckland – Penrose	SH	22.8	23.7	18.8	19.5	-	17.9	18	18.5	19.1	16.2	15.4	13.6	14.2	13.5
AUC043-045	Auckland – Takapuna	SH	21.5	20	19.5	20.2	18.5	17.7	17.7	16.6	16.6	16.1	11.5	12.5	12.3	11.9
AUC054-056	Auckland – Henderson	Local	12.7	12.3	12.8	11.9	10.4	9.9	10.1	-	-	9	7.2	6.9	8.9	7.2
AUC057-059	Auckland – Glen Eden	Back-ground	7.8	7.8	9.6	7.4	6	6	5.4	4.7	5.3	4.2	4.2	4.6	6.9	4.7
WEL073-075	Wellington central – Willis St	SH	-	-	-	-	-	-	14	14.1	12.6	11.7	11.5	10.6	10.3	9.7
CHR017-019	Christchurch – Riccarton	Local	33.9	-	36.6	38.6	-	39.1	34.1	32.9	29.9	30.7	24.8	26.7	21.0	23.4
CHR020-022	Christchurch – St Albans (Coles Pl)	Back-ground	-	-	10.6	12.2	11.6	11.3	11	9.6	-	9.4	9.0	-	-	-
CHR045-047	Christchurch – St Albans (English Park)	Back-ground	-	-	-	-	-	-	-	-	-	-	-	-	-	8.3

Notes:

a. Data 2010–19 reproduced from *National NO_2 monitoring network: correlations between passive and continuous results 2010 to 2019.* Technical report for Waka Kotahi NZ Transport Agency prepared by Emission Impossible Ltd, June 2020.

b. Equivalent passive monitor site ID. Continuous monitoring data for the AUC sites were provided by Auckland Council, for the WEL sites by Greater Wellington Regional Council, and for the CHR sites by Environment Canterbury.

Table C.5: Summary of NO_2 annual averages for co-located passive sampling sites operated by NZTA

Site ID[a]	Site name	Type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
AUC013-015	Auckland – Penrose	SH	17.5	18.8	17.8	17.3	15.2	14.7	14.2	15.8	15.1	12.7	23.3	24.1	21.7	22.7
AUC043-045	Auckland – Takapuna	SH	9.9	10.4	9.7	9.5	8.6	8.8	8.6	8.9	8.4	6.8	19.9	20.3	18.4	19.9
AUC054-056	Auckland – Henderson	Local	27	30.6	27.6	29.5	26.7	26.9	26.8	27	26.4	23.2	12.5	12.4	11.9	11.5
AUC057-059	Auckland – Glen Eden	Back-ground	29.8	30.9	28.8	31.7	29.9	29.7	28.2	29.5	27.9	27.4	6.6	6.8	6.1	5.7
WEL073-075	Wellington central – Willis St	SH	-	-	-	-	-	-	20.6	21.4	19.8	17.4	15.9	16.0	16.5	16.0
CHR017-019	Christchurch – Riccarton	Local	-	-	41.4	41.6	36.1	39.7	40.8	38.4	36.8	36	30.5	28.5	26.9	26.9
CHR020-022	Christchurch – St Albans (Coles Pl)	Back-ground	-	-	13.6	15	14.1	13.7	13.6	13.3	13.4	11.7	10.5	12.0	-	-
CHR045-047	Christchurch – St Albans (English Park)	Back-ground	-	-	-	-	-	-	-	-	-	-	-	-	11.6	11.2

Note:

a. Data 2010–19 reproduced from *National NO_2 monitoring network: correlations between passive and continuous results 2010 to 2019.* Technical report for Waka Kotahi NZ Transport Agency prepared by Emission Impossible Ltd, June 2020.