5.3 Sulphur dioxide in air

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State of knowledge of "Sulphur dioxide (SO_2) 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?

Sulphur dioxide (SO_2) is a water soluble, colourless, odourous gas that has the potential for adverse health and ecological impacts. It is derived from the combustion of sulphur containing fossil fuels and industry specific processes (e.g., fertiliser manufacturing, oil refinery and aluminium manufacturing). It also occurs naturally from geothermal activity and volcanoes. The main anthropogenic sources of sulphur dioxide in New Zealand are industrial processes including combustion and non-combustion activities and shipping (Metcalfe & Sridhar, 2018). However, in most urban areas where people reside domestic home heating and diesel vehicles are the main source of sulphur dioxide.

Sulphur dioxide oxidises in the air and combines with other chemicals to form particulate sulphate. Like other forms of fine particulate, sulphate can contribute to visibility degradation/ haze. Oxidation of sulphur dioxide in the air also creates sulphuric acid and can cause acid rain and associated ecological impacts if in significant concentrations. This is not generally considered a problem in Aotearoa.

The health impacts of SO_2 exposure are well known and understood. SO_2 is a strong respiratory irritant which acts directly on the upper airways. It causes coughing, mucus secretion and aggravates conditions such as asthma and chronic bronchitis. It can irritate the eyes. Common symptoms include wheezing, shortness of breath and chest tightness, especially during exercise or physical activity. Effects arise from short term exposures and can result in hospital admissions and premature mortality.

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 evidence on the health impacts of exposure to SO_2 is strong and there are hundreds of studies internationally used to characterise the relationships between premature mortality and respiratory hospital admissions and SO_2 exposure with a high certainty of evidence (Orellano et al., 2020). The certainty of evidence for hourly and 24-hour SO_2 exposures in exacerbation of asthma is moderate (Zheng et al., 2021).

The weight of evidence on spatial variability and exposures is relatively strong owing to solid source characterisation and monitoring networks. Typical population exposures can be characterised by monitoring carried out in a number of residential locations. Concentrations in these areas show consistency and coherence and are below guideline levels. Exposures near to Ports or industrial areas are more variable but have been well characterised through monitoring in high-risk areas. Concentrations in some high-risk areas exceed guideline values on occasion.

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)?

In residential areas of New Zealand concentrations of SO_2 have been gradually improving over the past ten years (Ministry for Environment, 2021). Areas near to shipping ports will have experienced a significant decrease in SO2 concentrations from January 2020 as a result of the impact of MARPOL Annex VI, which requires the use of low sulphur fuels (or alternative SO2 reducing technology) on ocean going vessels, as demonstrated for the Port of Tauranga by Iremonger, (2023). The National Environmental Standards for Greenhouse Gases includes restrictions for industrial coal combustion which will contribute to further improvements in SO_2 concentrations in areas where industrial coal burning is prevalent.

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?

Monitoring of SO_2 has been carried out in residential and industrial locations by Regional Councils. The purpose of the monitoring is typically to assess compliance with national standards and guidelines. Generally, the monitoring method used complies with the standard specified in the NESAQ[1] although in some instances, for example where the objective is to determine spatial variability in concentrations, low-cost passive samplers have been used.

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.

[1] Australian Standard AS 3580.4.1:2008, Methods for sampling and analysis of ambient air–Determination of sulphur dioxide–Direct-reading instrumental method.
[2] Australian/New Zealand Standard 3580.1.1:2016; Methods for sampling and analysis of ambient air - Guide to siting air monitoring equipment

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 SO_2 instrument that meets the NESAQ monitoring requirements can be several tens of thousands of dollars and cost thousands to tens of thousands of dollars per year to run. Low-cost passive samplers have been used for assessing spatial variability in SO_2 concentrations in Auckland (Talbot & Reid, 2017). This method is not suitable for regulatory monitoring owing to the long-term average data collected and the lower level of reliability.

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

We are not aware of any SO_2 monitoring being undertaken by iwi/hapū/rūnanga. The Bay of Plenty Regional Council carry out SO_2 monitoring using a NESAQ compliant method at the Whareroa Marae in Mount Maunganui.

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

SO_2 can be correlated with other air contaminants particularly other by-products of combustion where combustion is a predominant source**.** Airsheds tend to contain a variety of contributing sources each with differing ratios of contaminants which causes variability in the relationships. Additionally, airsheds may contain non combustion sources of SO_2. Thus, there is no reliable proxy for SO_2.

Part B—Current state and allocation options

B1. What is the current state of the attribute?

The current state of SO_2 in New Zealand is reasonably well understood at the national scale being monitored by Regional Councils and reported on by the Ministry for Environment, (e.g., Our Air - 2021)and Regional Councils (e.g., Boamponsem, 2023). In residential areas concentrations are generally well within NES and health-based guidelines including WHO (2021). There is spatial variability in SO_2 concentrations however, and the country has port and industrial hotspots where concentrations have exceeded health-based guidelines including at neighbouring residential locations (e.g., Whareroa Marae in Mount Maunganui).

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

We are not aware of any natural reference states for New Zealand for this attribute.

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)

National Environmental Standards for SO_2 include an hourly standard of 570 µg/m^3 that may not be exceeded and an hourly standard of 350 µg/m^3 that may be exceeded nine times in a 12 month period.

The World Health Organization, (2021) include a 24-hour average guideline of 40 µg/m^3 and the weight of evidence for this guideline is high. This value has been used in the Ministry for the Environments 2021 "Our Air 2021" publication for comparing 24-hour average SO_2 concentrations. There is no annual average guideline for SO_2 as impacts are associated with short term exposures. The WHO (2021 and 2005) air quality guidelines includes a 10-minute average SO_2 guideline of 500 µg/m^3.

The ambient air quality guidelines include critical levels of SO_2 for the protection of vegetation including agricultural crops (30 µg/m^3 annual and winter average) forest and natural vegetation (20 µg/m^3 annual and winter average) and lichen (10 µg/m^3 annual average).

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

We are not aware of any thresholds or tipping points with respect to ecological integrity or human health.

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 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.

A high standard of air quality is an outcome sought by iwi/hapū/rūnanga. In addition to discussing this attribute directly with iwi/hapū/rūnanga, in regard to air quality, there is likely to be tikanga and mātauranga Māori relevant to informing bands, allocation options, minimally disturbed conditions and/or unacceptable degradation in treaty settlements, cultural impact assessments, environment court submissions, iwi environmental management and climate change plans etc.

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, which includes SO_2. The pressures and drives 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 influenced primarily by meteorology and topography. These variables all impact on exposure and subsequent health effects are also influenced by underlying susceptibility (Figure 1).

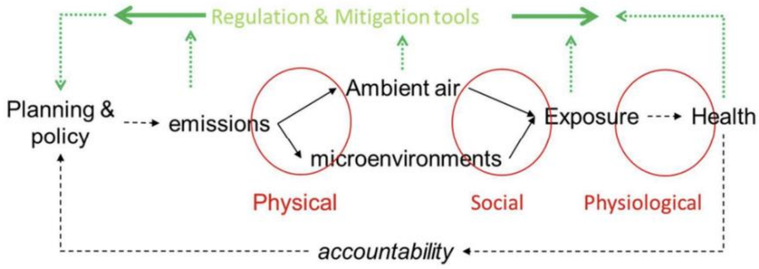

Figure 1. links in the chain from pollutant emissions to health effects

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

C2-(ii). Central government driven

National Engine Fuel Specifications Regulations have progressively reduced the sulphur content of diesel from 3000 parts per million in 2002 to 10 parts per million in 2009 and petrol to 10 parts per million in 2018 (MBIE, 2024). Air quality monitoring of SO_2 in residential areas supports an improvement in concentrations over this period. National Environmental Standards have also been implemented for SO_2 and these assist Regional Councils in managing concentrations of contaminants.

C2-(iii). Iwi/hapū driven

Iwi/hapū planning documents such as Environmental Management Plans and Climate Change Strategies/Plans may contain policies/objectives/methods seeking to influence air quality outcomes for the benefit of current and future generations. We are not aware of other interventions/mechanisms being used by iwi/hapū/rūnanga to directly affect this attribute.

C2-(iv). NGO, community driven

C2-(v). Internationally driven

Shipping SO_2 emissions have decreased significantly as a result of the implementation of Marpol Annex VI, an internationally driven legislation requiring the use of lower sulphur fuels in ocean going vessels. This is evidenced in air quality monitoring data around the Port of Tauranga which shows a significant decrease in SO_2 concentrations coinciding with Marpol Annex VI (Iremonger, 2023)

Part D—Impact analysis

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

Not managing concentrations of SO_2 in the air would result in increased premature mortality rates for all cause and respiratory mortality and increased hospitalizations for respiratory conditions as well as an increase in exacerbation of asthma, chronic bronchitis and respiratory conditions. The health impacts of short term exposures to SO_2 have been quantified at 0.59% increase in premature all-cause mortality and 0.67% increase in respiratory mortality per 10 μg/m^3 increase in 24-hour average SO_2 concentrations (Orellano et al., 2020).

Māori are disproportionately impacted as they share (with Pacific people) the highest respiratory health burden in New Zealand (Telfar Barnard & Zhang, 2018).

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 air quality related premature mortality in New Zealand has been estimated in the HAPINZ model as around $4,527,300 per life lost ($263,843 per year of life lost) and $31,748 per respiratory hospitalisation (Kuschel et al., 2022). The economic impacts would be spread nationally, e.g., across the health sector and with local hotspots in high-risk areas (e.g., increased lost work days owing to respiratory illness). Māori and Pacific people will be disproportionately impacted.

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 SO_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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