Ambient Air Quality (Nitrogen Dioxide) Monitoring Programme

Annual report 2007-2021

Tonkin + Taylor Limited

December 2022

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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. 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 less expensive, the monitoring network can cover a large number of sites.

Although a recent report[1] confirmed that passive monitoring results are typically higher than the corresponding continuous data (on average 33% higher), 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.

This report shows that, from 2016 to 2021, 99 percent[2] of monitoring sites are expected to have met the annual average NO_2 criteria adopted from the World Health Organization (WHO) 2005 air quality guidelines, and 3 percent are expected to have met the lower WHO 2021 criterion. Furthermore, when we look at the annual average results over the past few years, there is a general decline in NO_2 concentrations (improved air quality) across almost all of the monitoring areas.

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

[1] Emission: Impossible Ltd (June 2020). National air quality (NO_2) monitoring network: Correlations between passive and continuous results 2010 to 2019. Prepared for Waka Kotahi NZ Transport Agency.

[2] Calculated from the monitoring sites which had at least one valid annual average recorded from 2016 to 2020

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 this air can adversely affect peoples' health. People with pre-existing respiratory and heart conditions, the young, and older people are particularly vulnerable. 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.[3]

Air pollution comes from many sources including burning of fuels for 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.[4]

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.[5]

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 2021. 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 of these. 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 Organization (WHO) which states[6] 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 started 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 2021, monitoring was being conducted at 135

[3] Land Air Water Aotearoa website, https://www.lawa.org.nz/learn/factsheets/why-is-air-quality-important/, accessed June 2020

[4] Stats NZ Tatauranga Aotearoa Air Pollutant emissions https://www.stats.govt.nz/indicators/air-pollutant-emissions.

[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. Geneva: World Health Organization.

[6] World Health Organization. (2006). Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide, and sulphur dioxide. Geneva: World Health Organization

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, and 2020, and covered the period from the beginning of 2006 to the end of 2020. This report builds on that earlier work and includes data collected up to the end of 2021.

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, so they can 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 recent report[7] 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.

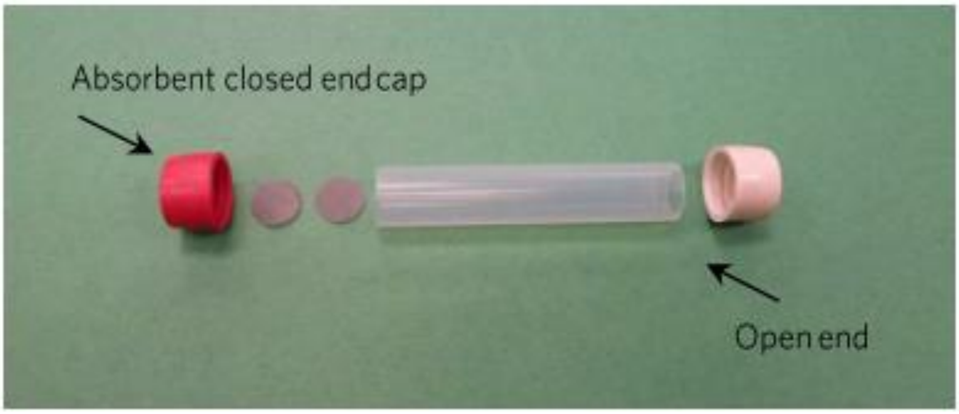


Figure 1: Diffusion Tube

[7] Emission: Impossible Ltd. (2020). National air quality (NO_2) monitoring network: Correlations between passive and continuous results 2010 to 2019. Prepared for Waka Kotahi NZ Transport Agency.

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 Taupo, 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)
- where elevated concentrations are most likely to occur.

Sites are classified by monitoring zone (refer to Figure 2), 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)).

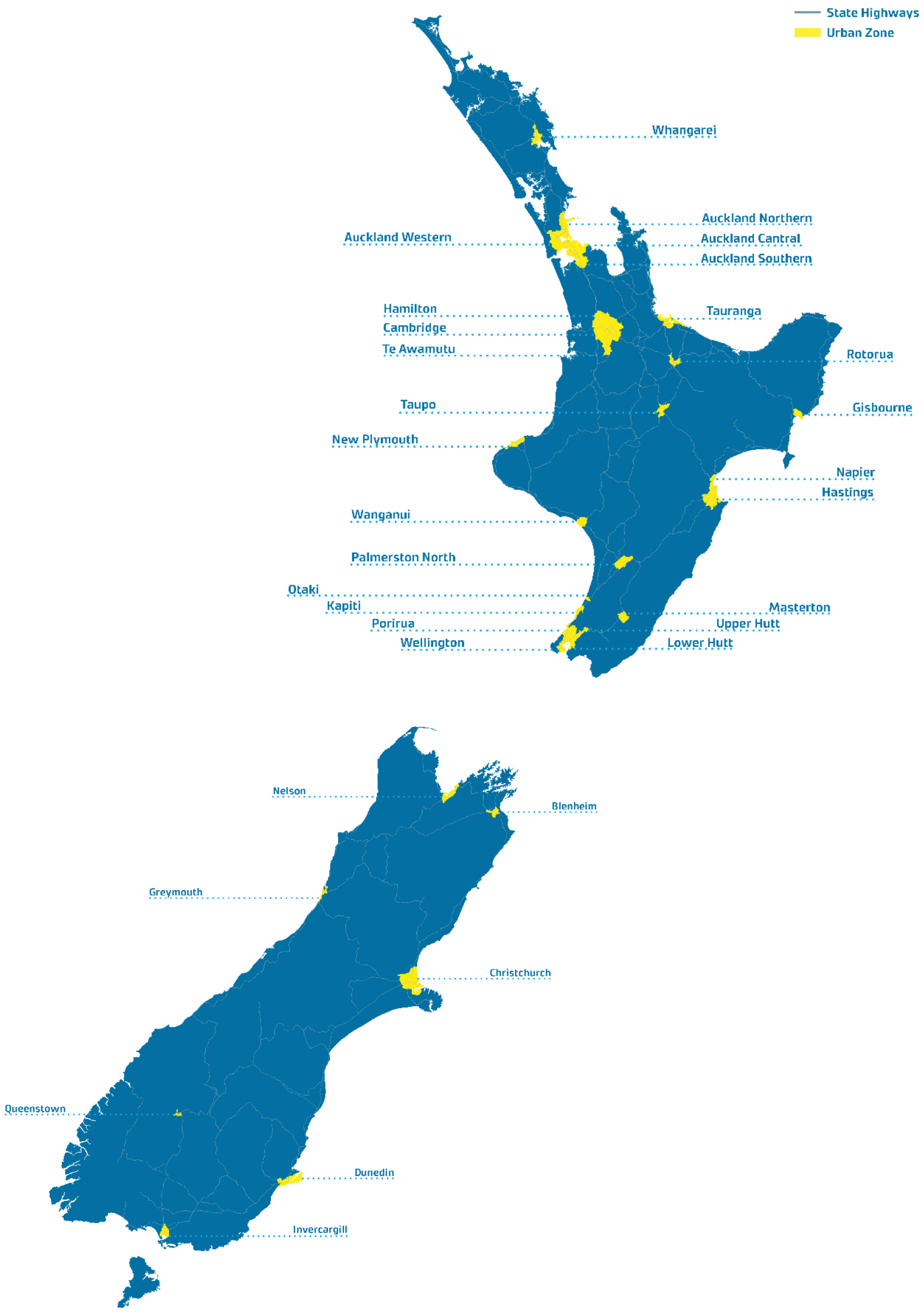


Figure 2: Waka Kotahi monitoring zones

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. The WHO has recently 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 1.

Table 1: NO_2 ambient air quality standards and guidelines

Standard or guideline	Averaging period	Concentration
Air Quality NES	1 - hour	200 $\mu g/m^3$
AAQG	24 - hour	100 $\mu g/m^3$
AAQG (ecosystems)	Annual	30 $\mu g/m^3$
WHO AQG 2005[a]	Annual	40 $\mu g/m^3$
WHO AQG 2021[a]	Annual	10 $\mu g/m^3$

Table Notes:
a See discussion in the following section

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 which exceeds the annual average WHO guideline (2005) is also likely to exceed the 1-hour average Air Quality NES for NO_2[8]. 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.

[8] Watercare Services Ltd and Emission Impossible Ltd. (2017). Ambient air quality (nitrogen dioxide) monitoring programme – Operating manual 2017/18. Prepared for Waka Kotahi NZ Transport Agency.

5.2. Changes to the World Health Organization 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. The status of the WHO AQG in New Zealand has been described by the Ministry for the Environment as follows:

> *The World Health Organization guidelines are based on an evaluation of the most recent science on health impacts from air pollution, and identify air pollution levels above which there are significant risks to human health. This is the only consideration used for setting the guideline levels. They are intended to inform air quality management, but, as international guidelines, are not legally binding*.[9]

Updates to the WHO AQG in 2021[10] included a four-fold reduction in the previous annual average NO_2 guideline value[11] from 40 µg/m³ to 10 µg/m³. The WHO 2021 AQG includes three Interim Targets for annual average NO_2, which provide for a progressive reduction from 40 µg/m³ (Interim Target 1) to 20 µg/m³ (Interim Target 3). The interim targets recognise that air quality in many locations will not meet the AQG 2021 and are intended to be regarded as steps towards the ultimate achievement of AQG levels in the future.

Because they are expressed as annual average concentrations, the WHO AQG are relevant to locations where people are likely to be exposed on a long-term continuous basis, so they are not relevant to roadside locations that are not representative of where people live.

Passive sampling is a screening monitoring method. The results are typically higher than from continuous monitoring methods. Limitations of the monitoring methodology should therefore be considered when comparing with air quality guidelines.

This report includes reference to the WHO 2005 AQG because these have been the reporting thresholds for air quality monitoring data across New Zealand to date, and because this allows comparison to findings from previous reporting. The data has also been assessed against the WHO 2021 AQG, to enable us to evaluate air quality using the most up-to-date guidelines.

[9] Ministry for the Environment & Stats NZ (2021). New Zealand's Environmental Reporting Series: Our air 2021. p 5. Retrieved from environment.govt.nz

[10] 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. Geneva: World Health Organization.

[11] World Health Organization. (2006). Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide, and sulphur dioxide. Geneva: World Health Organization.

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. Table 3 summarises the measured concentrations at monitoring locations that are identified as being within 20m of a sensitive receptor, such as a dwelling.

Table 3: Results at monitoring locations within 20 metres of a sensitive receptor

Site Classification	No. of monitoring locations with annual average concentrations in range			
	0–14.9 µg/m³	15–24.9 µg/m³	25–34.9 µg/m³	> 35 µg/m³
State Highway	9	24	5	0
Local road	7	8	5	0
Urban background	22	0	0	0

6.2. Is NO_2 air quality improving?

The monitoring results indicate that 99 percent[12] of monitoring sites over the period 2016 to 2021 were below the 40 µg/m³ annual average WHO 2005 NO_2 criterion and 3 percent below the WHO 2021 criterion.

Figure 3 shows the annual average NO_2 concentrations for the state highway monitoring sites in the three largest cities and the aggregated national results[13]. There has been a gradual decline in median values (represented by the inner yellow line within the boxes) from 2011 to 2021.[14]

The reasons for this trend of reducing average and median NO_2 concentrations at roadside sites, despite increases in vehicle travel[15] 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 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 this region. The minimum and maximum NO_2 concentrations indicated a similar trend to previous years.

[12] Calculated from the monitoring sites which had at least one valid annual average recorded from 2016 to 2021

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

[14] 2011 was chosen because this is when the first set of complete data is available for majority of sites

[15] https://www.nzta.govt.nz/assets/userfiles/transport-data/VKT.html

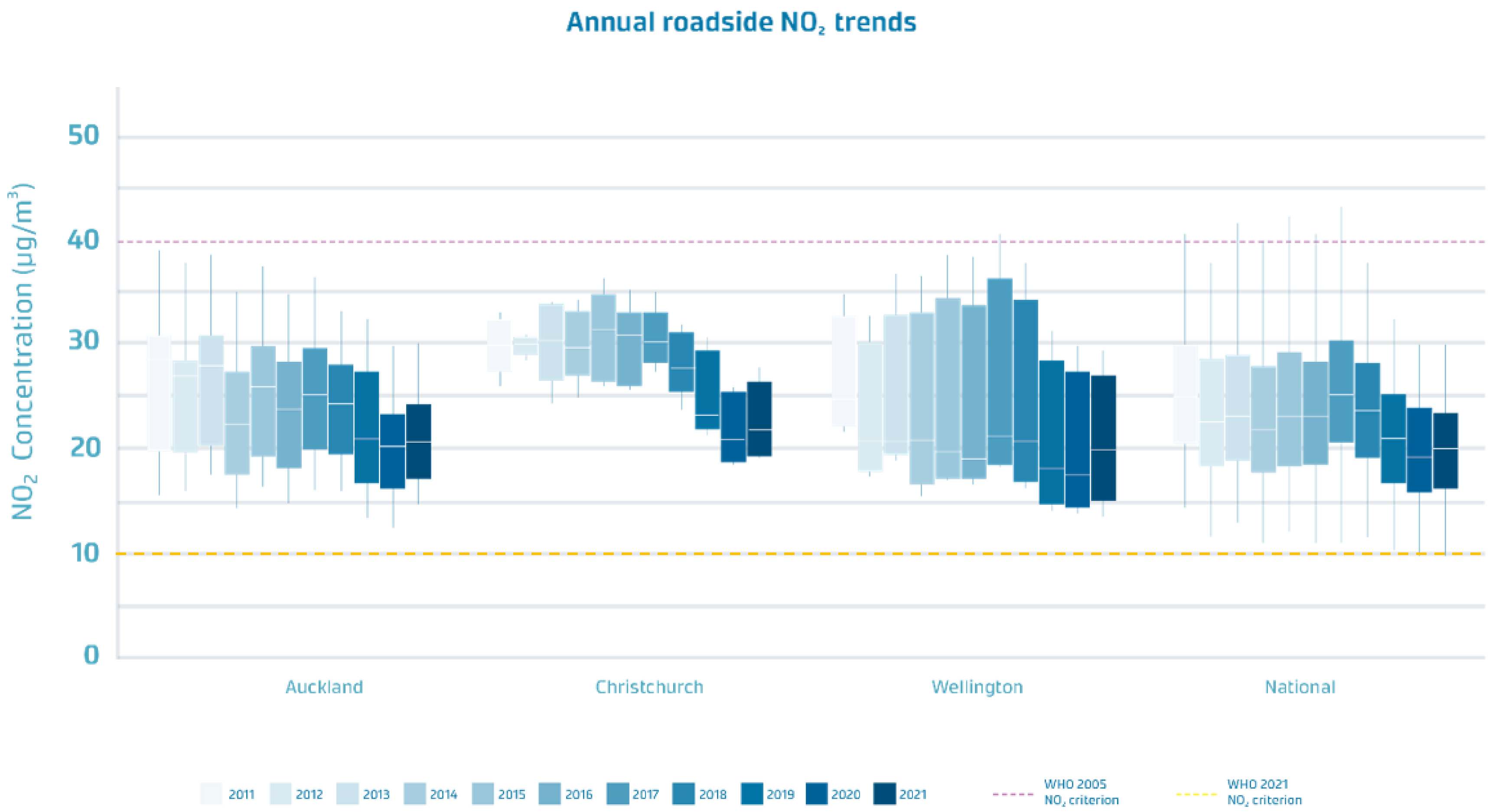


Figure 3: NO_2 concentrations at State Highway sites (2011 to 2021)

Since monitoring began in 2007, annual average NO_2 concentrations exceeding the WHO 2005 AQG ($\geq 40\ \mu g/m^3$) have been recorded at ten of the monitoring sites (please refer to the table in Appendix A). Since 2018, only three of these sites (two in Hamilton and one in Auckland) have continued to report annual average NO_2 concentrations greater than 40 $\mu g/m^3$. The changes in NO_2 levels over time at these three monitoring sites have been investigated in more detail, their characteristics discussed in Table 4 below and the changes in NO_2 concentrations illustrated in Figure 4.

A decreasing trend is observed as all three state highway monitoring sites over 2019 to 2021, and in 2021 none of the sites exceeded 40 $\mu g/m^3$.

Table 4: Locations where recorded NO_2 annual average concentrations exceeded the WHO 2005 AQG in 2018[16]

Site ID	Site name	Site type	Distance from road	Discussion
AUC009	CMJ / Canada St	State highway	11 m	Located at Canada Street, Newton near the Central Motorway. It is likely to be impacted by very high traffic volumes. In 2017, the Water-view Tunnel which is in the vicinity of site AUC009, was opened[17] and this may have con-tributed to the decrease in average NO_2 con-centrations recorded in from 2018 to 2021.
HAM003	Lorne St / Ohaupo Rd	State highway	10 m	Both are state highway sites and are located in Hamilton. In the future, there may be an im-provement of air quality in both locations due to the completion of the Hamilton section of the Waikato Expressway project in mid-2022.[18]
HAM013	Greenwood St / Killarney St	State highway	16 m	

[16] NZTA (2020). Ambient air quality (nitrogen dioxide) monitoring network – Annual report 2007-19, NZ Transport Agency, August 2020

[17] https://www.cityraillink.co.nz/newsletter-june-2022/mercury-lane-superstructure-begins accessed June 2022

[18] https://www.nzta.govt.nz/assets/projects/hamilton/docs/hamilton-section-newsletter-july-2022.pdf accessed October 2022

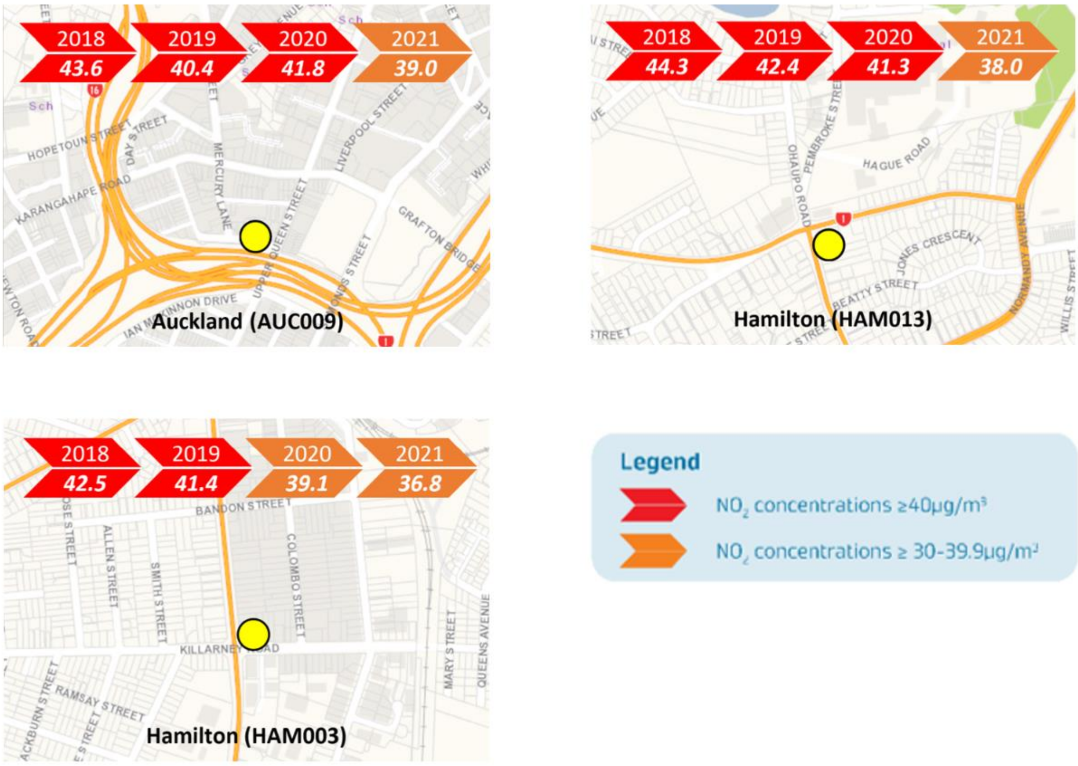


Figure 4: Locations where recorded NO_2 annual average concentrations exceeded the WHO 2005 AQG (≥40 µg/m^3) in 2018, and concentrations in subsequent years

Figure 5 shows the five locations that recorded annual average NO_2 concentrations greater than 30 µg/m^3 in 2021 and indicates whether NO_2 concentrations are generally increasing or decreasing since 2012 (2012 was chosen for comparison because this is when the set of complete data first became available for majority of sites).

One out of the five sites show a reduction in NO_2 concentrations since 2012. Two sites have had little change in NO_2 concentrations since 2012 and two sites (in Hamilton and Auckland) have had an increase in NO_2 concentrations since 2012. Overall, there are fewer sites that recorded annual average values ≥ 30µg/m^3 in 2021 than in previous annual reports.

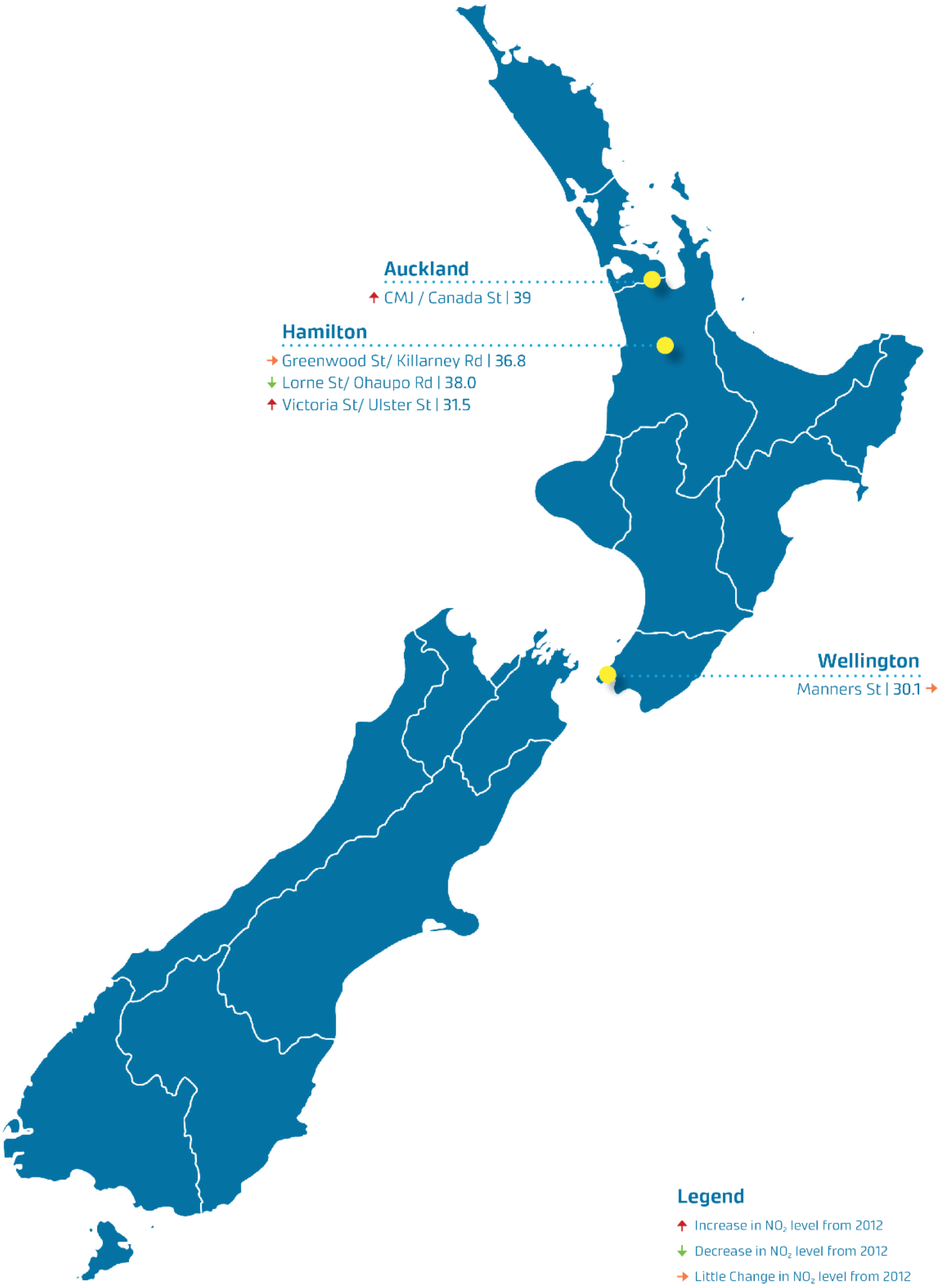


Figure 5: Locations where NO_2 annual average concentrations exceeded 30 µg/m^3 in 2021 and change compared to 2012

6.3. How do the results differ across New Zealand?

Figure 6 below shows the annual average NO_2 concentration averaged across the sites in each monitoring zone[19]. It shows that the highest average NO_2 monitoring results in 2021 were recorded in the Cambridge, Christchurch, Queenstown, Central Auckland and Northern Auckland monitoring zones. The lowest average monitoring results in 2021 were recorded in the Kapiti, New Plymouth and Greymouth monitoring zones. Tauranga, Te Awamutu and Whangarei monitoring zones did not have sufficient valid data in 2021 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[20].

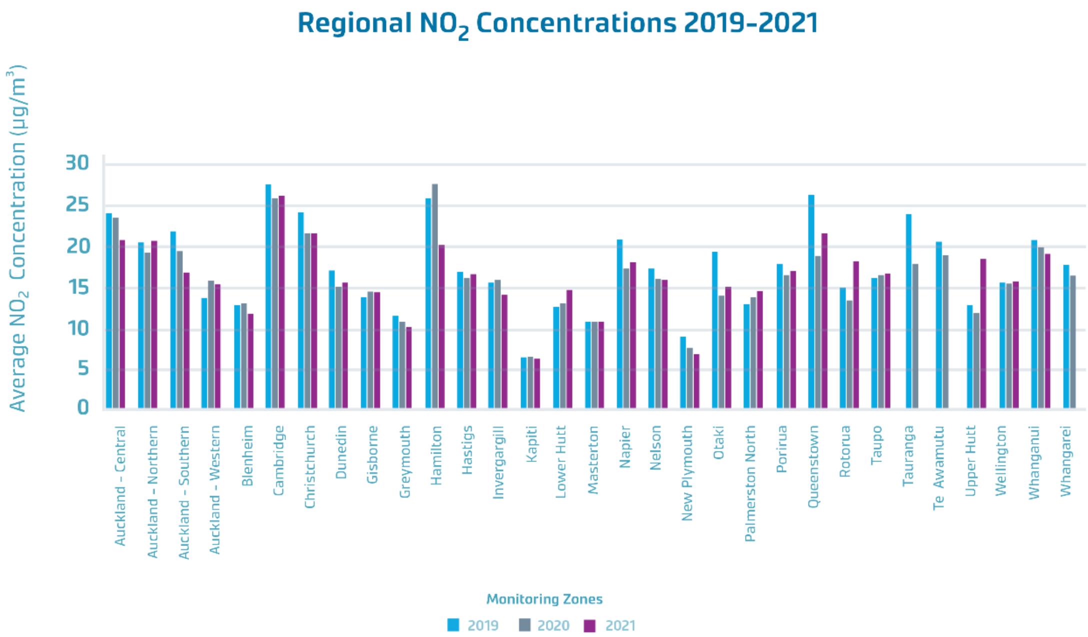


Figure 6: Average NO_2 concentrations measured in monitoring zones

[19] 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.

[20] Complete data for the three years is unavailable for Tauranga, Te Awamutu and Whangarei.

6.4. Are NO_2 concentrations higher in summer or winter?

Figure 7 illustrates how NO_2 concentrations vary seasonally. Further analysis (shown in Appendix B) shows that most sites record the highest NO_2 concentrations during June and record the lowest NO_2 concentrations 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.

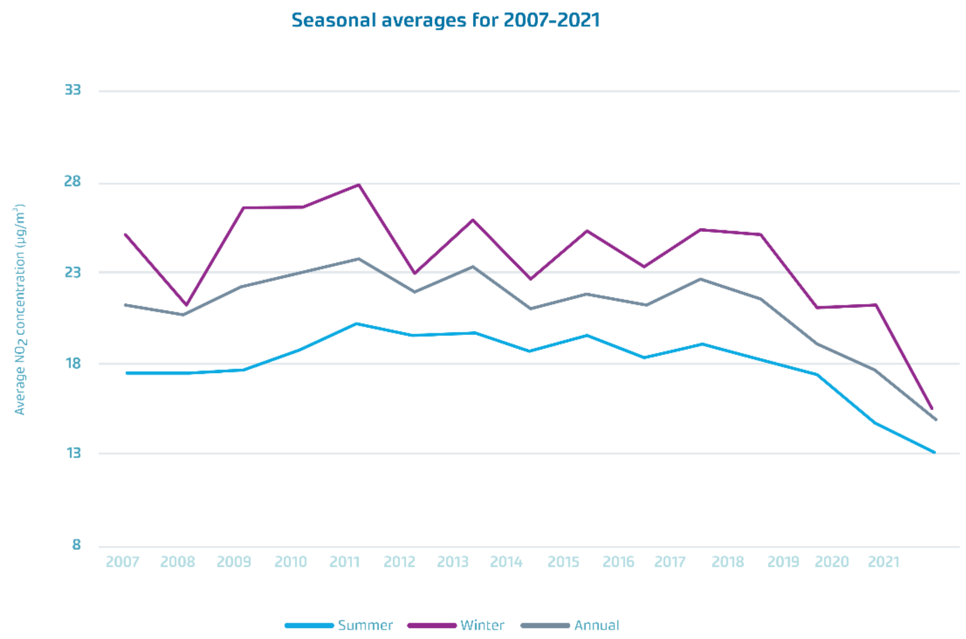


Figure 7: Seasonal variations in NO_2 concentrations[21]

7. How do we know the data is reliable?

At a small number of the monitoring sites (seven in 2021), 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 recent report found that the passive monitoring results were typically higher than the corresponding continuous monitoring data (on average 33% higher)[22]. 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. 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 results from the passive samplers is checked by comparing the monthly variation (coefficient of variation, CV) between the triplicate samples (presented graphically in Appendix C).

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

[22] Emission Impossible Ltd (2020). National air quality (NO_2) monitoring network: Correlations between passive and continuous results 2010 to 2019. Prepared for Waka Kotahi NZ Transport Agency.

The CV is calculated according to:

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

The precision of the diffusion tubes is categorised as “good” or “poor” as follows[23]:

- 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%.[24] For the triplicate sites in the network between 2016-2021, the overall average of all monthly CVs is calculated to be 4.7%.

The CV has been less than 10% for 90.5%, and less than 20% for 99.6%, of the triplicate samples during 2016-2021, indicating that the precision of the passive samplers is good.

8. Are there any future changes proposed to the 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.[25]

In the future, 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.

Waka Kotahi has also begun conversations with Regional Councils to improve coverage in parts of the existing local network – such as busy city centre streets, ports and growth areas (another NIWA recommendation).

[23] Department for Environment Food & Rural Affairs. (2021). Local air quality management technical guidance (TG16). p7-61. https://laqm.defra.gov.uk/documents/LAQM-TG16-April-21-v1.pdf accessed October 2022.

[24] Waka Kotahi NZ Transport Agency. (2017). Ambient air quality (nitrogen dioxide) monitoring network – Annual report 2007-16

[25] National Institute of Water & Atmospheric Research. (2021). Review of the National Air Quality Monitoring Network. Prepared for Waka Kotahi NZ Transport Agency

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

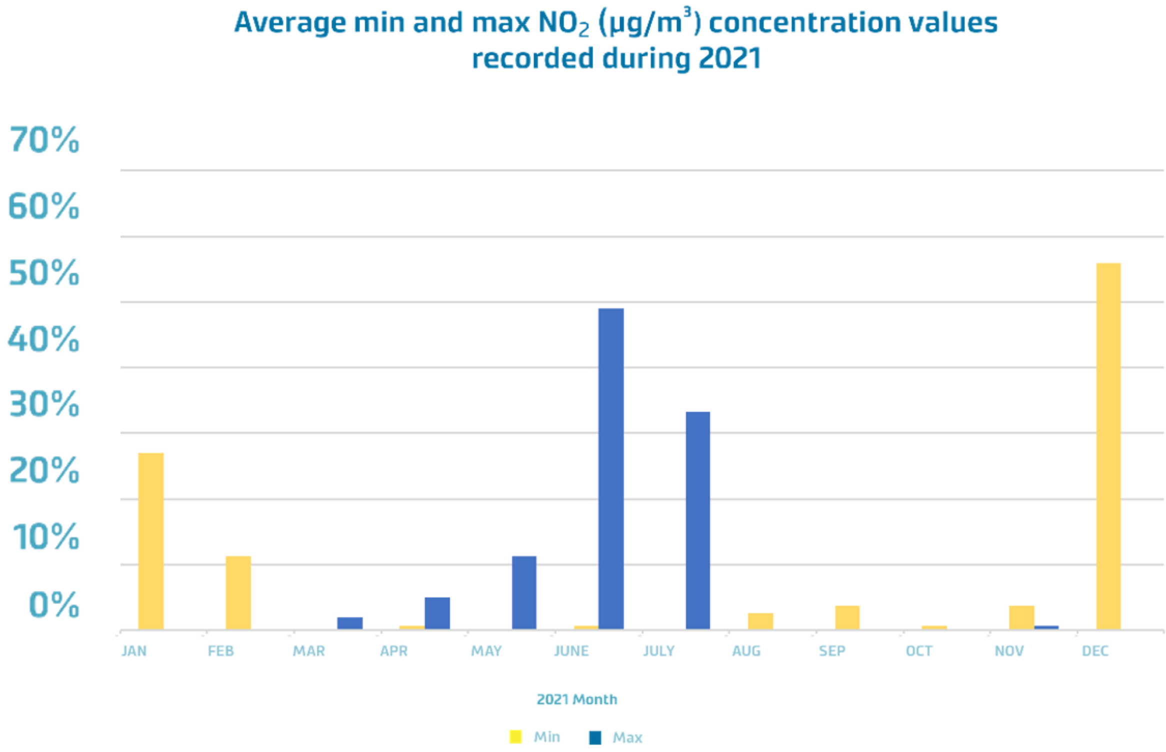
Table showing the ten locations which recorded annual average NO_2 concentrations exceeding WHO 2005 AQG since the monitoring programme began in 2007.

Zone	Site ID	Site type	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Auckland - Central	AUC009	SH	39.0	41.8	40.4	43.6	48.2	47.7	Insuf data	41	46.5	41.3	43.9	40.8	44.0	35.8	41.9
Hamilton	HAM013	SH	38.0	41.3	42.4	44.3	41.4	40.4	42.2	39.9	41.4	36.8	40.1				
Hamilton	HAM003	SH	36.8	39.1	41.4	42.5	42.9	40.5	41.4	38.7	38.4	37.5	40.4	39.0	40.0	38.3	36.1
Wellington	WEL049	Local	29.2	27.5	30.3	38.7	38.1	37.0	39.6	36.9	38.8	31.0	39.0	40.3			
Wellington	WEL008	SH	29.2	29.8	31.1	37.8	40.3	38.2	38.3	36.4	36.7	32.7	34.8	35.5	33.3	31.3	39.4
Christchurch	CHR017-19	Local	28.5	30.5	36.0	36.8	38.4	40.8	39.7	36.1	41.6	41.4					
Christchurch	CHR016	Local	28.1	27.9	31.0	35.0	40.7	32.1	35.1	35.3	37.5	33.6	36.8				
Auckland - Western	AUC063	Local	25.8	26.2	Insuf data	30.2	32.5	33.7	35.8	34.6	37.4	36.8	40.8	38.3			
Auckland - Central	AUC060	Local	25.1	26.9	28.8	32.0	36.2	36.7	38.9	34.9	38.8	37.6	40.3	39.9			
Auckland - Southern	AUC068	SH							Decom	40.9	46	41.5	44.7	43.3			

The sites are listed in order based on the annual average NO_2 concentrations recorded in 2021.

Appendix B: Minimum and maximum recorded NO_2 concentrations during 2021

The following graph illustrates the percentage of sites that recorded the highest (blue) and lowest (yellow) NO_2 concentration in each month of 2021. During 2021, 94% of the monitoring sites had the highest NO_2 concentrations observed during the May to July period (Autumn) and 94% of the monitoring sites had the lowest NO_2 concentrations observed during the December to February period (summer). This is a similar trend to previous years.



Appendix C: Co-located passive monitors (triplicate samplers)

The following graphs showing 2021 NO_2 levels recorded at each set of three co-located passive monitors. The closer the three results in each month, the higher the precision of the passive monitors.