5.5 Ozone in air

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State of knowledge of "Ozone (O_3) in air" attribute: – Good / established but incomplete – general agreement, but limited data/studies

Section A—Attribute and method

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

Ozone (O_3) is a pale blue, reactive gas with a pungent odour. It is produced naturally in the upper atmospheres where helps protect earth from harmful ultraviolet rays and is referred to as the ozone layer. In the lower atmosphere it occurs as a result of human activities forming through chemical reactions of contaminants such as nitrogen dioxide with volatile organic compounds in the presence of sunlight. Ozone may also be formed by commonly used equipment such as photocopiers, laser printers, and other electrical devices and thus also has the potential to be an indoor air pollutant.

Adverse health impacts of ozone exposure include chest pain, cough, throat irritation and congestion. It exacerbates existing respiratory conditions such as asthma, bronchitis and emphysema and can cause respiratory inflammation and reduce lung function (USEPA, 2024). Short term exposures are also associated with all cause premature mortality (Orellano et al., 2020). Additionally there is potential for long-term exposure impacts including premature all cause and respiratory mortality (Huangfu & Atkinson, 2020). The impacts of ozone on sensitive plants include reduced photosynthesis and increased risk of disease, damage from insects, harmed from severe weather and effects of other pollutants (USEPA, 2023). These impacts can then have ongoing ecological effects such as changes to the specific assortment of plants present, changes to habitat quality and changes to water and nutrient cycles (USEPA, 2023).

A precursor to ozone formation is nitrogen dioxide (NO_2). The main anthropogenic sources of nitrogen dioxide (and thus ozone formation) in New Zealand is motor vehicles, industry (Metcalfe & Sridhar, 2018), and shipping (not fully included in Metcalfe & Sridhar, (2018)). Domestic home heating also contributes to volatile organic compounds (VOC) another a precursor to ozone formation. Farm animals are a source of methane, a VOC that can contribute to ozone formation.

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 short term health impacts of exposure to ozone is strong with thousands of studies carried out internationally on the relationship between ozone concentrations and emergency department visits and hospital admissions due to asthma. The certainty of evidence for 8 hourly or 24-hour ozone exposure in exacerbation of asthma is high and for hourly average exposure the certainty of evidence is moderate (Zheng et al., 2021). The certainty of impact for long term exposures including all-cause and respiratory premature mortality endpoint is rated low to moderate (Huangfu & Atkinson, 2020). The evidence of impact on ecosystems appears to be strong (Grulke & Heath, 2020).

The weight of evidence on spatial variability and exposures to ozone is weak owing to limited monitoring networks and complex chemical formation mechanisms. Ozone formation is temperature dependent with highest concentrations occurring during the warmest months of the year. Daily maximum of 8-hour mean concentrations are typically reported rather than 24-hour averages because of the strong diurnal variation in ozone concentration. Thus, concentrations should be highest in temperate areas downwind of high precursor emission areas (particularly nitrogen oxides NOx) such as Auckland.

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)?

The change in ozone concentrations in New Zealand has been assessed at one site only and was found to be indeterminate (Ministry for Environment, 2021). The formation of ozone is a complicated photochemical reaction that occurs in the lower atmosphere. Changes in ozone concentrations are a combined process of other effects such as anthropogenic emissions, topographic characteristics, and meteorological influences. Nitrogen oxides (NOx) is one of the significant ozone precursors. However, reducing NOx will not guarantee a downward ozone trend. Specific weather phenomena (e.g., anticyclones and sea–land breezes) can enhance specific meteorological parameters that govern the transport and diffusion of ozone and its precursors (Nguyen et al., 2022)

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 ozone is carried out in Auckland and Wellington using a method that complies with the specifications of the NESAQ[1]. Results are compared with hourly, eight hourly and daily guideline values for health purposes.

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 (AS/NZS 3580.1.1:2016) can be problematic.

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1 Australian Standard AS 3580.6.1:1990, Methods for sampling and analysis of ambient air–Determination of ozone-Direct-reading instrumental method

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 ozone 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.

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

We are not aware of any ozone monitoring being undertaken by iwi/hapū/rūnanga

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) are a significant ozone precursor, and VOCs are also ozone precursors. The relationships are complex and impacted by meteorology. Reducing NOx will not guarantee a downward ozone trend (Nguyen et al., 2022).

Part B—Current state and allocation options

B1. What is the current state of the attribute?

We have a moderate understanding of ozone concentrations in New Zealand. Air quality monitoring for ozone is carried out by two regional councils (Auckland, where precursor emissions are highest, and Wellington). Neither location exceeds the NESAQ for ozone (one hour average of 150 $\mu g/m^3$). Ozone concentrations at both sites are within the ambient air quality guideline eight hour value of 100 $\mu g/m^3$ and the WHO (2021) value of 60 $\mu g/m^3$, although Ministry for Environment, (2021) reports that the maximum eight hour average concentrations at Patumahoe (Auckland) was only just compliant with the latter guideline in 2019 (at 59.3 $\mu g/m^3$).

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

Photochemistry involving methane accounts for much of the rise in ozone over the oceans and remote land areas (World Health Organization, 2021). Methane is a VOC that is much less reactive than the other VOCs but is present at much higher concentrations, having risen in concentration over the past 100 years owing to its increasing use as fuel, and is released from rice fields and farm animals (World Health Organization, 2021).

There are no known natural references states suitable for management or allocation options.

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 1-hour average standard for ozone is 150 $\mu g/m^3$ with no allowable exceedances.

The ambient air quality guideline for an eight-hour average exposure is 100 µg/m^3 (Ministry for the Environment, 2002) and the WHO (2021) guideline for an eight hour average exposure is 60 µg/m^3.

The ambient air quality guideline (Ministry for the Environment, 2002) includes critical levels for protection of ecosystems. These are based on cumulative exposure over a concentration threshold of 85.6 µg/m^3 and are calculated for daylight hours only. The critical levels vary from 428 µg/m3 -h, over 5 days, to 21,400 µg/m^3 -h over 6 months.

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

There is a threshold for ecological effects of 85.6 µg/m^3 (40ppb) for an hourly average. A threshold for health impacts was not been able to be determined for the WHO (2021) guideline review (Huangfu & Atkinson, 2020; Orellano et al., 2020).

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.

A high standard of air quality is an outcome sought by iwi/hapū/rūnanga (see Section 3.2 for one example). 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?

The Ministry for the Environment regularly publishes a SOE report on air quality, most recently in 2021, which includes ozone (Ministry for Environment, 2021). The pressures and drives are generally reasonably well understood for most air contaminants but are more complex for ozone owing to the photochemical formation mechanisms. The state can be monitored. There is a non-linear chain from precursor emissions to concentrations, complicated by variability in temperature and meteorology, to exposure and subsequent health effects that incorporates a number of variables (Figure 1).

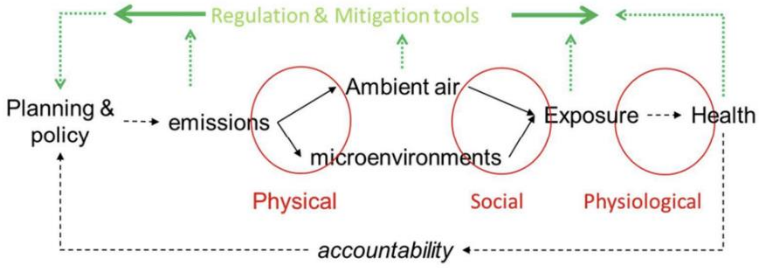

Figure 1. links in the chain from pollutant emissions to health effects

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

There are no intervention mechanisms directly targeting ozone although emission standards for motor vehicles impact on emissions of NO_2, a precursor to ozone but also a significant contaminant. Monitoring of NO_2 across New Zealand shows a decrease in annual average concentrations from 2011 to 2020 at six out of seven air quality monitoring sites (Ministry for Environment, 2021).

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

Part D—Impact analysis

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

Not managing concentrations of precursors to ozone formation may result in increased respiratory health impacts including increased hospitalizations for respiratory conditions and premature mortality. The health impacts of short term exposures to ozone have been quantified at 0.43% increase in premature mortality per 10 $\mu g/m^3$ increase in 24-hour average ozone concentrations (Orellano et al., 2020). There is also the potential for reduced yields in crops and damage to forests if ozone concentrations were to increase.

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

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 for respiratory hospitalisations (Kuschel et al., 2022).

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 health impacts, which would lead to economic impacts of ozone exposure would likely be felt in the more temperate areas of New Zealand in locations downwind of precursors sources areas e.g., Auckland.

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 for increased ozone formation in New Zealand as the photochemical reaction potential increases with temperature. The relationships are complex, however, and overall impacts are difficult to predict as weather phenomena such as ground frosts, which are predicted to decrease with climate change, impact on the transport and diffusion of O_3 and its precursors.

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