AMBIENT AIR QUALITY (NITROGEN DIOXIDE) MONITORING PROGRAMME

Annual report 2007-2019

TONKIN & TAYLOR LTD

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New Zealand Government

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EXECUTIVE SUMMARY

Waka Kotahi NZ Transport Agency (Waka Kotahi) established a national nitrogen dioxide (NO_2) monitoring programme, known as the National Air Quality Monitoring 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 the regulatory continuous monitors (used to assess compliance with standards) but, because they are less expensive, the monitoring network can cover a larger number of sites.

A recent report[1] has confirmed that passive monitoring results are typically higher than the corresponding continuous data (on average 33% higher), and therefore passive sampling is conservative, which is useful as a screening method to identify hotspots and to look at trends in longer term average NO_2 concentrations.

This report shows that, from 2016 to 2019, 96[2] percent of the diffusion tube monitoring sites were below the World Health Organization (WHO) annual NO_2 guideline value. Furthermore, when we look at the 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 has plans to further refine the Network by including new sites and relocating some existing sites to more optimal locations.

[1] Emission: Impossible Ltd (June 2020). National air quality (NO2) 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 2019.

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 Maori[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 2015, on-road vehicle emissions were the main contributor to nitrogen oxides in our air, producing 39% (47,800 tonnes) of human-generated NO_2 emissions, 70% of which was from diesel vehicles[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 affect lung growth in children and cause damage to plants.

This report describes the results from the Waka Kotahi National Air Quality Monitoring Network and reviews data gathered from the beginning of 2007 up to the end of 2019. Results are compared spatially (i.e. at different sites) and temporally (i.e. year to year and seasonally).

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 Organisation (WHO) which states 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 established 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 2019, monitoring was being conducted at 135 locations. Waka Kotahi's overall aim is to see a decreasing trend in NO_2 concentrations measured at these sites.

The last report that was prepared to summarise the results from the National Air Quality Monitoring Network was published in 2017 and covered the period from the beginning of 2007 to the end of 2016. This report builds on that earlier work and includes data collected up to the end of 2019.

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

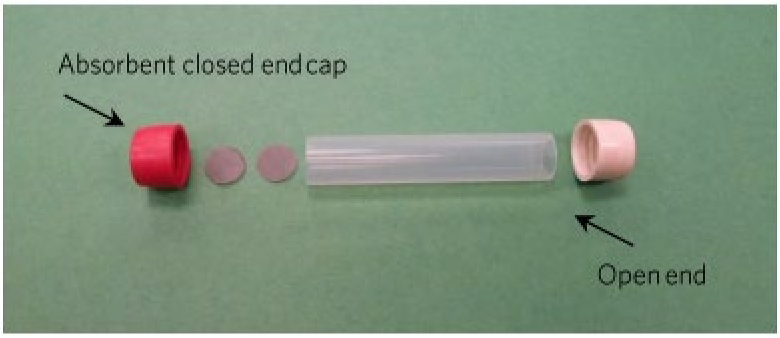
[4] Our air 2018, Ministry for the Environment & Stats NZ (2018). New Zealand's Environmental Reporting Series: Our air 2018.

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[5] 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 National Environmental Standards for Air Quality (Air Quality NES) and 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 7cm 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



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:

[5] Emission: Impossible Ltd (June 2020). National air quality (NO2) monitoring network: Correlations between passive and continuous results 2010 to 2019. Prepared for Waka Kotahi NZ Transport Agency.

- that are sensitive to adverse air pollution effects (i.e. sites are generally within 50m 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), broadly corresponding to towns or cities with populations greater than approximately 30,000 and site type (highway, local or background).

Each site is also allocated a unique site identification (site ID) code.

Figure 2: NZTA passive monitoring zones

How do we interpret the results?

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. 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)[6] has set an annual average guideline of 40 micrograms[7] per cubic metre (µg/m^3).

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 1.

Table 1: NO_2 ambient air quality standards and guidelines

Standard or guideline	Averaging period	Concentration
Air Quality NES	1 - hour	200µg/m^3
AAQG	24 - hour	100µg/m^3
AAQG (ecosystems)	Annual	30µg/m^3
WHO	Annual	40µg/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 which exceeds the annual average WHO guideline 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.

[6] WHO (2006). Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide, and sulphur dioxide, World Health Organisation, October 2006.
[7] 1 microgram = 0.000001 grams.
[8] NZTA (2017). Ambient air quality (nitrogen dioxide) monitoring programme – Operating manual 2017/18, prepared by Watercare Services Ltd and Emission Impossible Ltd for NZ Transport Agency, October 2017.

Waka Kotahi uses the assessment criteria shown in Table 2 to help identify locations with degraded air quality due to motor vehicle emissions, including those where the WHO annual average guideline may be exceeded.

Table 2: Waka Kotahi assessment criteria for annual average NO_2 passive monitoring results

Annual average concentration	Descriptor	Notes
≥ 40 µg/m^3	High	Identifies locations where the WHO annual NO_2 guideline may be exceeded and air quality effects of motor vehicles need further investigation
≥ 30 µg/m^3 to 39.9 µg/m^3	Medium	Identifies locations where air quality may be degraded because of motor vehicle emissions and may cause adverse effects

WHAT DO THE MONITORING RESULTS TELL US?

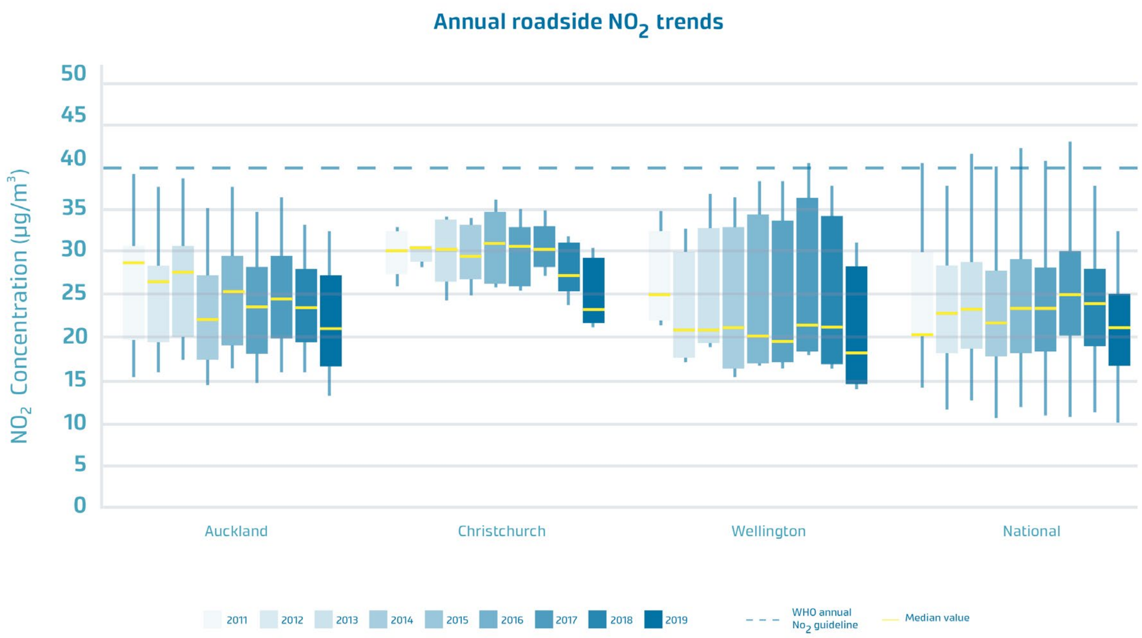
Is NO_2 air quality improving?

The monitoring results indicate that 96 percent[9] of monitoring sites over the period 2016 to 2019 were below the WHO annual NO_2 guideline.

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[10]. There has been a gradual decline in median values (represented by the inner yellow line within the boxes) from 2011 to 2019[11], with a clearer trend of improving air quality over the last 3 years.

The reasons for this trend of reducing average and median NO_2 concentrations at roadside sites over the last 3 years despite the increase in vehicle travel[12] 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).

Figure 3: State highway sites and NO_2 concentration levels 2011-2019



Since monitoring began in 2007, high annual average NO_2 concentrations (≥40µg/m³) have been recorded at ten of the monitoring sites (please refer to the table in Appendix B).

The changes in NO_2 levels over time at the four monitoring sites that recorded high (≥40µg/m³) annual average NO_2 concentrations in 2016 have been investigated in more detail. These sites are discussed in the table below and the changes in NO_2 concentrations are illustrated in Figure 4.

The three state highway monitoring sites (in Auckland and Hamilton) which recorded high (≥ 40µg/m³) concentrations in 2016, continued to have high NO_2 concentrations values recorded for the subsequent three years (2017-2019). Concentrations at the local road monitoring site in Christchurch have reduced and are now considered medium.

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[9] Calculated from the monitoring sites which had at least one valid annual average recorded from 2016 to 2019.

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

[11] 2011 was chosen because this is when the first set of complete data is available for majority of sites.

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

Table 3: Locations recording high NO_2 annual average concentrations in 2016[13]

Site ID	Site name	Site type	Distance from Road	Discussion
AUC009 (a&b)	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 Waterview Tunnel which is in the vicinity of site AUC009, was opened[14] and this may have contributed to the decrease in average NO_2 concentrations recorded in 2018 and 2019.
CHR017-019	ECan Riccarton Rd	Local road	10 m	Located in the retail area of Riccarton Road (approximately 30 metres east of the Westfield Riccarton Mall) which is one of the city's busiest bus routes. The reduction in the NO_2 annual average concentrations recorded in 2019 may have been due to the roadworks that started in February 2019 and that recently completed (underground pipes were replaced and the road was resurfaced and reshaped)[15].
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 improvement of air quality in both locations due to the Waikato Expressway project which is being completed in stages and the Hamilton section is due to be completed in late 2021[16].
HAM013	Greenwood St/Killarney St	State highway	16 m	

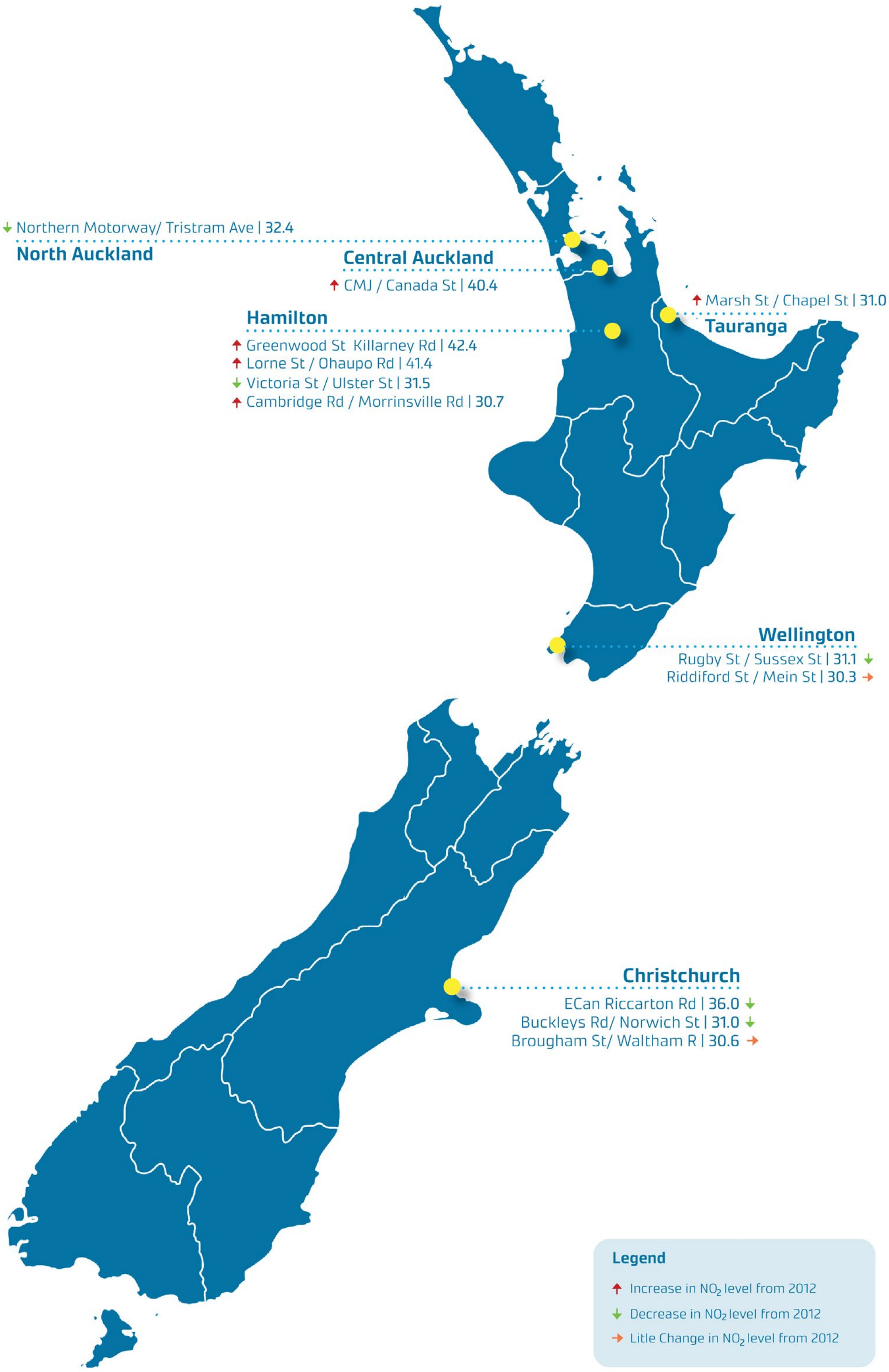
[13] NZTA (2017). Ambient air quality (nitrogen dioxide) monitoring network – Annual report 2007-16, NZ Transport Agency, November 2017.
[14] https://www.nzta.govt.nz/projects/the-western-ring-route/waterview-tunnel/, accessed June 2020.
[15] https://ccc.govt.nz/transport/transport-projects/riccarton-road-upgrade, accessed June 2020.
[16] https://www.nzta.govt.nz/projects/waikato-expressway/, accessed June 2020.

Figure 4: Locations which recorded high (≥40µg/m³) NO_2 annual average concentrations in 2016 and the concentrations in subsequent years

Figure 5 shows the locations that recorded high (≥40µg/m³) and medium (≥30-39.9µg/m³) annual average NO_2 concentrations in 2019 and indicates whether NO_2 concentrations are generally increasing or decreasing since 2012 (2012 was chosen for comparison because this is when the first set of complete data is available for all twelve sites).

Five out of the twelve sites show a reduction in NO_2 concentrations since 2012. Three sites have had little change in NO_2 concentrations since 2012 and four sites (three of which are in Hamilton) have had an increase in NO_2 concentrations since 2012.

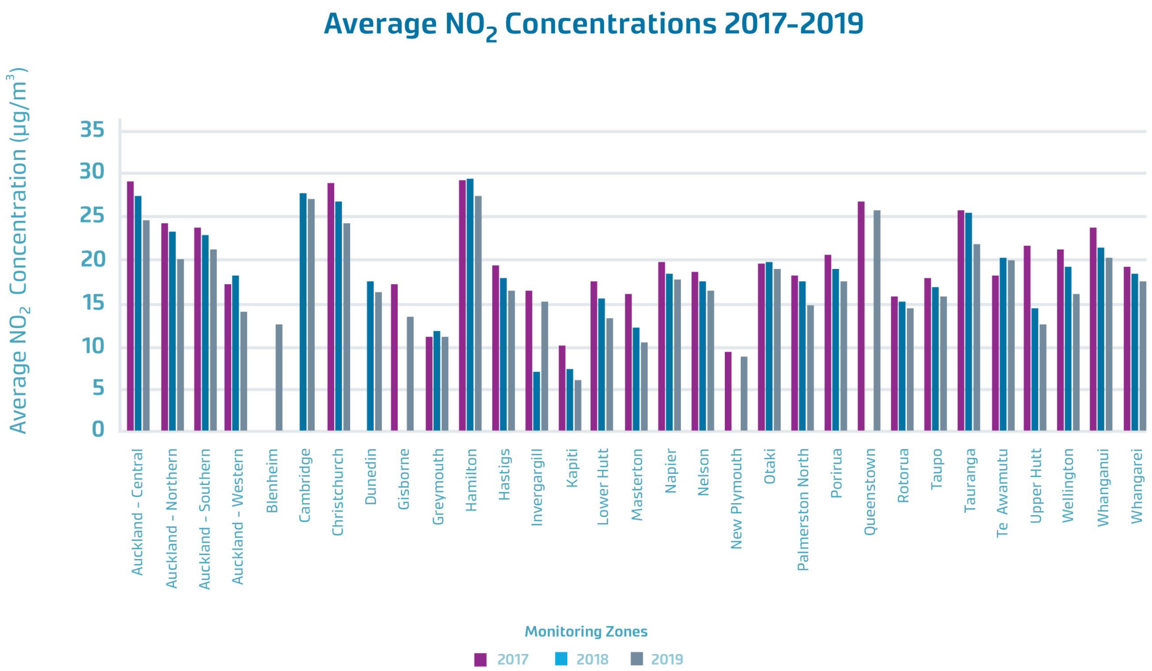
Figure 5: Locations of medium (≥ 30-39.9µg/m^3) and high (≥ 40µg/m^3) average NO_2 concentrations recorded in 2019 and change compared to 2012



How do the results differ across New Zealand?

As can be seen from Figure 6 below, the highest average NO_2 monitoring results in 2019 were recorded in the Cambridge, Hamilton and Queenstown monitoring zones[17]. The lowest average monitoring results in 2019 were recorded in Masterton, Greymouth, Kapiti and New Plymouth monitoring zones. 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[18].

Figure 6: Average NO_2 concentrations measured in NZ monitoring zones



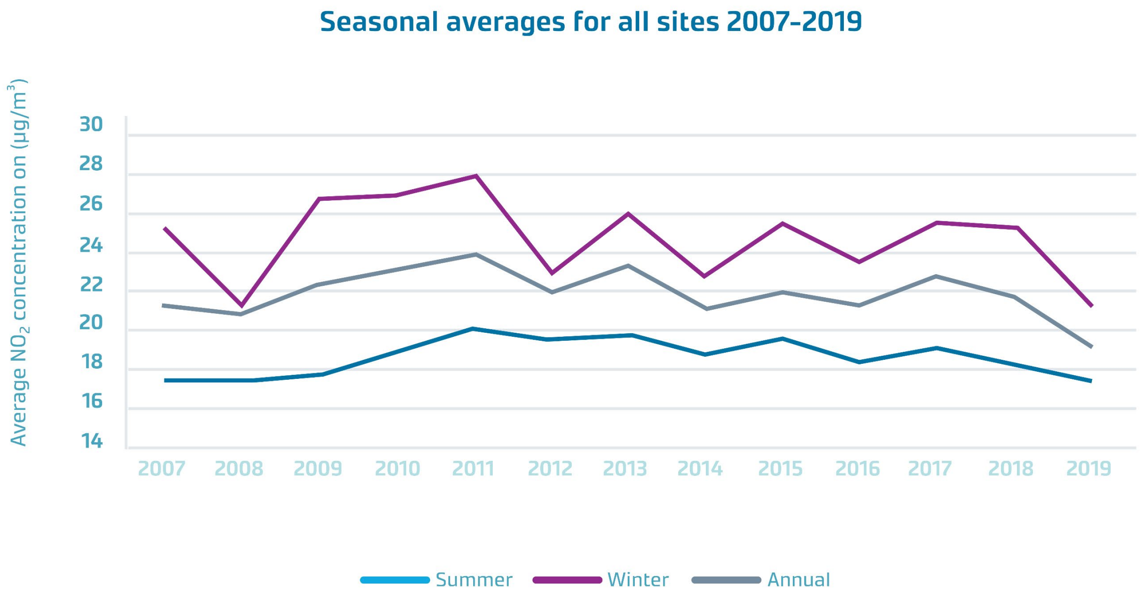
[17] This is based on data from all road types however the numbering of monitoring sites varies between zones, e.g. Queenstown only has one monitoring site, whereas Auckland Central has 18 monitoring sites.
[18] Complete data for the three years is unavailable for Blenheim, Cambridge, Gisborne, New Plymouth and Queenstown.

Are the NO_2 concentrations higher in summer or winter?

Figure 7 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 (please refer to Appendix C).

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: Varying NO_2 concentration levels during the seasons[19]



HOW DO WE KNOW THE DATA IS RELIABLE?

At a small number of the monitoring sites (seven in 2019), 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)[20]. 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 passive samplers' results is checked by comparing the monthly variation (coefficient of variation, CV) between the triplicate samples (presented graphically in Appendix A).

The CV is calculated according to:

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

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

[20] Emission Impossible Ltd (2020). National air quality (NO2) monitoring network: Correlations between passive and continuous results 2010 to 2019. Prepared for Waka Kotahi NZ Transport Agency.

The precision of the diffusion tubes is categorised as “good” or “poor” as follows[21]:

- 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 has been less than 8%[22]. For the triplicate sites in the network between 2016-2019, the overall average of all monthly CV's was calculated to be 6%. Only one poor site (overall average CV greater than 10%) was recorded between 2016-2019 for the Christchurch triplicate in 2016. The CV has been less than 20% for 97.3% of the triplicate samples during 2016-2019, indicating that the precision of the passive samplers is good.

ARE THERE ANY FUTURE CHANGES PROPOSED TO THE PROGRAMME?

Waka Kotahi has plans to include new monitoring sites and relocate 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[23].

Waka Kotahi has also begun conversations 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).

A non-linear correlation can be used to “adjust” the annual average NO_2 concentrations from passive sampling so they are closer to the results that would be obtained using a continuous (regulatory) monitoring technique. The correlation developed for the 2019 year (Emission Impossible Ltd, 2020) is as follows:

Equivalent reference NO_2 concentration ($\mu g/m^3$, annual average) = $-0.0279x^2 + 2.1556x - 3.5442$

Where:

x is the concentration of NO_2 measured using a passive sampler ($\mu g/m^3$, annual average)

If this relationship is applied to the results at the three state highway monitoring sites (in Auckland and Hamilton) which recorded high ($\geq 40 \mu g/m^3$) concentrations in 2019, then all of these sites would be expected to comply with the WHO ambient annual air quality guideline. In the future, the use of an adjustment factor will give Waka Kotahi greater confidence in identifying any areas in the national network where the annual average NO_2 air quality guideline value may be exceeded.

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[21] DEFRA (2016). Local air quality management, technical guidance LAQM TG(16). Published by Department for Environment, Food and Rural Affairs, April 2016.
[22] NZTA (2017). Ambient air quality (nitrogen dioxide) monitoring network – Annual report 2007-16, NZ Transport Agency, November 2017
[23] National Institute of Water & Atmospheric (NIWA) 2020 - Review of the National Air Quality Monitoring Network