NZ TRANSPORT AGENCY
WAKA KOTAHI

Trends in air quality impacts from roads in New Zealand 2007–16

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ABSTRACT

The NZ Transport Agency is a Crown entity responsible for managing almost 11,000 kilometres of state highways in New Zealand. The state highway system accounts for about 12% of New Zealand's roads and around half of the 43 billion vehicle kilometres New Zealanders travel each year.

The Transport Agency is required to comply with the Land Transport Management Act (LTMA) 2003 to

'contribute to an effective, efficient, safe, and safe land transport system in the public interest'

and with the Resource Management Act (RMA) 1991 which

'seeks to promote sustainable management of natural and physical resources including air ... requires avoiding, remedying or mitigating any adverse effects of activities on the environment'.

Emissions from the state highway network are assessed annually using passive sampling data gathered at selected sites with nitrogen dioxide (NO_2) taken as a general proxy for motor vehicle-related air pollution. The overall aim is to see a decreasing trend in NO_2 concentrations. This aligns with the NZ Government's national land transport objectives which seek to deliver

'a land transport system that increasingly mitigates the effects of land transport on the environment'.

This paper describes the key features of the network, compares the trends seen in the monitoring results with trends in the fleet activity, emission factors and climate since the network commenced monitoring in 2007 and indicates future plans for the programme.

KEYWORDS: vehicle emissions, ambient monitoring, passive sampling, nitrogen dioxide.

INTRODUCTION

EFFECTS AND SOURCES OF AIR POLLUTION IN NEW ZEALAND

New Zealand has relatively good air quality due to our low population density, close proximity to the sea, and remoteness from other continents and sources of pollution. However, there are some areas, mostly in our cities and towns, where air quality is degraded. Air pollution usually occurs when a high level of emissions (caused by high traffic numbers or homes being heated by open fires or older wood burners) combines with poor dispersion conditions (such as calms, temperature inversions, valleys or street canyons).

Air pollution impacts human health as well as reducing visibility and causing brown haze. Health effects can range from respiratory irritation, headaches and coughing through to more serious conditions. More than 256 people in New Zealand are estimated to die prematurely each year due to air pollution associated with motor vehicle emissions (Kuschel et al. 2012).

This pollution also results in 142 extra hospital admissions for respiratory and cardiac illnesses, and around 352,000 restricted activity days each year.

Home heating and motor vehicles are the main sources of pollution in New Zealand. The relative amounts and types of pollutants produced by motor vehicles vary according to the age of the vehicle, whether it is petrol- or diesel-powered, how well-maintained and tuned it is, and how hard the engine is working. In addition, the amount and type of pollutants vary with the way the vehicle is being driven, the level of congestion, and the geography of the road network.

NITROGEN DIOXIDE AS AN INDICATOR POLLUTANT

The impact of road transport on air quality in New Zealand varies locally. It may be that in many (or even most) locations the impacts of road transport on air quality are minor, but how are we to know? As the saying goes 'You cannot manage what you do not measure.'

Motor vehicles produce a complex mix of contaminants. It is not feasible to monitor all of these, so the NZ Transport Agency has identified one pollutant, nitrogen dioxide (NO_2) as a proxy for motor vehicle pollutants. This is consistent with the recommendation of the World Health Organization (WHO 2006) 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.'*

Nitrogen oxides incorporate several species that exist in the atmosphere, which collectively are referred to as NO_X and result principally from fossil fuel combustion, when nitrogen in the air that is used to burn the fuel gets oxidised. The most common NO_X compounds are nitrogen dioxide (NO_2) and nitric oxide (NO). NO is the primary product emitted directly but this is eventually oxidised by other pollutants present in ambient air to form NO_2. Motor vehicles have been identified as a major source of NO_X emissions in most main centres in New Zealand (MfE 2007).

RATIONALE FOR MONITORING

The NZ Transport Agency is a Crown entity responsible for managing almost 11,000 kilometres of state highways in New Zealand. The state highway system accounts for about 12% of New Zealand's roads and around half of the 43 billion vehicle kilometres New Zealanders travel each year (MoT 2016). The Transport Agency is required to comply with the Land Transport Management Act (LTMA) 2003 to

> *'contribute to an effective, efficient, safe, and safe land transport system in the public interest'*

and with the Resource Management Act (RMA) 1991 which

> *'seeks to promote sustainable management of natural and physical resources including air ... requires avoiding, remedying or mitigating any adverse effects of activities on the environment'*

The Transport Agency is committed to protecting and enhancing the natural, cultural and built environment in its Environmental and Social Policy (NZTA 2013a). This policy is given effect to through the NZ Transport Agency's Environmental Plan (NZTA 2008), Environmental and Social Responsibility Standard (NZTA 2016) and associated guidelines and specifications.

The Environmental Plan was last updated in 2008 and provides direction and approaches to address a range of environmental and social impacts arising from the state highway network, including air quality. The Transport Agency intends to develop a new Plan during 2017/18 which will apply to the overall New Zealand transport system not just the state highway network. The direction and objectives relating to air quality in the current Environmental Plan 2008 will be reviewed and updated as appropriate, including consideration of relevant current Government policy and direction relating to transport-related air pollution and/or vehicle emissions. This includes the Government Policy Statement on Land Transport Funding (MoT 2017) which contains the objective:

> *'A land transport system that increasingly mitigates the effects of land transport on the environment'*

Of relevance to the transport-related air quality trends discussed in this paper is the following performance indicator in the Environmental Plan 2008:

> *'annual assessment of vehicle emissions from the state highway network gathered from selected sites using diffusion tubes to measure nitrogen dioxide (NO_2) as a surrogate measure. The objective is to monitor a decreasing trend in emissions of NO_2.'*

OBJECTIVES OF THE NATIONAL MONITORING NETWORK

The primary objectives of the Transport Agency's national air quality monitoring network are to:

1. Report against the air quality performance indicator in the Environmental Plan 2008.
2. Identify where there may be an air quality problem on the state highway network.
3. Indicate trends and seasonal variations.

The results of the national network are also used by the NZ Ministry of Transport as a national Transport Indicator relating to public health (PH001) (MoT 2013).

FEATURES OF THE NATIONAL NETWORK

This section outlines the sampling method, sites and analysis techniques used in the national network. Full details are available in the *Ambient air quality (nitrogen dioxide) monitoring programme – operating manual* 2013/14 (NZTA 2013b).

MONITORING METHOD

Ambient NO_2 concentrations can be measured by continuous analysers or passive samplers. Continuous analysers measure instantaneous concentrations and are the regulatory method for assessing compliance against national environmental standards and guidelines (based on 1-hour and 24-hour averages). Passive sampling is only able to measure longer term averages (such as monthly) and is less accurate than continuous monitoring but it provides a means for assessment of NO_2 at many sites. Passive monitoring is not meant to replace continuous monitoring. It is screening monitoring technique which provides a snapshot using a well-established and well-understood method that is relatively cheap and effective.

The passive samplers used in the national network are NO_2 passive diffusion tubes (shown in figure 1). The samplers are acrylic or polytetrafluoroethylene tubes approximately 7cm long with an internal diameter of 1cm and machined ends to attach tight fitting caps. Two stainless steel mesh discs coated with triethanolamine (TEA), which absorbs NO_2, are located at the closed end of the tube and held in position by an opaque coloured cap. The coloured end cap helps to prevent the degradation of the NO_2 absorbed TEA complex by sunlight. The open end of the tube has a clear or white removable cap which is used as a lid to seal the diffusion sampler before and after exposure.

FIGURE 1: PASSIVE SAMPLERS USED IN THE NATIONAL NO_2 MONITORING NETWORK (NZTA 2017a)

a. close up of a passive diffusion tube used in the monitoring

b. a passive diffusion tube deployed at the central motorway junction, Auckland

Passive diffusion tubes collect NO_2 by molecular diffusion. The diffusion flow rate of NO_2 through the tube is described by Fick's first law of diffusion. At the end of the sampling period, the resulting concentration of NO_2 is a function of the amount of NO_2 absorbed by the tube, the diffusion coefficient for NO_2 in air and the length of time the tube has been exposed (typically one month).

The tubes used in the national network are supplied and analysed by the Scientific Services Laboratory of Staffordshire County Council in Stafford, United Kingdom. Monitoring of NO_2 concentrations using passive diffusion tubes is widely used throughout the United Kingdom by various local authorities as a means of assessing NO_2 levels from traffic (DEFRA 2016).

MONITORING SITES

The network is comprised of 30 monitoring zones. These include each main urban area in New Zealand, as defined by Statistics New Zealand (Stats NZ 2013), as well as 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.

In 2007 and 2008, 53 locations were monitored throughout New Zealand. The Transport Agency expanded the network in 2009 to include background and local road locations and then undertook a further significant expansion in 2010 to improve coverage. In 2016, the national network monitored NO_2 concentrations in 129 locations as shown in figure 2.

Monitoring sites in the national NO_2 monitoring network are classified as:

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

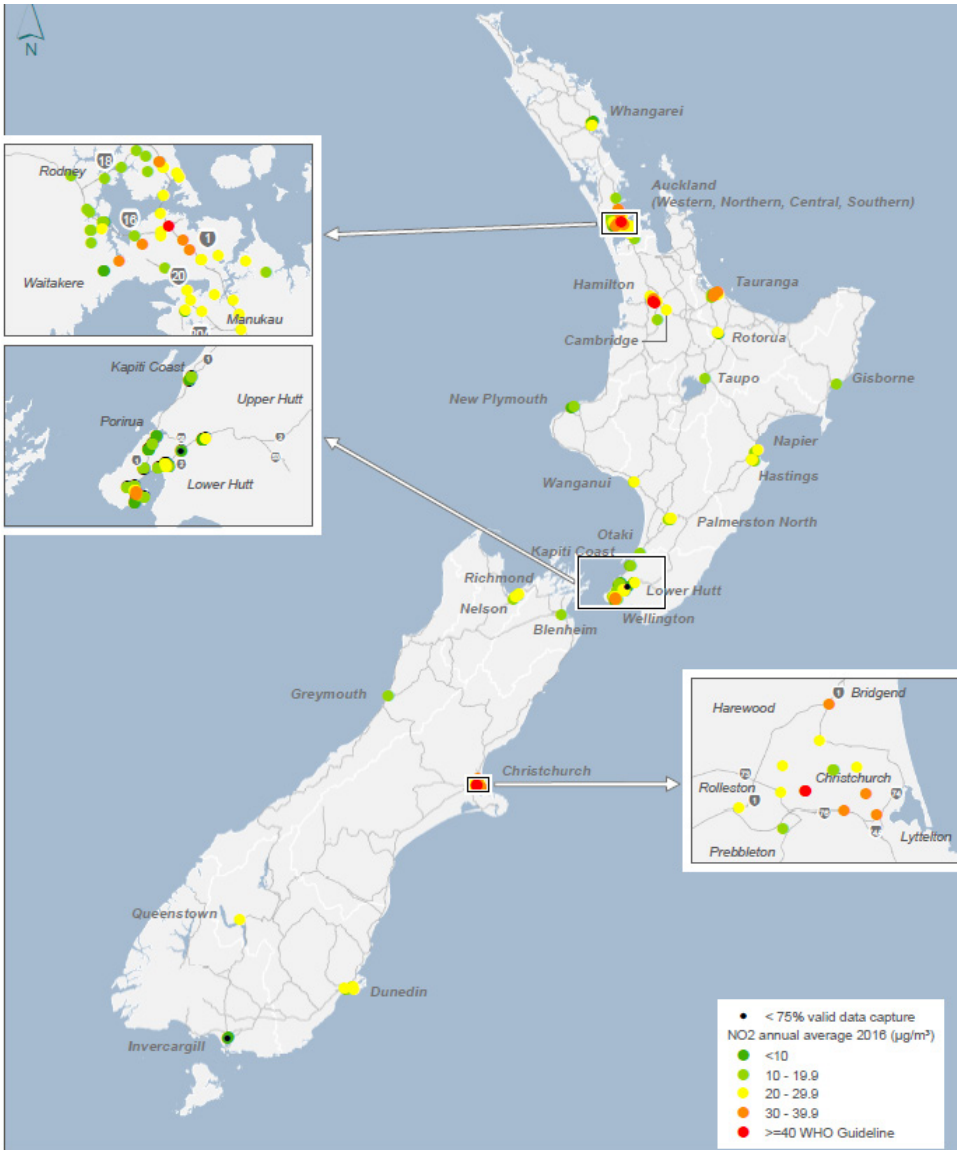
The actual locations within each zone are selected based on several other considerations, as follows:

- Sites are generally within 50 metres of either a school or residential areas to represent exposure of populations that are sensitive to adverse air pollution effects resulting from vehicle emissions.
- State highway sites are located on sections of the state highway network with the highest traffic flows in the region (typically where the annual average daily traffic (AADT) count is greater than 20,000 vehicles per day) and sections of the state highway network with congestion (based on 'level of service' indicators). These are intended to represent locations where elevated concentrations are most likely to occur.

Several monitoring sites have triplicate passive samplers, which are co-located with regional council continuous monitors to assess the precision and accuracy of results.

Full information on all sites in the national NO_2 network is available in a separate site metadata report (NZTA 2013c).

FIGURE 2: MAP OF THE NATIONAL NO_2 MONITORING NETWORK IN 2016 AND ASSOCIATED ANNUAL AVERAGES (NZTA 2017a).



ANALYSIS OF RESULTS

New Zealand has 1-hour and 24-hour values for ambient NO_2 concentrations set in the National Environmental Standards (NES) and the Ambient Air Quality Guidelines (AAQG) respectively (MfE 2011; MfE 2002). For NO_2, the NES is 200µg/m^3 (1-hour average). There is also an AAQG for NO_2 of 100µg/m^3 as a 24-hour average. There are no health-based New Zealand guidelines associated with exposure to NO_2 for periods of time longer than 24 hours. However, WHO has an annual average guideline for NO_2 of 40µg/m^3 (WHO 2006).

The passive monitoring undertaken measures monthly average NO_2 concentrations but these are not directly comparable to short-term standards and guidelines. However, a 2008 review of regional council monitoring results suggests that any site which exceeds the annual average WHO guideline is also likely to exceed the NES for NO_2 (NIWA 2008). 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.

WHO highlights that health effects may occur at levels below the annual average guideline, and recommends that a lower value should be used if NO_2 is monitored as an indicator of overall pollution levels. Since the publication of the latest WHO guideline in 2006, new studies have emerged showing stronger associations with both short-term and long-term exposure to NO_2. A meeting of WHO experts in late 2015 identified reviewing the long-term exposure guideline for NO_2 as a top priority in the upcoming update of the global air quality guidelines (WHO 2015).

Because the national network measures NO_2 as a marker for the concentrations and risks of the complex combustion-generated pollution mixtures, it may be appropriate to consider a lower annual guideline. Consequently, both 'high' and 'medium' sites are identified annually from the passive monitoring results, according to the NZ Transport Agency criteria shown in table 1.

TABLE 1: NZ TRANSPORT AGENCY ASSESSMENT CRITERIA FOR ANNUAL AVERAGE NO_2 PASSIVE MONITORING RESULTS (NZTA 2017a)

Containment	Annual average concentration	Descriptor	Notes
Nitrogen dioxide	≥40µg/m^3	High	Identifies locations where the WHO annual NO_2 guideline is likely to be exceeded and air quality effects of motor vehicles need to be reduced.
	≥30µg/m^3	Medium	Identifies locations where air quality is degraded as a result of motor vehicle emissions and may cause adverse effects.

DATA ANALYSIS

The passive diffusion tubes measure total NO_2 accumulated for a period of one month. Annual averages are calculated and presented in maps and summary tables *for only those sites with:*

- a minimum of 75% valid data (ie at least nine months out of 12 of results), and
- at least one valid monthly average for winter (ie a valid average for July, August or September) and summer (ie a valid average for January, February or March).

Triplicate passive samplers are co-located with regional council continuous NO_2 monitors at several monitoring sites. Annual average results for these sites are calculated if each of the triplicate sites meet the conditions stated above and:

- if all three individual triplicate results have at least at least 75% valid data; then average all three results; or
- if only two of three individual triplicate results have at least 75% valid data, then average the two results only.

Similarly, a seasonal average is calculated if there are at least two valid monthly averages for summer and winter (ie at least 66% valid data for the season). For triplicates, a seasonal average is calculated if two of the three triplicate results have at least two valid monthly averages for summer and winter.

The NZ Transport Agency national passive monitoring network has been setup and is operated in general accordance with the UK's *Local air quality management technical guidance* (DEFRA 2016), which includes requirements for quality assurance and quality control.

The results from co-located triplicate passive samplers are used to check the precision (or repeatability) of the results. The tubes are all located next to each other and as close as possible to the sample inlet of the continuous NO_2 analyser. To check the precision of the passive monitoring results the coefficient of variation (CV), also known as the relative standard deviation, is calculated for the triplicate samples each month. The higher the CV value the greater the spread between the triplicate samples. The annual average concentrations measured at these sites are compared to continuous monitors to provide an indication of the accuracy of passive tubes.

The coefficient of variation (CV) is calculated for the triplicate diffusion tubes each month for quality assurance according to:

$$CV = SD/mean*100$$

where SD and mean are the standard deviation and average, respectively, of the triplicate results.

Diffusion tubes are considered to have 'good' precision where the CV of duplicates or triplicates based on eight or more individual periods during the year is less than 20%, and the overall average CV of all monitoring periods is less than 10% (DEFRA 2016). Diffusion tubes are considered to have 'poor' precision where the CV of four or more individual periods is greater than 20% and/or the 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 since 2007, the average CV has been less than 8% on average. The CV has been less than 20% for just under 95% of the triplicate samples, indicating that the precision of the passive samplers is good.

RESULTS FOR 2007 TO 2016

This section summarises the key results from 2007 to 2016. It provides examples of the typical results that are reported in detail each year in the annual report (NZTA 2017a).

ANNUAL AVERAGES ACROSS THE NATIONAL NETWORK BY YEAR

The annual averages recorded across the national network are mapped each year for comparison with previous years. As seen in figure 2, which is for 2016, results are colour-coded from green through to red depending on set concentration bands.

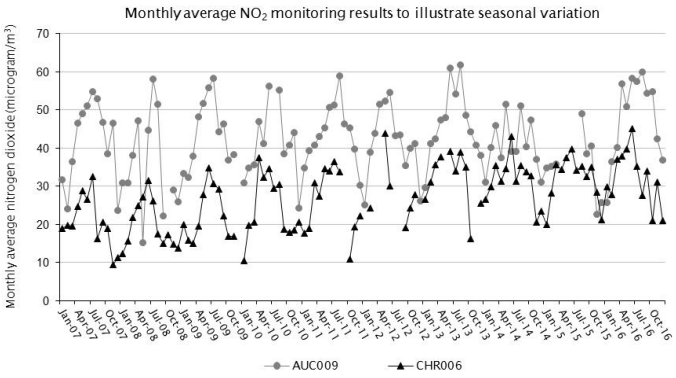
Colour-coding enables the easy identification of hot spots or potential hot spots in the network.

MONITORING ZONE RESULTS

Results for the 30 monitoring zones are presented as maximum, minimum and average graphs as shown in figure 3. Results for each site category (ie state highway, local road and background) are shown for each zone and indicate the year by year trends since monitoring began in 2007.

Although the number of samplers as well as the distances of each sampler from the roads varies per monitoring zone, these results provide a useful snapshot of the variation in NO_2 concentrations across the country. The results indicate that the monitoring zones with the highest maximum NO_2 concentrations are Auckland Central, Christchurch and Hamilton.

FIGURE 3: MAXIMUM, MINIMUM AND AVERAGE NO_2 ANNUAL VALUES IN THE AUCKLAND – CENTRAL MONITORING ZONE SINCE 2007 (NZTA 2017a).



IDENTIFICATION OF 'HIGH' SITES

Locations which record high (≥40µg/m³) and medium (30-39.9µg/m³) annual average NO_2 concentrations are summarised annually. Note: triplicate sites are reported with the average of at least two annual values (assuming that at least two of three samplers have a minimum of 75% valid data).

Since 2007, eight national network sites have recorded 'high' annual average NO_2 concentrations, as shown in table 2. All of these sites have consistently recorded high or medium readings since they were commissioned. In these locations, the air quality may be exceeding the WHO annual NO_2 guideline and therefore the effects of vehicle emissions need to be reduced.

TABLE 2: SUMMARY OF THE ANNUAL AVERAGES RECORDED AT ALL 'HIGH' SITES SINCE 2007 (NZTA 2017a).
AUC=AUCKLAND, CHR=CHRISTCHURCH, HAM=HAMILTON, AND WEL=WELLINGTON

Site ID	Site name	Annual average (µg/m3)									
		2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
AUC009	CMJ/ Canada St	47.9	<75% data	41.0	46.5	41.3	43.9	40.8	44.0	35.8	41.9
CHR017 CHR018 CHR019	ECan Riccarton Rd (triplicate site)	40.8*	39.7*	36.1*	41.6*	41.4*	<75% data	<75% data	NC	NC	NC
HAM003	Lorne St / Ohaupo Rd	40.5	41.4	38.7	38.4	37.5	40.4	39.0	40.0	38.3	36.1
HAM013	Greenwood St / Killarney Rd	40.4	42.2	39.9	41.4	36.8	40.1	<75% data	NC	NC	NC
WEL049	Riddiford St / Mein St	37.0	39.6	36.9	38.8	31.0	39.0	40.3	NC	NC	NC
AUC060	New North Rd / Mt Albert Rd	36.7	38.9	34.9	38.8	37.6	40.3	39.9	<75% data	NC	NC
AUC063	Great North Rd / Rata St	33.7	35.8	34.6	37.4	36.8	40.8	38.3	<75% data	NC	NC
AUC068	George Bolt Dr / Kirkbride Rd	DC	<75% data	40.9	46.0	41.5	44.7	43.3	<75% data	NC	NC

Note: In the above table, the high values are shaded to distinguish them from the medium values. An * is used to indicate that the value shown is an average of the results for the ECan Riccarton Road triplicate site. The start and end dates vary for all sites – these are indicated with NC (not commissioned) or DC (decommissioned).

Each year, the 'high' sites are discussed in the annual report, covering:

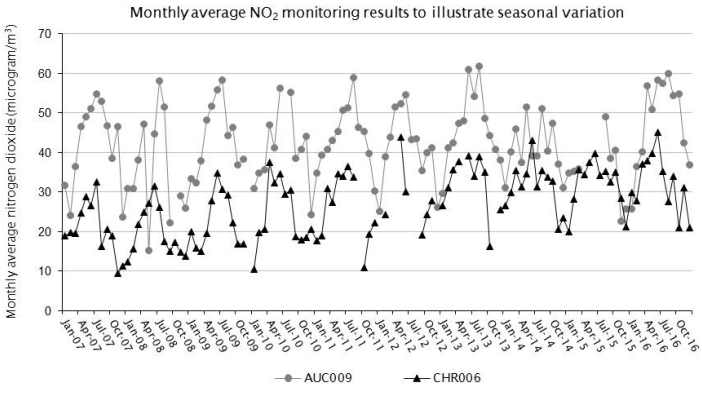
- a brief description of the site
- a summary of the annual averages since monitoring commenced
- an estimate of the likely traffic volumes and composition (ie heavy vehicles) impacting the site
- a list of any NZ Transport Agency or local transport authority projects in the planning or underway to improve vehicle-related air pollution in the vicinity.

SEASONAL VARIATIONS

NO_2 concentrations vary seasonally, with higher concentrations being observed during winter. Previous urban airshed modelling undertaken in Auckland suggests that regional NO_2 levels are ozone-limited (Gimson 2005) and background ozone levels across New Zealand are higher in winter than in summer (MfE 2004). Therefore, elevated winter NO_2 concentrations are likely to be a result of poor dispersion conditions and higher background ozone in winter, rather than an increase in NOx emissions due to domestic fires (which are generally low emitters of NO_2 relative to motor vehicles).

Figure 4 shows the seasonal variation for two typical passive monitoring sites – AUC009 in the Auckland CBD and CHR006 in a suburb of Christchurch.

FIGURE 4: SEASONAL VARIATION IN MONTHLY AVERAGE NO_2 CONCENTRATIONS FOR TWO SITES TYPICAL OF THE NATIONAL NETWORK (NZTA 2017a)



Seasonal averages for winter (July, August and September) and summer (January, February and March) are reported each year. Ratios are also calculated for all sites with valid summer and winter averages (ie with data for at least two out the three months for each season).

In the first five years of the network operation (2007 to 2011), the ratio averaged at around 1.45, indicating that NO_2 concentrations in winter were almost one and a half times the summer concentrations. However, in the most recent five years (2012 to 2016), the average ratio has dropped to 1.30 indicating that the difference between the summer and winter averages has become less pronounced. This may be due to changes in ozone levels (which impact NO_2 concentrations), increases in average temperatures across New Zealand or other factors. Insufficient monitoring data for ozone exist to confirm whether ozone levels have changed. Annual averages for 2007 to 2011 from NIWA's 'Seven-Station' temperature series were 0.13°C higher than the 1981-2010 average but 0.34°C higher for 2012 to 2016 (NIWA 2017a).

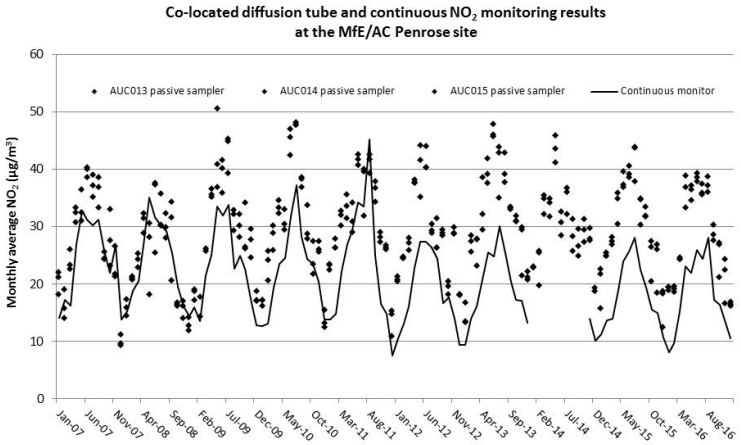
PASSIVE VERSUS CONTINUOUS METHODS

The results from passive samplers are not directly comparable with those of continuous monitors because the measurement techniques are different.

The first site in the national network to have NO_2 passive diffusion tubes (in triplicate) co-located with a continuous NO_2 monitor was the Auckland Council (AC) site at Penrose in Auckland (AUC013-015). This site was first established in 2007. Five more co-located sites were added in 2009, with a further expansion in 2010. Seven monitoring sites in the network were co-located with regional council continuous NO_2 monitors in 2016.

The results for Penrose are illustrated in more detail in figure 5, which shows that the passive samplers generally follow the trends for the continuous monitor but do not match exactly, especially at higher NO_2 concentrations.

FIGURE 5: COMPARISON OF PASSIVE MONITORING (TRIPLICATE RESULTS) AND CONTINUOUS MONITORING RESULTS AT PENROSE IN AUCKLAND (NZTA 2017a)



These results show that the passive monitoring results are typically higher than the corresponding continuous data (on average 33% higher). This contrasts with a comparison undertaken by Auckland Council, which found that passive monitoring results were usually lower than the corresponding continuous data (on average 17% lower at Penrose) (ARC 2007).

In the UK, a series of adjustment factors are applied to passive monitoring results to make them directly comparable with the results gained from continuous monitoring methods. Following a nationwide survey of NO_2 diffusion tube co-location studies, the Department for Environment, Food and Rural Affairs (DEFRA) has developed a set of tools to better address local bias and diffusion tube chemistry (DEFRA 2016). Their results suggest that passive tubes close to the road are more likely to underestimate concentrations, once they have been adjusted for laboratory bias, and conversely tubes further away from roads are more likely to overestimate concentrations. It is important to note that their analysis suggests that it is not the distance from the road that matters, but the different concentrations of nitric oxide, nitrogen dioxide and ozone that this reflects.

However, the results to date suggest that the relationship between passive and continuous monitoring results is not consistent. Consequently, adjustment factors are not currently applied to the national network results.

ANNUAL TRENDS FROM 2007 TO 2016

The wealth of information now available enables more detailed analysis of annual trends to be undertaken. Preliminary analysis of the 10-year dataset now available is discussed below.

The percentage change in measured annual averages between 2007 and 2016 was calculated for the 34 sites that have been operating since 2007 and have at least 75% valid data for 2007, 2011, 2012 and 2016.

The annual NO_2 concentrations for these sites are higher by an average of 14% in 2016 than in 2007. Whilst results vary spatially, the majority of the sites (26/34) show at least some increase in measured NO_2, with 12 sites recording increases of 20% or more.

However, the trends in the first five years of monitoring data (2007 to 2011) appear to be quite different to trends in the last five years (2012 to 2016). Annual average concentrations were 23% higher on average in 2011 than in 2007, with 30 sites showing increases of more than 20%. In contrast, annual average concentrations in 2016 showed no change (0%) relative to 2012, with only one site showing an increase of more than 20%.

The concentrations measured by the national NO_2 network reflect not only the activity and emissions of the fleet but also climate variability.

Since the national network commenced monitoring NO_2:

- average temperatures have increased across New Zealand. 2016 was 0.83°C warmer than the 1981-2010 average from NIWA's 'Seven-Station' temperature series (and was the warmest year ever recorded) versus 2007 which was only 0.06°C warmer (NIWA 2017a)
- New Zealand's climate has swung between El Niño and La Niña five times since 2007. These events can be significant but account for less than 25% of the year-to year variance in seasonal rainfall and temperature at most locations (NIWA 2017b)
- national fleet travel, measured as vehicle kilometres travelled (VKT), has increased by 5.6% from 2007 to 2015 (MoT 2016)
- per vehicle NO_2 and NO_x emissions, predicted from the NZ Vehicle Emission Prediction Model (VEPM), have in theory improved by 13% and 38% respectively (NZTA 2017b).

A preliminary analysis of nationally-averaged data shows no statistically significant correlation between the trends seen in the annual average NO_2 concentrations and potential climate and activity parameters, with the exception of predicted NO_2 and NO_X emissions. Total national emissions of NO_2 and NO_x can be estimated from the actual VKT and the predicted per vehicle emissions factors from VEPM.

Interestingly, the correlations whilst strong (R^2=0.77 in the case of NO_2 emissions) are also negative. In theory, this result means that concentrations have increased in the face of apparent reductions in emissions. In reality, this result more likely suggests that the NO_2 emission factors currently being used in VEPM are not adequately capturing real world emissions. This has been identified world-wide as a limitation of most emissions models, particularly in the UK (Carslaw et al. 2011).

Working backwards from the actual concentrations and actual VKT, NO2 emission factors in VEPM would have to be approximately 20-30% higher than currently predicted for emissions to directly match the concentrations being measured in the national network.

Given that NO_2 concentrations are highly dependent on local conditions, more detailed analyses of individual sites needs to be undertaken to confirm the presence and extent of this under-estimation. A study is currently (2017) underway, utilising a portable emissions monitoring system (PEMS) to confirm real-world emissions from typical New Zealand fleet. Once the study is complete, the PEMS results together with the national network measurements and remote sensing data will form an invaluable dataset to better understand (and better manage the air quality impact of) New Zealand's vehicle fleet emissions.

CONCLUSIONS

KEY FINDINGS

Since 2007, eight national network sites have exceeded the WHO annual average NO_2 guideline of 40µg/m³. These sites are located near both busy local roads and state highways in Auckland, Hamilton, Wellington, and Christchurch.

NO_2 concentrations vary seasonally. In earlier years, the winter to summer ratio averaged at 1.45. However, more recently, the ratio has dropped to 1.30 indicating that the difference between the summer and winter averages has become less pronounced. This may be due to changes in ozone levels (which impact NO_2 concentrations), increases in average temperatures across New Zealand or other factors.

The passive monitoring results from the network are typically higher than the corresponding continuous data. However, the relationship between the monitoring data has not been consistent to date so results are not adjusted when reported.

For the sites with complete data records, annual average NO_2 concentrations in 2016 have increased by 14% on average versus 2007 but have actually been static on average between 2012 and 2016. A preliminary analysis shows no statistically significant correlation between the trends seen in the annual average NO_2 concentrations and potential climate and activity parameters, with the exception of predicted NO_2 and NO_X emissions. Interestingly, the correlations whilst strong are also negative. This suggests that the emission factors currently being used in VEPM are under-predicting and should be up to 30% higher to adequately capture real world emissions. However, further analysis is required to confirm this.

WHERE TO FROM HERE

In recent years, the development of the passive sampling network has been largely in increasing the quantity of sites to improve the coverage and representativeness of the results. The wealth of data now available provides an opportunity for any future development to now focus on enhancing the value of the results, by using the information to better understand how the Transport Agency can contribute to a reduction in adverse air quality effects from land transport and specifically by:

- undertaking air quality investigations for any national network monitoring sites where the annual average NO_2 concentration measured by passive samplers exceeds 40µg/m³
- enhancing the availability of complimentary datasets to support data analysis including; traffic volume, speed, and percentage of heavy vehicles in close proximity to key national NO_2 monitoring network sites
- investigating the relationship between continuous and passive NO_2 monitoring results and evaluate the suitability of statistical tools for developing appropriate correlation factors and establishing uncertainties
- investigating the relationship between continuous and passive NO_2 monitoring results and other air pollutants measured at co-located sites to provide an indication of whether NO_2 concentrations and trends are providing a good proxy for overall vehicle pollution
- utilising the national network data, together with data collected from PEMS and remote sensing studies in New Zealand to better understand and predict the impact of vehicle emissions.

Annual data are uploaded annually into the Transport Related Air Quality Monitoring System (TRAMS) database, after receiving the last analysis report for December of the previous year. Annual and seasonal averages, together with links to the site metadata files as PDFs, can be viewed and accessed via the Monitoring section for Air quality and climate in the Highways Information Portal website (https://www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/air-quality-climate/monitoring/).

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