5.2 Nitrogen dioxide in air

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State of knowledge of '*Nitrogen Dioxide in Air*' attribute: Excellent / well established – comprehensive analysis/syntheses; multiple studies agree.

Part A—Attribute and method

A1. How does the attribute relate to ecological integrity or human health?

NO_2 is a brownish gas mostly emitted by combustion of fossil fuels. Motor vehicles and industrial combustion activities are the main sources of NO_2 in New Zealand (Metcalfe & Sridhar, 2018) although shipping is also a potentially significant source. At an urban scale the spatial distribution in NO_2 concentrations are generally aligned with the road network (Figure 1). NO_2 has also been identified as an indoor air pollutant (Shaw et al 2020, Vardoulakis et al 2020, Gillespie-Bennett et al 2008). Indoor sources of NO_2 include most forms of gas combustion used for cooking or heating.

Health impacts are well known and understood. Short-term exposure to high concentrations of nitrogen dioxide causes a range of respiratory effects include decreased lung function, increased airway hyperresponsiveness, and inflammation of the airways (Health Canada, 2015) and premature mortality (Orellano et al., 2020). It can also cause asthma attacks (US EPA, 2016). Indoor NO_2 has also been found to cause respiratory symptoms in asthmatic children (Health Canada, 2015).

Long-term exposure is associated with all-cause, cardiovascular, and respiratory mortality (Huang et al., 2021). It may cause asthma to develop and lead to decreased lung development in children. It may also increase the risk of certain forms of cancer (US EPA, 2016).

NO_2 is oxidised in the atmosphere to become nitric acid and can cause acid rain if in significant concentrations. This is not generally considered a problem in Aotearoa. Nitric acid can react to become nitrate in aerosol particles, thus contributing to particulate pollution (Xue 2014). NO_2 can cause damage to plants (USEPA, 2024).

Environmental effects also include contribution to the brown haze often seen over Auckland (Dirks et al 2017) through light absorption. Whilst NO_2 is a brown coloured gas, the brown colour of haze typically occurs as a result of scattering of light by particles of varying sizes including by particulate nitrate (Wilton, 2003).

NOx (nitric oxide and nitrogen dioxide) in the atmosphere can also contribute to nutrient pollution in coastal waters. (https://www.epa.gov/nutrientpollution/basic-information-nutrient-pollution)

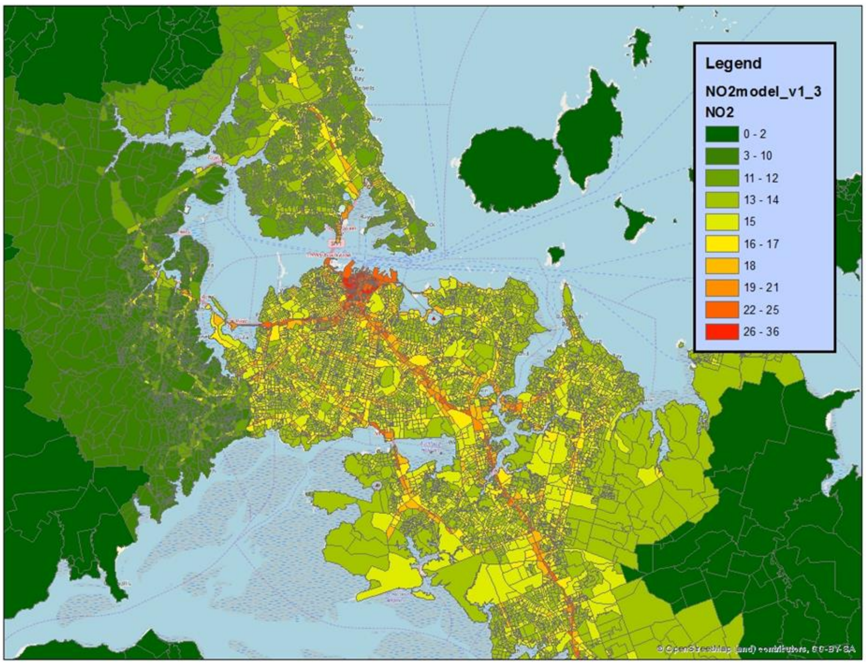

Figure 1. Modelled NO_2 concentrations in Auckland (NIWA, 2019)

A2. What is the evidence of impact on (a) ecological integrity or (b) human health? What is the spatial extent and magnitude of degradation?

The weight of evidence on the short term harmful effects of NO_2 is strong (Orellano et al., 2020). The weight of evidence for long term exposures and all cause and respiratory morality is low to moderate and high for chronic obstructive pulmonary disease (Huangfu & Atkinson, 2020).

Health impacts are well understood and characterised, including in Aotearoa where studies have shown NO_2 impacts to include premature mortality, hospital admissions for asthma in children with effect estimates higher than many other reported studies (Hales et al., 2021). Effect estimates have been used to quantify impacts at a population level (Kuschel et al., 2022). Current estimates of the health impacts in Aotearoa are shown in Table 1

Table 1. Health impacts of NO_2 in Aotearoa (from Kuschel et al 2022)

Health impacts in 2016 due to anthropogenic NO_2 air pollution (in case numbers)	
Premature deaths (all adults)	**2,025**
Cardiovascular hospitalisations (all ages)	**1,987**
Respiratory hospitalisations (all ages)	**6,544**
Asthma prevalence (0-18 yrs)	**13,229**

Spatial extent of monitoring is limited to urban areas. Spatial distribution estimates of NO_2 emissions from motor vehicles by NIWA, based on measurements by NIWA and others show that concentrations are highest close to roads and diminish rapidly away from roads (NIWA, 2019). Other peak locations are likely to include Ports and industrial areas.

Cost estimates in Aotearoa are beginning to emerge since the publication of the latest HAPiNZ report (Kuschel et al 2022). The annual health cost of NO_2 is estimated to be NZ$9.4 billion (Table 2)

Table 2. Annual costs of NO_2 in Aotearoa (from Kuschel et al 2022)

Annual costs in 2016 due to anthropogenic NO_2 air pollution (in millions of NZ$)	
Premature deaths (all adults)	$9,168
Cardiovascular hospitalisations (all ages)	$73
Respiratory hospitalisations (all ages)	$208
Asthma prevalence (0-18 yrs)	$2
Total	**$9415**

A3. What has been the pace and trajectory of change in this attribute, and what do we expect in the future 10 - 30 years under the status quo? Are impacts reversible or irreversible (within a generation)?

Near roadsides and in residential areas of New Zealand, concentrations of NO_2 have been improving over the past 15 years in a non-linear fashion (Bluett et al., 2016; Ministry for Environment, 2021). Bluett et al., (2016) concludes that emission controls for vehicles have resulted in reduced NO_2 emissions from petrol vehicles but not light duty vehicles (LDV) using diesel. A step change reduction in NO_2 from shipping is likely to have occurred from January 2020 as a result of MARPOL Annex VI.

Existing central government policies are likely to result in significant reductions in NO_2 from motor vehicles over the next 10-30 years. The impact of changes in vehicle fleet composition, including increased electric vehicle use, on NO_2 emissions are integrated into the national vehicle fleet emission model[1] (VEPM 7.0) (New Zealand Transport Agency, 2019). This model indicates an 88% reduction in NO_2 emissions from motor vehicles over the next 26 years (VEPM with default model parameters, https://www.vepm.co.nz/). Waka Kotahi also aim to reduce total kilometres travelled by the light fleet by 20% by 2035 through improved urban form and providing better travel options (Waka Kotahi, 2024) and this will result in further improvements in NO_2. Variations in fleet characteristics that provide an upward pressure on NO_2 emissions include increased proportion of diesel vehicles in the LDV fleet and increased milage of the petrol LDV fleet (more older and gross emitting vehicles) (Bluett et al., 2016).

The impact of National Environmental Standards for Greenhouse Gases from Industrial Process Heat on NO_2 is uncertain as alternative sources adopted and consequent NO_2 emission quantities is not known.

[1] Whilst VEPM includes assumptions around integration of Euro 6/VI vehicles these may not reflect the impact of existing policy and thus improvements may be underestimated.

A4-(i) What monitoring is currently done and how is it reported? (e.g., is there a standard, and how consistently is it used, who is monitoring for what purpose)? Is there a consensus on the most appropriate measurement method?

Regulatory monitoring for compliance with the National Environmental Standards for Air Quality (NESAQ) is carried out by regional councils and unitary authorities. The methods used comply with the standard specified in the NESAQ[1].The number of locations varies but it is currently monitored for regulatory purposes in nine sites around the country, in Auckland, Greater Wellington and Christchurch (MfE 2021).

NO_2 is also routinely measured using Palmes type diffusion tubes (DEFRA 2008). The largest of these is run by Waka Kotahi, who maintains a network of 120 NO_2 tubes across the country (Longley and Kachhara 2021). Waka Kotahi has specific objectives in its state highway environmental plan for improving air quality, including understanding the contribution vehicle traffic to air quality, ensuring new state highway projects do not directly cause national environmental standards for ambient air quality to be exceeded and contributing to reducing emissions where the state highway network is a significant source of exceedances of national ambient air quality standards. The NO_2 tubes assist by identifying NO_2 hotspots and providing information on trends in emissions from motor vehicles (Longley & Kachhara, 2021).

NO_2 tubes are less accurate than regulatory methods and have very limited temporal resolution giving at a minimum monthly average concentrations (Longley & Kachhara, 2021). The advantages are that they are much cheaper and easier to use, and this allows much greater spatial coverage, giving a better depiction of population exposure (see e.g. Ma et al 2019, Ma et al 2022).

A4-(ii) Are there any implementation issues such as accessing privately owned land to collect repeat samples for regulatory informing purposes?

Cost is the main implementation issue although in some areas finding a location that meets siting requirements[2] can be problematic.

A4-(iii) What are the costs associated with monitoring the attribute? This includes up-front costs to set up for monitoring (e.g., purchase of equipment) and on-going operational costs (e.g., analysis of samples).

A new NO_2 instrument that meets the NESAQ monitoring requirements typically costs around $30,000 - $50,000 to purchase and several thousand dollars per year to run. Alternatives such as Palmes tubes are available but have limited adoption owing to the low temporal resolution and non-compliance with the NESAQ. These typically cost less than $2000 per year per site with price varying with bulk runs.

A5. Are there examples of this being monitored by Iwi/Māori? If so, by who and how?

We are not aware of any NO_2 monitoring carried out by iwi/hapū/rūnanga.

[1] Australian Standard AS 3580.5.1:1993, Methods for sampling and analysis of ambient air—Determination of oxides of nitrogen—Chemiluminescence method

[2] Australian/New Zealand Standard 3580.1.1:2016; Methods for sampling and analysis of ambient air - Guide to siting air monitoring equipment

A6. Are there known correlations or relationships between this attribute and other attribute(s), and what are the nature of these relationships?

Nitrogen oxides (NOx) is a precursor to ozone formation. Whilst there is a relationship between these contaminants it is complex and impacted by meteorology (Nguyen et al., 2022). NO_2 can be correlated with other combustion related air contaminants particularly those predominantly arising from motor vehicles in urban areas (e.g., CO). However, the ratios of contaminants discharged varies with combustion fuel type confounding ambient air correlations when multiple combustion sources contribute (e.g., domestic heating also contributes to CO in urban areas of Aotearoa).

Part B—Current state and allocation options

B1. What is the current state of the attribute?

The current state is reasonably well understood from a combination of regulatory monitoring and passive sampler networks. The Ministry for the Environment issues regular State of the Environment reports with the latest air quality one being in 2021. Monitoring of NO_2 in the larger urban areas of Auckland, Wellington Region and Christchurch show compliance with the NESAQ but elevated concentrations for other exposure durations relative to some other guideline values (Ministry for Environment, 2021).

NIWA has used a national network of passive samplers based on the Waka Kotahi-NZTA network extended by campaign-based sampling in previously unmonitored locations to create a national motor vehicle NO_2 exposure model (Ma et al 2019, Ma et al 2022).

Some air quality data for regulatory monitoring of NO_2 are nationally available on the LAWA website (https://www.lawa.org.nz/).

Regional councils and unitary authorities are responsible for regulatory monitoring. Some publish data on their websites (e.g., https://knowledgeauckland.org.nz/) but for others, although data are usually available, they can be hard to find.

B2. Are there known natural reference states described for New Zealand that could inform management or allocation options?

Natural concentrations from e.g., lightening are very low, thus natural reference conditions would be expected to be extremely low or zero. Tracking of anthropogenic NO_2 is the only factor important for urban health purposes.

B3. Are there any existing numeric or narrative bands described for this attribute? Are there any levels used in other jurisdictions that could inform bands? (e.g., US EPA, Biodiversity Convention, ANZECC, Regional Council set limit)

The NESAQ contains a one hour average threshold concentration of 200ug/m^3 but no annual standard. The NZ air quality guidelines from 2002 also have a daily guideline of 100 µg/m^3 and an annual guideline value of 40ug/m^3. The WHO (2021) includes a 24-hour average guideline of 25 µg/m^3 and an annual average guideline of 10 µg/m^3. Many urban areas in Aotearoa could exceed this guideline. The ambient air quality guidelines for New Zealand include a critical value for NO_2 for the protection of ecosystems of 30 µg/m^3.

B4. Are there any known thresholds or tipping points that relate to specific effects on ecological integrity or human health?

Epidemiological studies in New Zealand found no evidence of a threshold concentration value at which there is no effect from NO_2 (Hales et al., 2021). The WHO (2021) have set guidelines based on the lowest concentrations at which effects are robustly demonstrated from studies meeting specified criteria (through meta-analysis). These do not represent no effects thresholds however as the prevalence of lower concentrations without effect is not tested.

B5. Are there lag times and legacy effects? What are the nature of these and how do they impact state and trend assessment? Furthermore, are there any naturally occurring processes, including long-term cycles, that may influence the state and trend assessments?

Some health studies for air contaminants report lag effects between exposures and health endpoints. These do not impact on state or trend assessments. Changes in climate over time may have an impact on concentrations of air contaminants. For example, a predicted decrease in frost days, which are particularly conducive to the build-up of air contaminants in many areas, may result in improvements in concentrations.

B6. What tikanga Māori and mātauranga Māori could inform bands or allocation options? How? For example, by contributing to defining minimally disturbed conditions, or unacceptable degradation.

Good air is considered a taonga and Māori are often disproportionately affected by poor air quality (Telfar Barnard & Zhang, 2018). However, whilst air as a taonga is often mentioned in iwi environmental strategies, we are not aware of any iwi explicitly planning to reduce air pollution exposure of their members.

Part C—Management levers and context

C1. What is the relationship between the state of the environment and stresses on that state? Can this relationship be quantified?

MfE regularly publishes a SOE report on air quality, most recently in 2021. The pressures and drivers are reasonably well understood as are (at a general or high level) the response and state. The relationship between emissions and concentrations is spatially and temporally dependent primarily influenced by meteorology and topography. These variables all impact on exposure and subsequent health effects are also influenced by underlying susceptibility (Figure 2).

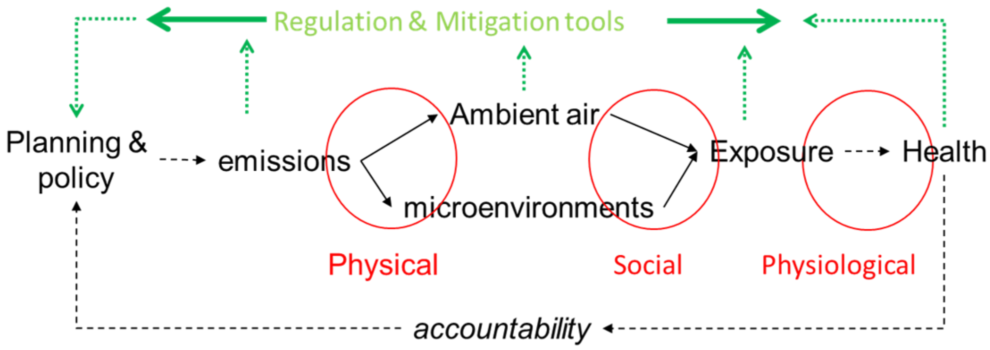

Figure 2. Links in the chain from pollutant emissions to health effects

C2. Are there interventions/mechanisms being used to affect this attribute? What evidence is there to show that they are/are not being implemented and being effective?

C2-(i). Local government driven

National Environmental Standards for Air Quality include a limit value for NO_2. Whilst these standards assist Regional Councils in managing concentrations of contaminants, they have limited mechanisms available for managing NO_2 emissions from motor vehicles.

C2-(ii). Central government driven

The national introduction of emission standards for motor vehicles has resulted in a reduction in exhaust NO_2 emissions. The effects of this in decreasing ambient NO_2 has been demonstrated over time (Bluett et al., 2016,Ministry for Environment, 2021).

C2-(iii). Iwi/hapū driven

We are not aware of any iwi or hapū activity.

C2-(iv). NGO, community driven

Most community air quality projects we are aware of have concentrated on particle concentrations, usually from wood burning. NIWA has conducted numerous community collaborations on particles, but we are not aware of any involving NO_2. There have been school projects measuring $NO_{2,}$ but it appears not to be a community concern compared to particles.

C2-(v). Internationally driven

The global driver and lead of air quality guidelines is the WHO. Aotearoa's NESAQ were largely based on WHO guidelines published in the 1990s (and reaffirmed in 2005). In 2021 the WHO substantially revised its guidelines, setting much lower values for many pollutants including NO_2 (see above). MfE, along with most environmental agencies around the world is considering its response to the new guidelines.

Part D—Impact analysis

D1. What would be the environmental/human health impacts of not managing this attribute?

Not managing concentrations of NO_2 in the air would result in increased premature mortality rates for all cause, cardiovascular, and respiratory mortality hospitalizations for respiratory conditions as well as an increase in exacerbation of asthma. The health impacts of long term exposures to NO_2 in Aotearoa have been quantified at 9.7% increase in premature all-cause mortality (adults 30+ years) per 10 $\mu g/m^3$ increase in annual average NO_2 concentrations (Hales et al., 2021). Māori will be disproportionately impacted. The contribution of NO_2 to environmental impacts such as Auckland's Brown Haze will also continue.

Climate impacts: Whilst NO_2 does not have direct climate impacts, it is co-emitted with many pollutants that do. Existing policies targeting motor vehicle emissions of CO_2, including the 20% reduction in VKT by 2035 (Waka Kotahi, 2024) will result in improvements in NO_2 as indicated above.

D2. Where and on who would the economic impacts likely be felt? (e.g., Horticulture in Hawke's Bay, Electricity generation, Housing availability and supply in Auckland)

The cost of NO_2 air pollution is estimated in HAPINZ at NZ$9.4 billion per year in deaths, illness and lost productivity (Kuschel et al., 2022) (See Tables 1 and 2 above).

The health impacts of NO_2 exposure would affect those in living near to roadways and in urban areas with higher emission densities and where meteorology and topography are more conducive to elevated concentrations.

Māori are disproportionately affected by respiratory and cardiovascular disease (Mason et al., 2019; Telfar Barnard & Zhang, 2018) and will be more susceptible to the health impacts of NO_2 exposure.

D3. How will this attribute be affected by climate change? What will that require in terms of management response to mitigate this?

There is the potential that NO_2 concentrations may decrease slightly in some areas as a result of climate change. This may occur if climate change results in fewer ground frosts as the associated low wind speeds and decreased vertical dispersion increase the potential for degraded air.

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