AMBIENT AIR QUALITY (NITROGEN DIOXIDE) MONITORING PROGRAMME

Annual report 2007 - 2022

30 June 2023

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WAKA KOTAHI NZ TRANSPORT AGENCY

Te Kāwanatanga o Aotearoa New Zealand Government

More information

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Executive summary

Waka Kotahi NZ Transport Agency (Waka Kotahi) started a national nitrogen dioxide (NO_2) monitoring programme, known as the National Air Quality Monitoring Network ("the Network") in 2007. 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 less expensive, 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. Studies[1] conducted on the Network in New Zealand confirmed that passive monitoring results are typically higher than the corresponding continuous data (on average 33% higher).

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 report is the first year that Waka Kotahi have reported against the WHO AQG 2021. For 2022, 18.2% percent of monitoring sites are expected to have met the annual average NO_2 criteria. It should be noted that most of the monitoring locations in the Network are roadside monitors and are 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 almost all of the monitoring areas.

Waka Kotahi continues to further refine the Network by including new sites and relocating some existing sites to more optimal locations over time.

[1] Emission: Impossible Ltd (2020) '*National air quality (NO_2) monitoring network: Correlations between passive and continuous results 2010 to 2019*'.

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, treasured resource, possession or cultural item, including te reo, culturally significant species) and part of the 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, wind-blown dust and pollen. There are many pollutants emitted from these sources including 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% (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 Waka Kotahi NZ Transport Agency (Waka Kotahi) National Air Quality Monitoring Network and reviews data gathered from the beginning of 2007 up to the end of 2022. Results are compared spatially (i.e. at different sites) and temporally (i.e. year to year and seasonally).

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

Motor vehicles produce a complex mix of contaminants, so it is not feasible to monitor all components. Therefore, Waka Kotahi 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[4] that:

> "*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.*"

Waka Kotahi instigated a national NO_2 monitoring programme, known as the National Air Quality Monitoring 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 2022, monitoring was being conducted at 159 locations. Waka Kotahi's overall aim is to see a decreasing trend in NO_2 concentrations measured at these sites.

The previous reports that were prepared to summarise the results from the National Air Quality Monitoring Network were published in 2017, 2019, 2020, 2021 and 2022, and covered the period from the beginning of 2006 to the end of 2021. This report builds on that earlier work and includes data collected up to the end of 2022.

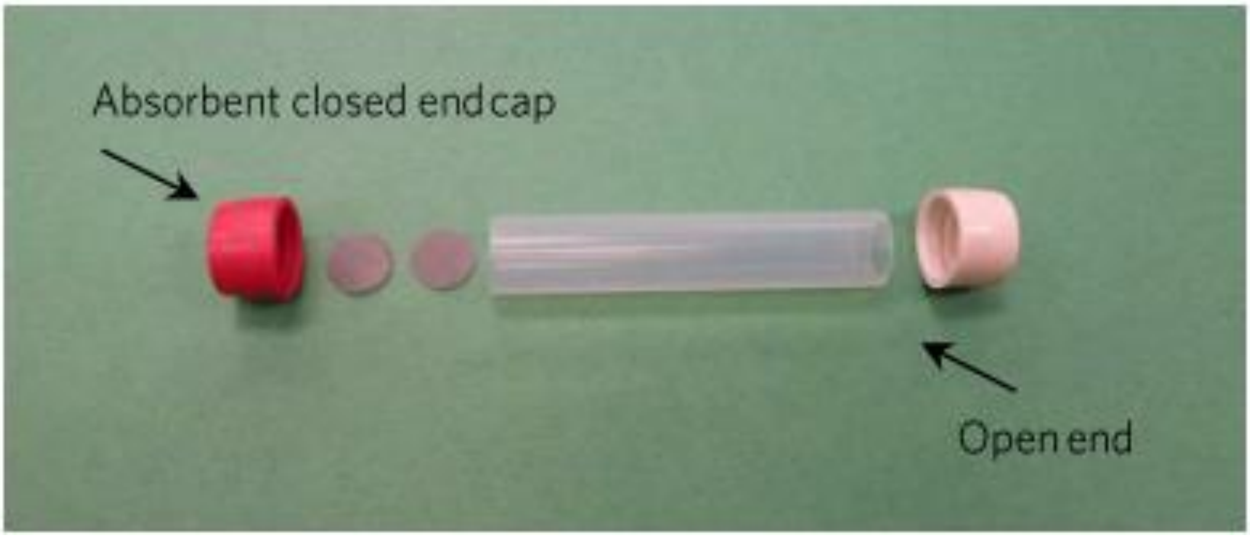
[2] Land Air Water Aotearoa (2021) *'Factsheet: Why is air quality important?'.*
[3] Stats NZ Tatauranga Aotearoa (2021) '*Air pollutant emissions*'.
[4] World Health Organisation (2005) *'Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide, and sulphur dioxide'.*

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. In addition, a 2020 report[1] confirmed that passive monitoring results are typically higher than the corresponding continuous data (on average 33% higher). 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 Waka Kotahi. The programme uses diffusion tubes for passive sampling of NO_2. Passive samplers consist of a small plastic tube, approximately 7 cm 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?

Waka Kotahi monitoring zones have been established for each main urban area in New Zealand, as well as for Taupō, Otaki, 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.

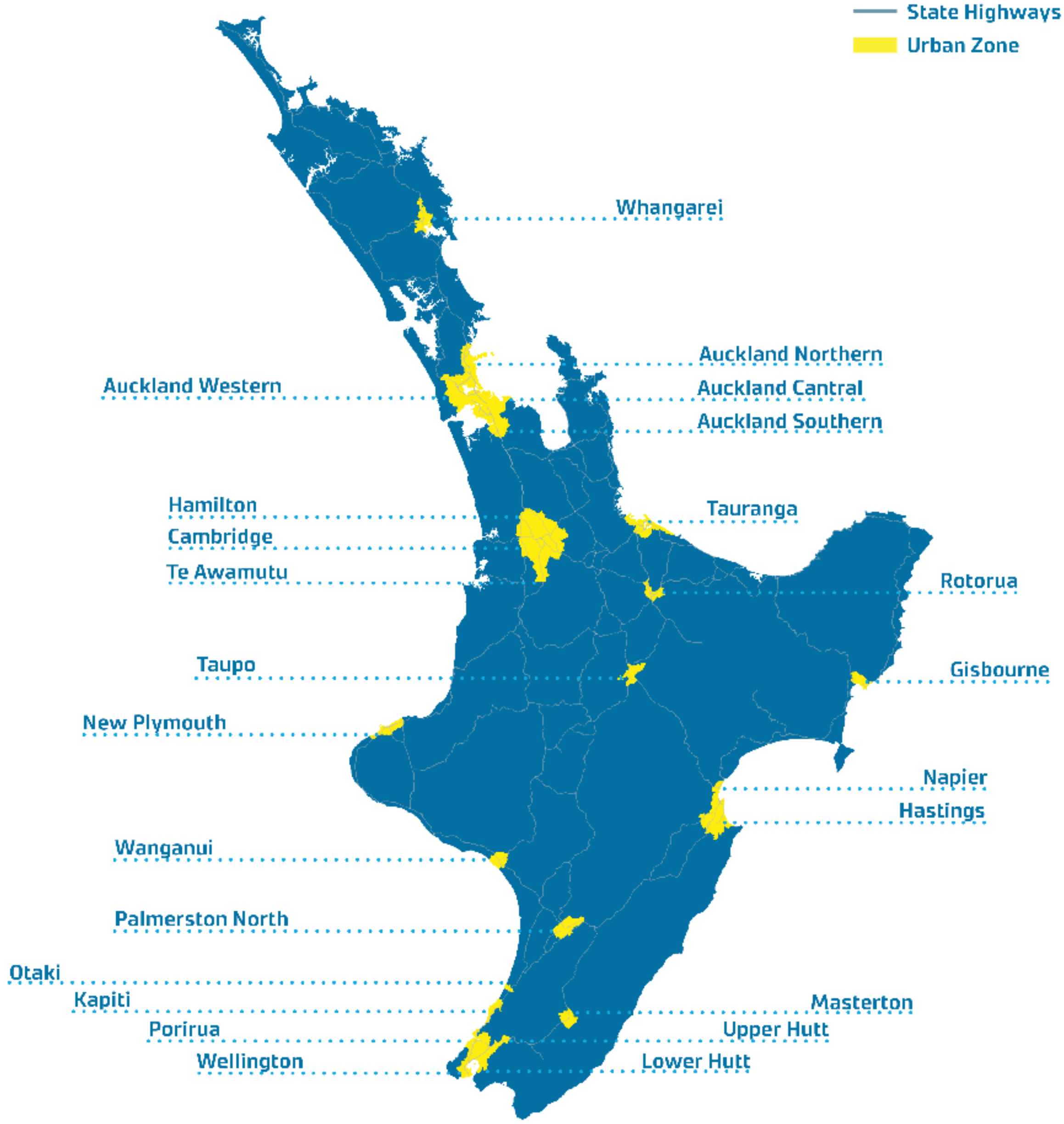
The monitoring sites are spread across each Waka Kotahi region and are generally intended to measure exposure to road vehicle emissions at locations:

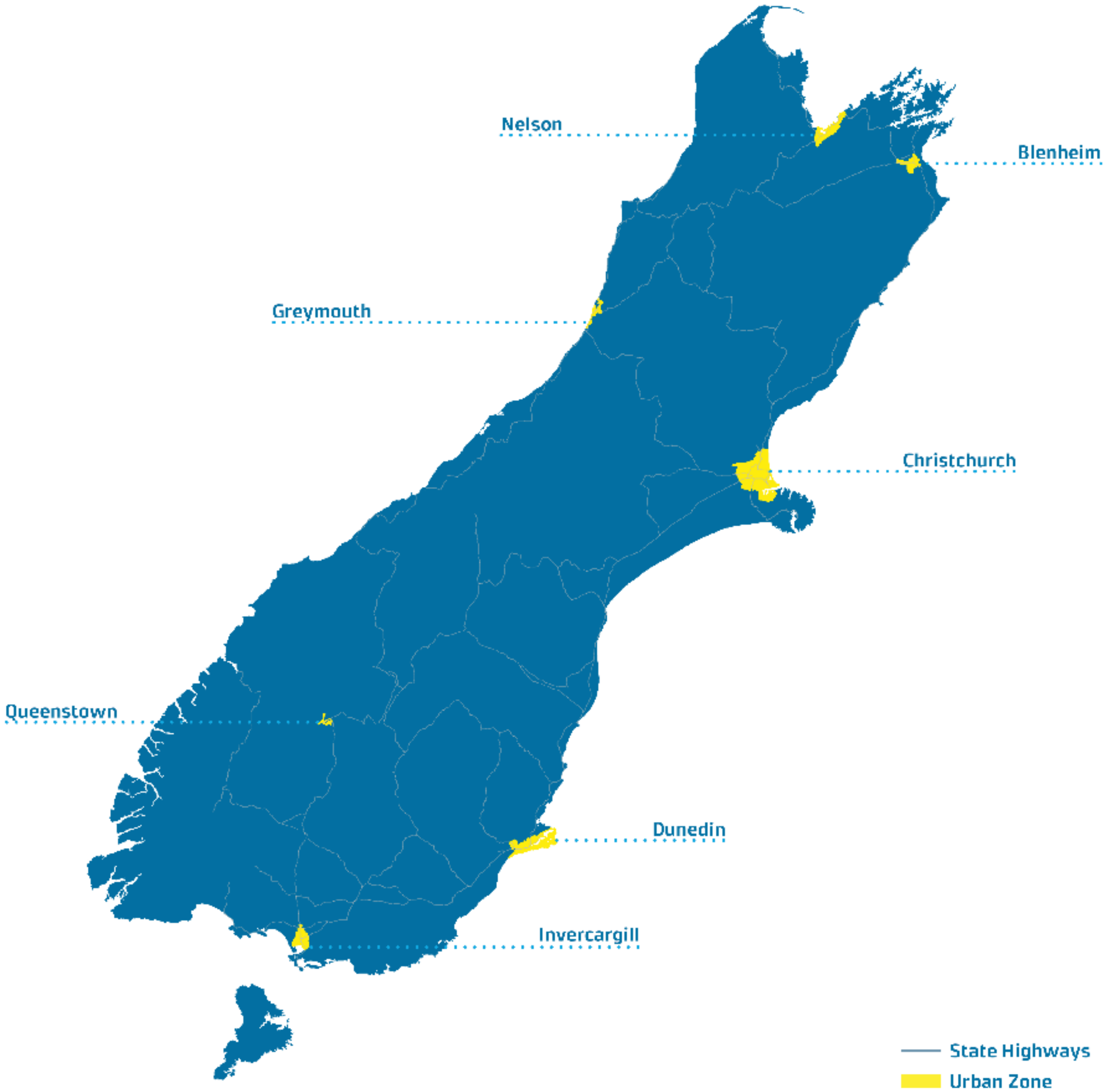
- that are sensitive to adverse air pollution effects (i.e. sites are generally within 50 m of either a school or residential areas), or
- where elevated concentrations are most likely to occur.

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 (e.g. siteID(a), siteID(b)).

Figure 4.1: Waka Kotahi 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 two valid monthly averages for summer and winter (i.e. at least 66% valid data for the season).

An **annual average** concentration can be calculated where there is a minimum of 75% valid data (i.e. at least nine months out of 12 of results), and at least one valid monthly average for winter (i.e. a valid average for July, August or September) and summer (i.e. 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, i.e. 1-hour and 24-hour average concentrations in the National Environmental Standards for Air Quality (Air Quality NES) and the Ambient Air Quality Guidelines (AAQG), respectively. There are no New Zealand health-based guidelines for exposure to NO_2 over time periods longer than 24 hours. However, the World Health Organization (WHO) has set air quality guidelines for annual average NO_2

concentrations. 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 µg/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
WHO AQG 2021[a]	Annual	10 µg/m^3

Notes: [a] See discussion in the following section. The previous WHO AQG was 40 µg/m^3

The National Air Quality Monitoring Network measures monthly average NO_2 concentrations, which are not directly comparable to the short-term standards and guidelines. A 2008 review of regional council monitoring results suggested that any site that exceeds 40 µg/m^3 (the annual average 2005 WHO guideline that has now been superseded) is also likely to exceed the 1-hour average Air Quality NES for NO_2[5]. This means that, through careful choice of sampling sites and the use of passive samplers as screening devices, locations where standards and guidelines are most likely to be exceeded due to motor vehicle emissions can be identified.

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

Historically Waka Kotahi has used two NO_2 assessment criteria to help identify locations with degraded air quality due to motor vehicle emissions; these have been superseded by the use of the WHO AQG 2021. Further information is provided in Section 4 about the limitations when comparing the passive sampler results directly with air quality guidelines.

5.2. Changes to WHO air quality guidelines

The World Health Organisation 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[6] included a reduction in the previous annual average NO_2 guideline value[4] 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.

The WHO AQG 2021 have 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.

[5] Watercare Services Ltd and Emission Impossible Ltd (2017) '*Ambient air quality (nitrogen dioxide) monitoring programme – Operating manual 2017/18*'.
[6] World Health Organisation (2021) '*WHO global air quality guidelines Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*'.

It should be noted that globally, including in many areas within New Zealand, the annual mean background concentration of NO_2 is expected to be above 10 µg/m³. The WHO AQG 2021 of 10 µg/m³ is seen as a long-term target criterion for environmental regulatory agencies to move towards.

6. What do the monitoring results tell us?

6.1. 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 much of the 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 m of a sensitive receptor, such as a dwelling.

Table 6.1: Results at monitoring locations within 20 metres of a sensitive receptor, 2022 data

Site Classification	No. 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	32	5	1
Local road	3	16	1	0
Urban background	18	3	0	0

6.2. Is NO_2 air quality improving?

The monitoring data for 2022 showed that 18.2% percent of monitoring sites are expected to have met the much lower WHO 2021 AQG (compared with almost all sites meeting the previous WHO 2005 AQG). As discussed previously, most monitoring locations are near-roadside, where people are very unlikely to be exposed 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[7]. There has been a gradual decline in median values from 2011[8] to 2022.

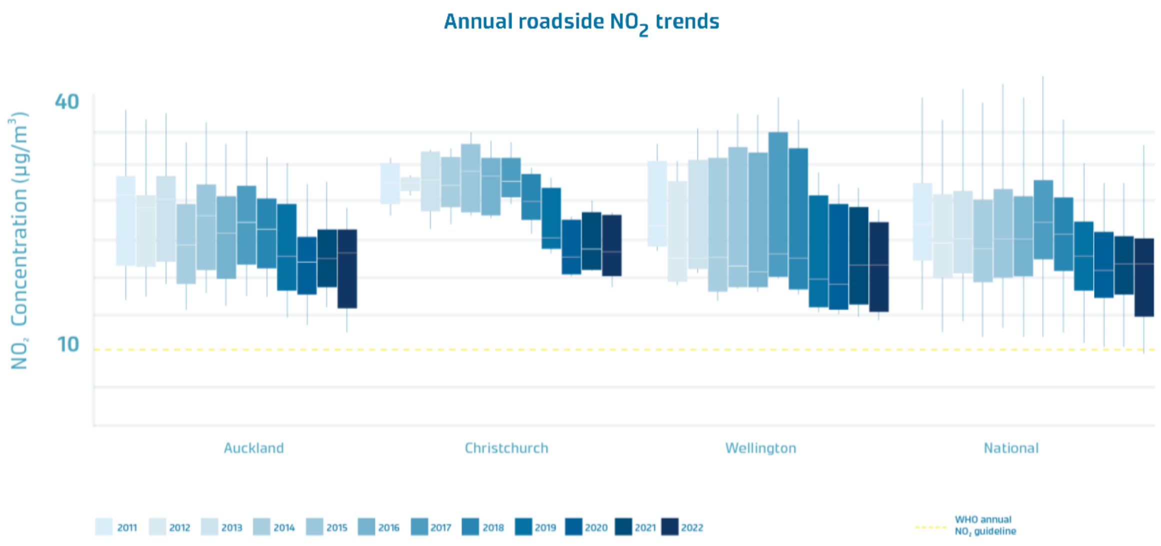
The reasons for this trend of reducing average and median NO_2 concentrations at roadside sites, despite increases in vehicle travel is likely due to changes in source emissions (e.g. improvements in the emissions from the vehicle fleet) and/or meteorology (e.g. emissions may be better dispersed in some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

The COVID-19 pandemic may have partially contributed to NO_2 concentration trends in 2020 and 2021. The partial nationwide lockdown, 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 period, which reduced the availability of valid data for sites in

[7] All sites from across the country, including those outside of major cities.
[8] 2011 was chosen because this is when the first set of complete data is available for majority of sites.

this region. The minimum and maximum NO_2 concentrations indicated a similar trend to previous years and are consistent with measurements recorded in 2022.

Figure 6.1: State highway sites and NO_2 concentration levels 2011-2022



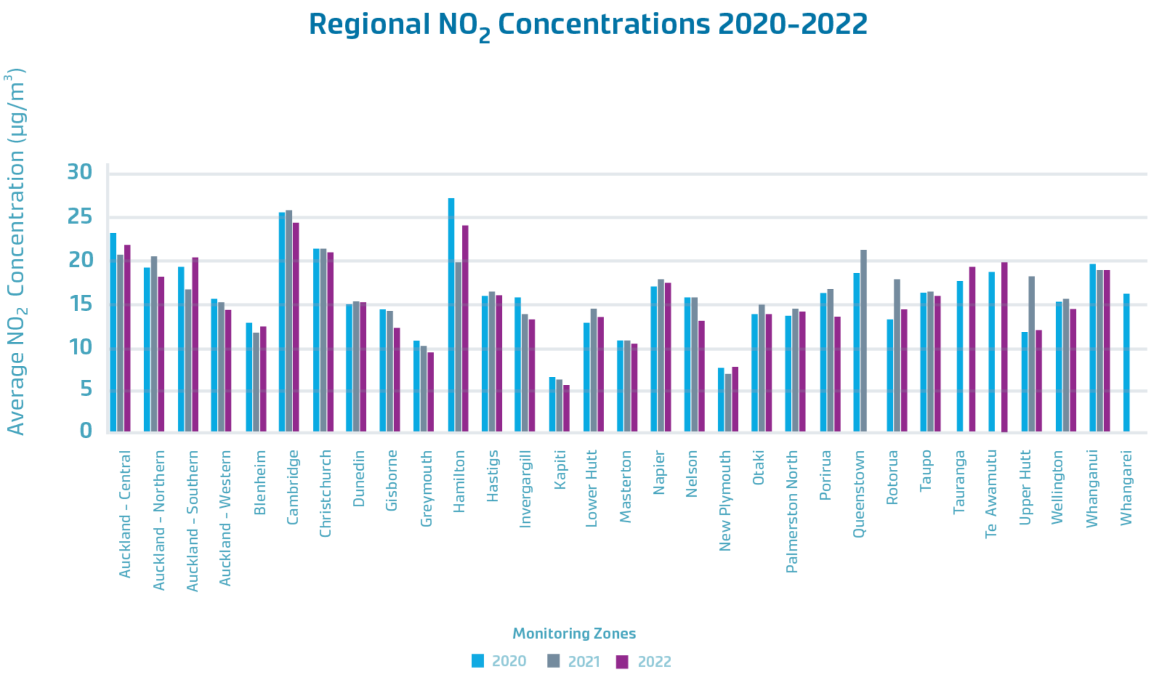
6.3. How do the results differ across New Zealand?

Figure 6.2 below shows the annual average NO_2 concentration averaged across the sites in each monitoring zone[9]. It shows that the highest average NO_2 monitoring results in 2022 were recorded in the Cambridge, Hamilton, Central Auckland, Christchurch and Southern Auckland monitoring zones. The lowest average monitoring results in 2022 were recorded in the Kapiti, New Plymouth and Greymouth monitoring zones. Queenstown and Whangarei monitoring zones did not have sufficient valid data in 2022 to produce an annual average.

When we look at the average results over the three years, there is a general decline in NO_2 concentrations (improved air quality) across almost all of the monitoring zones[10].

[9] This is based on data from all road types however the numbering of monitoring sites varies between zones, e.g. Queenstown only has one monitoring site, whereas Auckland Central has 18 monitoring sites.
[10] Complete data for the three years is unavailable for Tauranga, Te Awamutu and Whangarei.

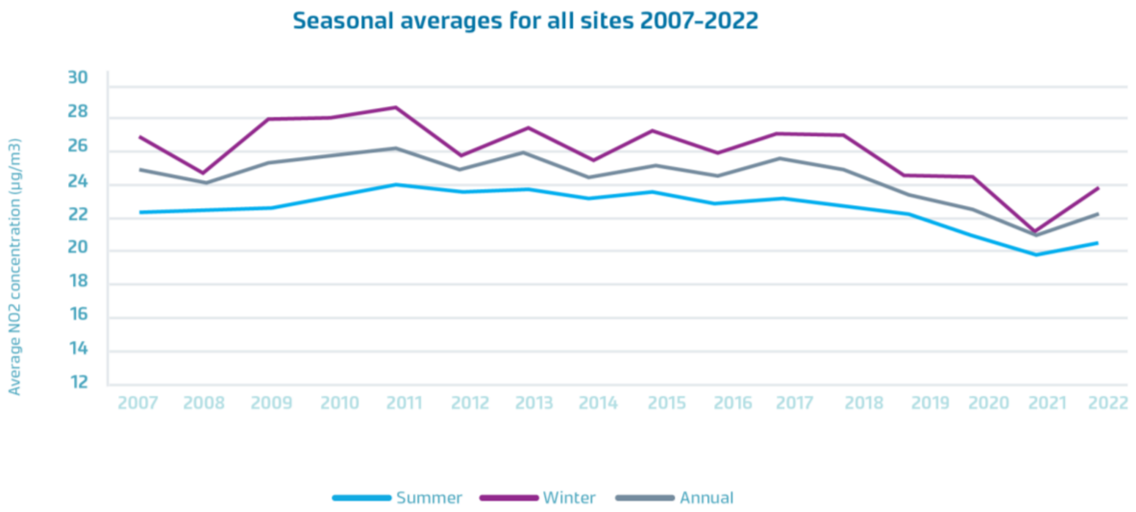
Figure 6.2: Average NO_2 concentrations measured in NZ monitoring zones



6.4. 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.

Figure 6.3: Varying NO_2 concentration levels during the seasons[11]



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

7. How do we know the data is reliable?

At a small number of the monitoring sites (seven in 2022), three 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.

A 2020 report found that the passive monitoring results were typically higher than the corresponding continuous monitoring data (on average 33% higher)[1]. It was noted that this finding is broadly consistent with a database of over one thousand co-location studies compiled by the UK Department of Environment, Food and Rural Affairs (DEFRA)[12]. The report also found that there was a strong non-linear correlation between the annual average NO_2 concentrations measured using passive and continuous techniques. This finding increases confidence in the reliability of passive sampling as a screening method, but also confirms that the results should not be directly compared to guideline values.

The precision of the passive samplers results is checked by comparing the monthly variation (coefficient of variation, CV) between the triplicate samples (presented graphically in Appendix B).

The CV is calculated according to:

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

The precision of the diffusion tubes is categorised as “good” or “poor” as follows[13]:

- 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%.
- Diffusion tubes are considered to have "poor" precision where the CV of four or more individual periods is greater than 20% and/or the overall average CV is greater than 10%.

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

For the triplicate sites in the network between 2007-2016, the average CV for all triplicate samples taken between 2007 and 2016 had been less than 8%[14]. For the triplicate sites in the network between 2016-2022, the overall average of all monthly CV’s is calculated to be 4.6%.

The CV has been less than 10% for 88.9% and less than 20% for 99.2% of the triplicate samples during 2016-2022, indicating that the precision of the passive samplers is good.

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

Over time Waka Kotahi intends to split the monitoring network 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, following recommendations by National Institute of Water & Atmospheric (NIWA) who recently carried out a review of the National Air Quality Monitoring Network[15].

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

[12] UK Department of Environment, Food and Rural Affairs (2023) *‘National bias adjustment factors’*.
[13] UK Department for Environment, Food and Rural Affairs (2022) *‘Local air quality management, technical guidance LAQM TG(22)’*.
[14] Waka Kotahi NZ Transport Agency (2017) ‘*Ambient air quality (nitrogen dioxide) monitoring network – Annual report 2007-16*’.
[15] National Institute of Water & Atmospheric (NIWA) (2021) ‘*Review of the National Air Quality Monitoring Network*’.

concentrations decrease at set distances from a linear source and this transverse data could assist in the geospatial modelling of NO_2.

Waka Kotahi also works with Regional Councils 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 Hawkes 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.

Table A.1: Results at monitoring locations within 20 metres of a sensitive receptor, 2022 data

Zone	Site ID	Site type	NZTM easting	NTZM northing	2022	2021	2020	2019	2018	2017	2016	2015	2014
Auckland - Central	AUC009	SH	1756848	5919273	35.8	39.0	41.8	40.4	43.6	48.2	47.7	-	41
Hamilton	HAM013	SH	1799056	5814544	34.5	38.0	41.3	42.4	44.3	41.4	40.4	42.2	39.9
Hamilton	HAM003	SH	1800756	5813015	33.7	36.8	39.1	41.4	42.5	42.9	40.5	41.4	38.7
Wellington	WEL008	SH	1748917	5426328	26.5	29.2	29.8	31.1	37.8	40.3	38.2	38.3	36.4
Christchurch	CHR017-19	Local	1567570	5180276	25.4	28.5	30.5	36.0	36.8	38.4	40.8	39.7	36.1
Christchurch	CHR016	Local	1573683	5179994	24.8	28.1	27.9	31.0	35.0	40.7	32.1	35.1	35.3
Auckland - Southern	AUC068	SH	1759293	5906550	-	-	-	-	-	-	-	Decom	40.9

Note: The sites are listed in order based on the annual average NO_2 concentrations recorded in 2022. Red indicates an exceedance of criterion.

Appendix B: Co-located monitors

Figure C.1, C.2 and C.3 present the 2022 monitored concentrations recorded for three co-located monitors.

Figure C.1: 2022 average monthly NO_2 monitoring for AUC054a-56a

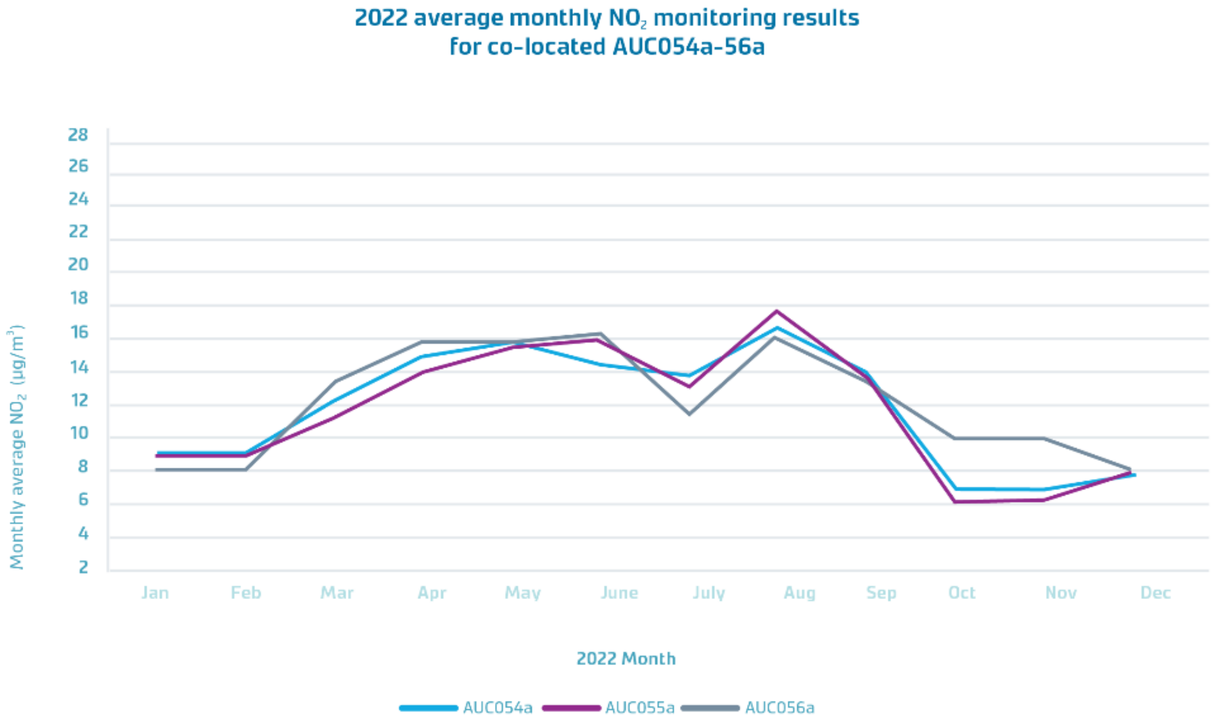


Figure C.2: 2022 average monthly NO_2 monitoring for WEL073-075

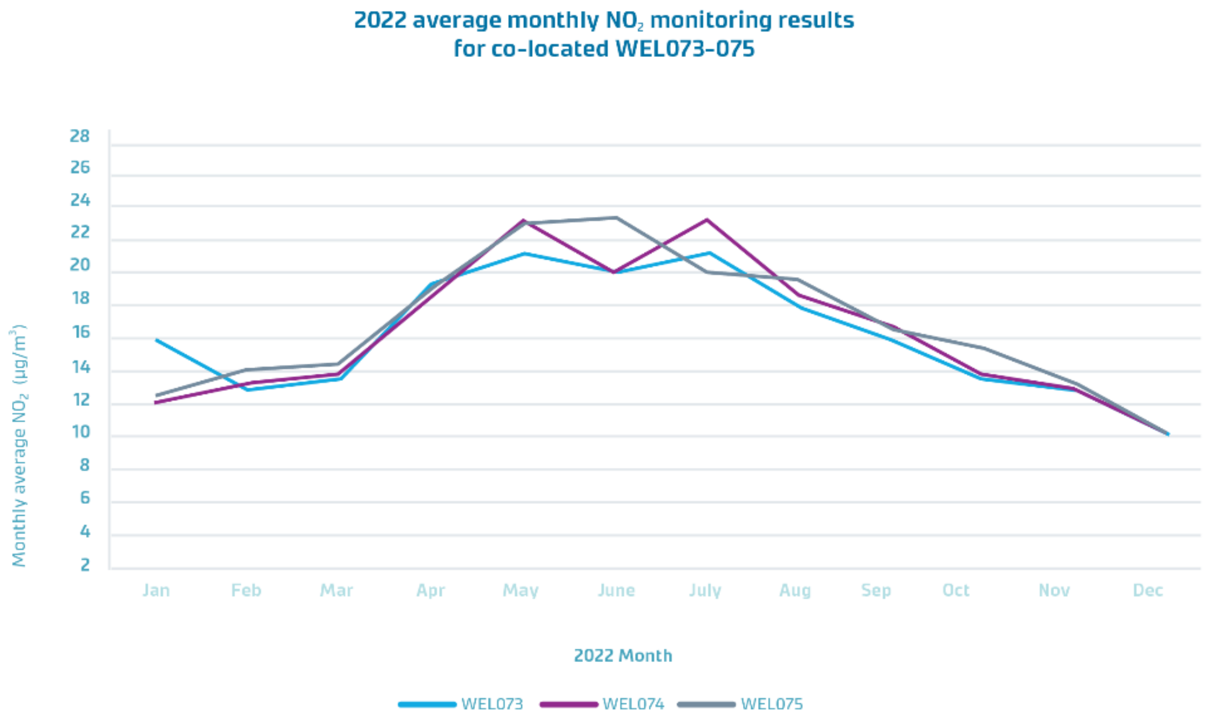


Figure C.3: 2022 average monthly NO_2 monitoring for CHR017-019