NIWA
Taihoro Nukurangi

Nitrogen Dioxide concentrations data

Categorisation and standardisation

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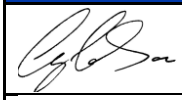
Quality Assurance Statement		
	Reviewed by:	Guy Coulson
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Contents

1 Introduction

1.1 Context

Ministry for the Environment, in partnership with Statistics New Zealand, is legislatively mandated to produce regular reports on the state of the environment, including air quality. Data on nitrogen dioxide concentrations were previously used in Environment Aotearoa 2015 and provided the basis for a key measure for the air domain story. Previous scoping work has identified additional data on nitrogen dioxide that would provide important additional information on state and pressures for New Zealand's air. This dataset will greatly expand the number of sampling sites that can be analysed and allow reporting of NO_2 concentrations in many more cities and towns.

1.2 Purpose and scope of this report

This report supports the provision of NO_2 concentrations data. It describes the methods used to obtain these data in sufficient detail for Stats NZ to complete a quality assurance process. In particular this report describes how measurement sites have been classified in terms of their representativeness, and how a 'roadside adjustment' has been applied at some sites to try to reduce bias introduced by the variation in distances of different measurement sites from major roads. This report also describes limitations associated with the data.

The data itself is provided in an accompanying spreadsheet.

2 Methods

2.1 Origin and description of raw data

The NO_2 data provided to MfE for air domain reporting originates entirely from the National Monitoring Network maintained by the NZ Transport Agency (NZTA).

NZTA network data is suitable for national environmental reporting because:

- It is a long-term continuous dataset and likely to persist into the foreseeable future
- It is reasonably accurate (see summary of data quality assurance in Appendix 2)
- It has high internal comparability
- It has fairly good geographical coverage
- Extensive documentation describing the network, site metadata and processes and procedures for its management are available from NZTA (see https://www.nzta.govt.nz/resources/air-quality-monitoring/).

For this work the data was supplied directly to us by NZTA in a single spreadsheet including site metadata. Data was available from January 2010 until December 2016 inclusive. Data for 2017 is not yet available.

All raw data consists of a single concentration per month per site. All samples are analysed at the same laboratory in the UK (Staffordshire County Council Scientific Services).

For environmental reporting annual average concentrations are used. This is primarily because NO_2 concentrations at most sites typically vary with season, plus additional variation between months can be introduced by anomalous meteorological conditions. Using annual average concentrations reduces the impact of both random and systematic meteorological variation, allowing data from different locations to be compared with minimal meteorological bias. Annual averages were already applied in the data provided to us by NZTA according to rules specified by NZTA (see NZTA (2016) section 3.3.3, which is also reproduced in the Appendix).

The NZTA network has been capturing monthly data continuously since 2007, beginning with 48 sites around the country. The network was periodically enlarged peaking at 148 sites from May 2010 (Figure 2-1). Sites are occasionally discontinued or (more likely) re-located, often due to local changes to the road network. Some consolidation has occurred since late 2012 so that by December 2016 the network consisted of 132 sites covering all towns and cities with populations larger than 45,000 (~68 % of the national population).

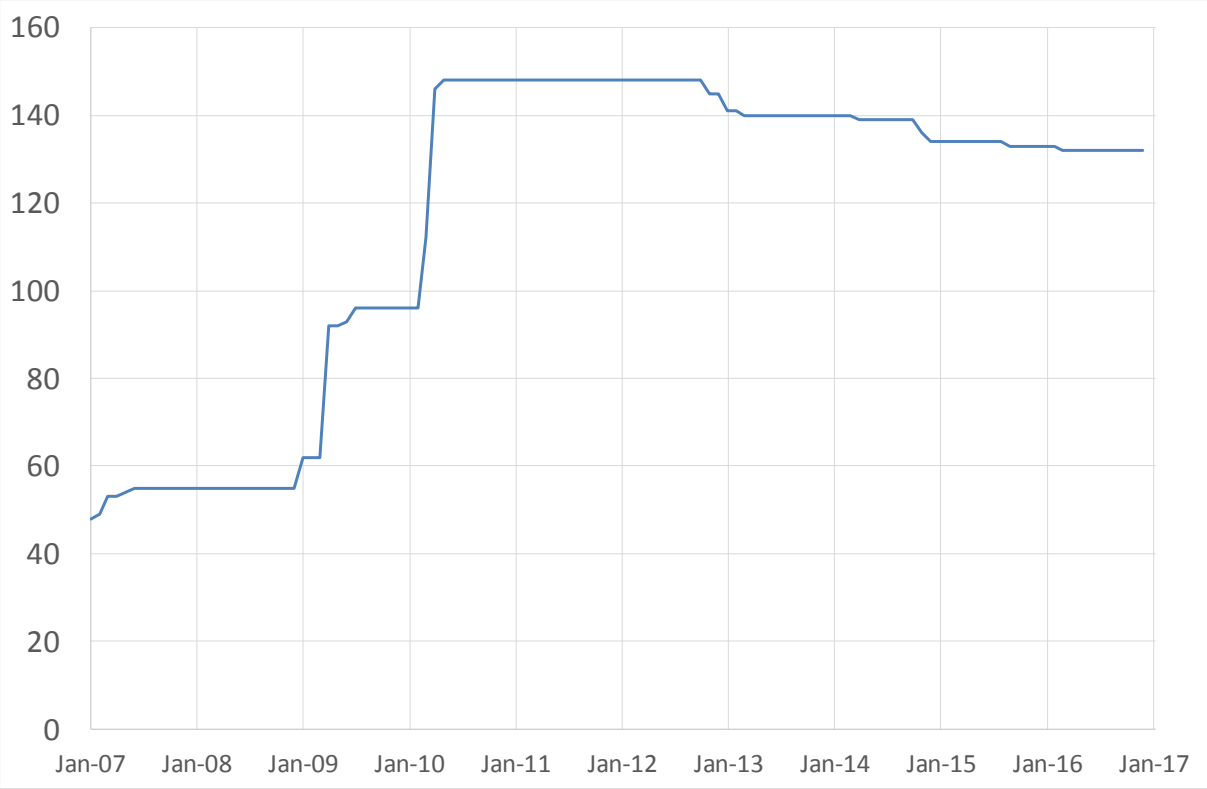

Figure 2-1: Number of sites in the NZTA NO_2 Monitoring Network.

2.2 Site categorisation

2.2.1 Purpose of the categorisation system

Sites in the NZTA network have been categorised with respect to their representativeness, as required by MfE. A wealth of research, including ongoing work at NIWA, has shown that monthly-average measurements of NO_2 in the air are broadly representative of an urban area, except where they are influenced by highly local (< 150 m) factors. The most common local factor is a major road. Other influences include features that tend to increase emissions (intersections, persistent traffic congestion or unusually high concentrations of diesel vehicles) or reduce dispersion (street canyons, awnings). This leads us to propose a site categorisation system based on three main categories:

- Urban Background sites. Generally representative of all residential locations across an urban area that are not subject to any localised sources or atypical influences.
- Roadside sites. Intended to be representative of a wide range of roadside sites within an urban area, with the caveat that such sites will span a wide range of concentrations due to variation in traffic volumes and different distances from the road.
- Peak sites – any location where concentrations are likely to be as high or higher than urban background and roadside sites whilst also being representative of a range of similar sites within an urban area – in practice busy central streets with taller than average buildings (street canyons), or major road intersections.

It should be noted that the 'urban background' and the 'roadside' form a continuum and that any boundary between them is essentially arbitrary. Nevertheless, as a first approximation, NO_2 concentrations only become substantially elevated within 150 m of a road, as illustrated in Figure 2-2.

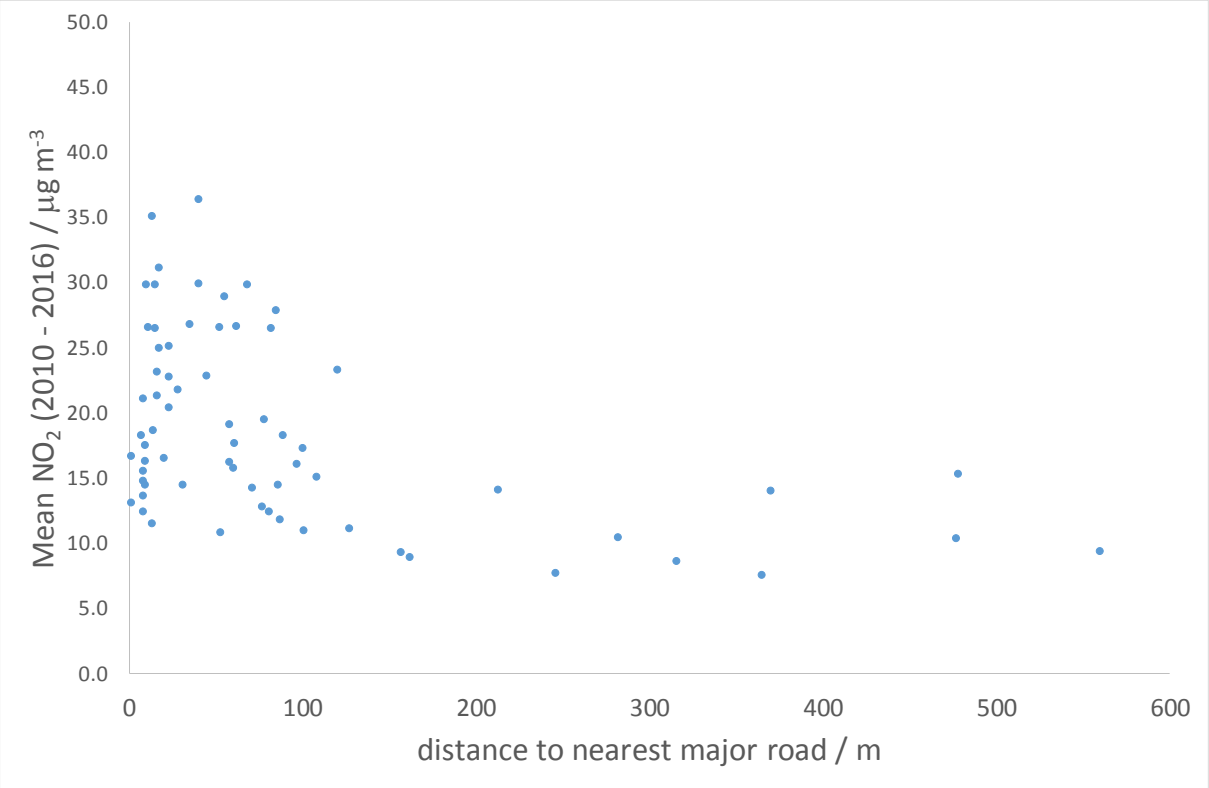

Figure 2-2: General relationship between long-term average NO_2 and distance of site from major road for all non-peak sites.

2.2.2 Method for the categorisation system

Categorisation is based upon rules derived from research evidence. The results of the categorisation, and associated site data, are presented in the spreadsheet that accompanies this report. The key to the method is to identify the nearest major road to each site, to obtain a recent estimate of its Annual Average Daily Traffic volume (AADT). Although the distance of each site to that road kerb is provided in the metadata available from NZTA we have found there to be some errors, plus we have found that distance to the centreline is a more pertinent parameter. Therefore we have independently determined the shortest distance from the measurement site to the road centreline using ArcMap and satellite imagery.

At this point consistent AADT data is not available for the whole country. We have used the following data:

- For sites alongside State Highways we have used the 2016 traffic volumes from the nearest available traffic count site (data accessed from https://www.nzta.govt.nz/resources/state-highway-traffic-volumes/)
- For other roads in Auckland and Christchurch we have used the most recent traffic counts from the nearest traffic count site from the respective TLA websites :
  - https://at.govt.nz/about-us/reports-publications/traffic-counts/
  - https://www.ccc.govt.nz/transport/transport-projects/traffic-count-data/

- For other roads in Hamilton and Greater Wellington we have used data from the respective regional transport models:
  - Waikato Regional Transport Model
  - Wellington Strategy Transport Model

We do not have access to traffic data for other roads in other regions.

Our current categorisation rules[1] are as follows:

- A site located within an urban area that is more than 150 m from any road with Annual Average Daily Traffic (AADT) > 10,000 is classed as 'urban background'.
- A site located within 100 m of the centre of any roundabout or signalised intersection is classed as 'peak'.
- A site located in a street with AADT > 5,000 and building heights > 8 m on both sides is classed as 'peak'.
- A site within 150 m of the centreline of any road with Annual Average Daily Traffic (AADT) > 10,000 is classed as 'roadside' if AADT/distance > 600, otherwise it is classed as 'urban background'.

In addition to this categorisation sites with additional atypical and local influences are flagged in the spreadsheet.

Some sites are influenced by more than one major road. This means they are likely to be over-representative of the majority of roadside locations across an urban area. These have also been flagged in the spreadsheet. Such sites may not qualify as roadside using the criterion above when considering the influence of only one road. In these cases we have reviewed the concentrations at these sites relative to nearby roadside and urban background sites and re-categorised as 'roadside' if concentrations indicate a strong roadside influence. This has been applied to site AUC019 only.

The surroundings of each site has also been reviewed using satellite imagery. This has been used to flag potential localised influences that may locally elevate concentrations and reduce the representativeness of that site beyond its immediate locale. The results are flagged in the spreadsheet.

2.3 Roadside adjustment

2.3.1 Purpose of the adjustment

NO_2 concentrations can increase sharply close (within ≈150 m) to major roads. Concentrations gradients are non-linear, increasing with proximity to the road. This can introduce a bias into the NZTA Network data. Measurement sites are located over a wide range of distances from adjacent roads due to variations in the local logistical opportunities for mounting samplers. For example, the

[1] Research into the spatial variation in NO_2 is ongoing at NIWA. Future findings are likely to inform a revision to our categorisation rules.

average distance of roadside measurement sites to road centrelines is 65 m in central Auckland, 25 m in outer Auckland and only 2 m in Palmerston North. An adjustment method has been provided to compensate for this bias by estimating the NO_2 concentration if the site were moved to a fixed 25 m distance from the road centreline. 25 m has been chosen to broadly represent the typical distance of the closest property to a typical road, however the adjustment can be readily re-calculated for any other distance in the accompanying spreadsheet. This adjustment has the effect, for instance, of increasing average concentrations in central Auckland, and reducing concentrations in Palmerston North.

This adjustment is only applied to roadside sites as adjustment curves have not been or cannot be derived for other categories as peak sites are all individually different and background sites are assumed to be unaffected by distance to any individual road.

2.3.2 Method for the adjustment

The bias inherent in roadside data due to variation in the distance of each monitoring site from the road is adjusted using an empirically-derived function arising from NIWA research (Longley et al., *in preparation*). That function is:

$$C_x = A - Bln(x)$$

where C_x = concentration at distance x from the road centreline, and B is a constant representing the rate of concentration decay with distance. Although the value of B can vary we apply a 'typical' value of 3 for all sites.

Therefore, the concentration adjusted to 25 m is given by:

$$C_{25} = C_x - 3\big(ln(x) - ln(25)\big)$$

This function does not apply to the roadway itself where it would tend to over-estimate concentrations as x tends towards zero. This presents a problem for two of the NZTA sites, which sit in the road's central median (site CHR001 in Greymouth and site WAN007 in Palmerston North). These sites are therefore not adjusted using this function. However, this means that data from these two sites are no longer comparable to other sites and are likely to over-represent roadside concentrations in those towns.

Once these two sites are disregarded the average adjustment for all roadside data points is -0.4 μg m^{-3} (or -2 %). Adjustments range from -3.8 to +4.1 μg m^{-3} (or -34 % to +29 %).

3 Results and Limitations

3.1 Guide to the spreadsheet

The annual mean NO_2 concentrations for all sites, including site categorisation and roadside adjustment is provided in the accompanying spreadsheet.

The contents of each column is described below.

Column	Description
A – E	Data defined and provided by NZTA. Sites highlighted are 'triplicate' sites, i.e. three sites are co-located. The NO_2 data used the average of the three sites.
F – I	Localised influences that may impact the representativeness of the site based on NIWA criteria and opinion.
J – L	Data regarding the road whose emissions we believe likely to make the largest contribution to concentrations at the site.
J	Name of the road whose emissions we believe likely to make the largest contribution to concentrations at the site.
K	Estimate of Annual Average Daily Traffic volume on the closest section of the road named in column J to the site (see section 2.2.2 for data sources).
L	Shortest distance of site to centreline of road named in column J, determined using ArcMap and satellite imagery. Cells are highlighted where sites have been moved during the 2010-2016 period. See associated comments (column N) for more details.
M	Categorisation determined by NIWA. A formula has been used which is manually over-ridden in two cases (highlighted cells) – AUC019 (see section 2.2.2) and AUC039 (due to location being uncertain).
N	Additional commentary for individual sites
O – U	Annual mean NO_2 concentration data ($\mu g\ m^{-3}$) for each site provided by NZTA for each year 2010 – 2016 inclusive. Data failing to meet NZTA's quality criteria (see Appendix), or where no measurements were made, are reported as n/a.
V - AB	Estimated annual mean NO_2 concentration data ($\mu g\ m^{-3}$) for roadside sites adjusted to a site–to-centreline distance of 25 m using the method described in section 2.3.

3.2 Limitations

The following limitation should be acknowledged.

- Biases in the NZTA Network remain. In particular, roadside sites will represent different parts of the distribution of actual roadside impacts ranging from very close (<10 m) from the busiest roads to sites more setback (10 – 150 m) from less busy roads. Although the roadside adjustment is intended to reduce some of this bias it will not remove bias due to differences in how representative any roadside site is of other roadside locations in the same urban area.
- Peak sites are inherently atypical and the representativeness of any given site is effectively unknown. Some peak sites represent an extremely localised impact that may extend no more than 10 m, or may under-represent other unmonitored peak sites.

- The degree to which any urban background site represents all urban background sites across an urban area is somewhat uncertain. Ongoing research at NIWA is aiming to address this issue quantitatively. However, at this point we estimate that most urban background sites in the NZTA Network represent the entire urban area to within approximately +/- 3 $\mu g\ m^{-3}$.
- Illustrative data from Greater Wellington showing the variability in NO_2 concentrations between urban background, roadside and peak sites can be found in Longley et al. (2017).
- The categorisation scheme is partly based upon traffic volume data. For this work we have collected AADT data for some sites from a range of disparate sources. This is unlikely to introduce any significant mis-categorisation. However, this work will be made more robust once consistent AADT data is available for the complete road network.
- Three sites (AUC004, AUC049 and AUC109) have been re-located but new co-ordinates (and the date of re-location) have not been provided to us.
- Gaps in available AADT data have left 5 sites which cannot be categorised. This is because they are within 150 m of major roads for which we do not have AADT data (DUN008 in Dunedin, DUN010 in Invercargill, NAP006 in Napier, AUC171 in Whangarei and WEL062 in Nelson).
- The roadside adjustment equation is based on a limited observational database and is subject to a degree of uncertainty. In its current form it over-adjusts for sites in the central median (currently one site in Greymouth and one in Palmerston North) and is not recommended for such sites. NIWA intends to continue research to improve the equation and reduce any uncertainty its use introduces.
- The degree to which an intersection or roundabout constitutes a peak site is debatable. In many areas sites are located next to major intersections on major roads and recorded concentrations are clearly above those recorded at roadside and urban background sites in the same city. However, some sites are near relatively minor intersections or roundabouts, particularly WEL051 (Miramar) and AUC040 (Greenhithe). For now these sites are categorised as 'peak' although relatively low concentrations are observed there. Future research may seek to refine the association between intersections and the 'peak' category.
- The criterion that a site is 'roadside' if AADT/distance > 600 represents a simplification of our current understanding of roadside dispersion. This is currently the subject of ongoing research at NIWA and this criterion may be refined or replaced in the future as understanding develops further.
- We suspect that the representativeness of some roadside sites may be affected by the presence of noise walls between the major road and the measurement site. Walls are known to attenuate roadside concentrations albeit by a degree that is hard to predict. Based on a database of noise walls along Auckland motorways provided to us by NZTA, we suspect that this may affect sites AUC040, AUC008, AUC025, AUC011, AUC026 and

AUC039. This has been noted in the spreadsheet. There is currently insufficient data in New Zealand to estimate the magnitude of this effect.

- The roadside adjustment curve assumes that the roadway and measurement site are at approximately the same altitude. This assumption is not true for some sites. For example, sites AUC022 and WEL007 are elevated above the respective roads due to local topography. This means that such sites may report lower concentrations than would be expected for the given AADT and site-to-centreline distance. This has been noted in the spreadsheet. There may also be other sites similarly affected that we haven't identified.
- Concentrations at site AUC007 (on SH1 at the northern end of the Auckland Harbour Bridge) are consistently lower than we would expect given its close proximity to a very busy section of SH1. Whereas we do not question the validity of the data, we speculate that this site may have some unique characteristic suppressing concentrations and limiting its representativeness of other roadside locations. Other than speculate that this is due to open-ness of the site to the Waitemata Harbour, we are unable to identify what this characteristic is at this time.

4 Acknowledgements

All raw data was provided to us by Greg Haldane of the New Zealand Transport Agency.

5 References

DEFRA (2009). Local air quality management, technical guidance LAQM TG(09), Department for Environment, Food and Rural Affairs, February 2009.

Longley, ID (2017). Spatial monitoring survey of NO2 in Greater Wellington. Prepared for Greater Wellington Regional Council. NIWA Report 2017166AK.

NZTA (2016). Ambient air quality (nitrogen dioxide) monitoring network: Annual report 2007-15. New Zealand Transport Agency. ISBN 978-0-9941397-7-1

Appendix A NZTA methods for calculating annual average NO_2 concentrations and quality assurance

The following text is reproduced from "Ambient air quality (nitrogen dioxide) monitoring network: Annual report 2007-15", downloaded from https://www.nzta.govt.nz/resources/air-quality-monitoring/.

3.3.3 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 in the body of this report based on the following conditions:

- Sites must have 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).

Note: Previous reports (covering data up to the end of 2013) calculated an annual average for sites that met only the minimum 75% valid data condition. The new method mentioned above has been used to calculate annual averages from the beginning of 2014. Annual averages for previous years (2007 2013) were also recalculated using the new method and showed little difference in the results presented for all sites (including triplicates).

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.

Annual averages have not been calculated if two of three individual triplicate results have less than 75% valid data, or where all three individual triplicate results have less than 75% valid data.

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.

3.3.4 Quality assurance

The Transport Agency national passive monitoring network has been setup and is operated in general accordance with DEFRA (2009), 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 also as close as possible to the sample inlet of the continuous NO2 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 CV is calculated for the triplicate diffusion tubes each month for quality assurance according to:

CV = SD/mean*100

From DEFRA (2009), 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 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% (the average coefficient of variation for all triplicate samples taken between 2007 and 2015). 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.