5.4 Carbon monoxide in air

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State of knowledge of "Carbon monoxide (CO) in air" attribute: Excellent / well established – comprehensive analysis/syntheses; multiple studies agree

Section A—Attribute and method

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

Carbon monoxide (CO) is a flammable, colourless, odourless and tasteless gas that has the potential for adverse health impacts. It is derived primarily from the combustion of fuels although some non-combustion industrial processes also contribute to carbon monoxide emissions. The main sources of carbon monoxide in New Zealand are domestic heating related combustion activities, motor vehicles and outdoor burning activities (Metcalfe & Sridhar, 2018). Carbon monoxide is also produced by natural processes (e.g., volcanoes, fires and metabolism of organisms).

Health impacts of carbon monoxide exposure occur as inhaled carbon monoxide reaches the blood stream and attaches to haemoglobin that would otherwise carry oxygen around the body. This reduces the amount of oxygen available to the body (Raub & Benignus, 2002). For people with cardiovascular disease, short-term CO exposure can further reduce their body's already compromised ability to respond to the increased oxygen demands of exercise, exertion, or stress. Carbon monoxide can cross the placenta to gain access to the foetal circulation and can impact on the developing brain (Levy, 2015). Exposure to low levels in otherwise healthy people can causes dizziness, weakness, nausea, confusion and disorientation (Graber et al., 2007). As the carboxyhaemoglobin level increases health impacts can include coma, collapse, loss of consciousness and death (Varma et al., 2009).

Carbon monoxide is an indirect greenhouse gas as it reacts with other compounds which can result in an increase in greenhouse gases (Sobieraj et al., 2022).

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 CO for short term exposures (15 minute, hourly and eight-hour averages) is strong and is based on a range of methodologies. The 2021 World health organisation guideline review added a 24-hour average guideline to the existing 2005 WHO guideline values for 15 minute, hourly and eight hour average guidelines (World Health Organization, 2021). The 24-hour guideline is considered of moderate certainty by WHO and is based on an evaluation by Lee et al., (2020) which found relationships between exposure to CO and myocardial infarction.

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 results for which show consistency and coherence. Exposures near to roadsides can be more variable as concentrations decrease steeply with distance from the road and depend on surrounding topography and meteorology.

Increased indoor exposure to CO also occurs as a result of use of gas heating and cooking, open fires and wood burners, smoking and internal access garages (World Health Organization, 2010). Monitoring of carbon monoxide inside dwellings in Aotearoa found concentrations were low and within guideline values (BRANZ, 2019).

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)? [Provide evidence or examples of how fast the attribute has changed, whether the problem historical only or contemporary/ongoing, and what the prospects and pace of recovery might look like (reversable, yes or no)].

Near roadsides and in residential areas of New Zealand concentrations of CO have been gradually improving over the past 20 years (Bluett et al., 2016; Ministry for Environment, 2021). Emission standards for motor vehicles required the installation of catalytic converters from 2000 and these reduce exhaust CO emissions (Bluett et al., 2016). Additionally, the National Environmental Standards for wood burners required that only burners meeting a specified emission and energy efficiency criteria could be installed on properties less than 2 hectares in area from 2005. The latter is likely to have ongoing impact on CO concentrations as older less efficient burners are replaced with more efficient and lower emission alternatives.

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 CO has been carried out in residential and roadside locations by Regional Councils. The purpose of the monitoring is typically to assess compliance with national standards and guidelines. The methods used comply with the standard specified in the NESAQ[1]. Monitoring of CO is not a high priority for most Councils owing to existing low concentrations and good understanding of contributing sources.

[1] Australian Standard AS 3580.7.1:1992, Methods for sampling and analysis of ambient air–Determination of carbon monoxide-Direct-reading instrumental method

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

Continuous instrumental ambient air quality monitoring has been performed in urban areas for several decades. There do not appear to be major impediments to monitoring (i.e., pole-mounted sensors, or continuous monitoring sensors co-located with meteorological equipment, with analysing equipment in air-conditioned sheds).

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 CO instrument that meets the NESAQ monitoring requirements typically costs around $25,000 to purchase and several thousand 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 CO 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?

CO 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. This introduces variability in the relationships. For example, when traffic is the main contributor to CO concentrations of NOx would be higher than when residential combustion is the predominant source.

Part B—Current state and allocation options

B1. What is the current state of the attribute?

The current state of CO in New Zealand is reasonably well understood with concentrations being monitored by a small number of Regional Councils and reported on by the Ministry for the Environment, Regional Councils and Waka Kotahi. In residential areas and at roadside monitoring sites concentrations are well within health-based guidelines and standards (Ministry for Environment, 2021).

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.

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 CO include an eight-hour average standard of 10 mg/m^3 that may be exceeded once in a 12-month period and an hourly standard of 30 mg/m^3 that may not be exceeded. The weight of evidence for these standards is strong.

The World Health Organization, (2021) include a 24-hour average guideline of 4 mg/m^3 and the weight of evidence for this guideline is moderate. This value has been used in the Ministry for the Environments 2021 "Our Air 2021" publication for comparing 24-hour average CO concentrations. The WHO (2005 and 2021) guideline values include a 15-minute guideline for CO of 100 µg/m^3, an hourly average guideline of 35 µg/m^3 and an eight hour average guideline of 10 µg/m^3. There is no annual average guideline for CO as impacts are associated with short term exposures.

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

The relationship of carbon monoxide exposure and the COHb concentration in blood can be modelled using the differential Coburn-Forster-Kane equation (Coburn et al., 1965). Epidemiological studies of the impacts on cardiovascular disease mortality are not indicative of thresholds below which effects do not occur (Liu et al., 2018).

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. For example for associations between cardiovascular disease, coronary heart disease, and stroke Liu et al., (2018) report a present day and one day lag with CO concentrations. 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, regarding 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 plans, climate change strategies, etc.

<u>Part C—Management levers and context.</u>

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 CO. The pressures and drives are reasonably well understood as are (at a general or high level) the response and state. There is a non-linear chain from emissions to concentrations to exposure and subsequent health effects that incorporates a number of variables (Figure 1).

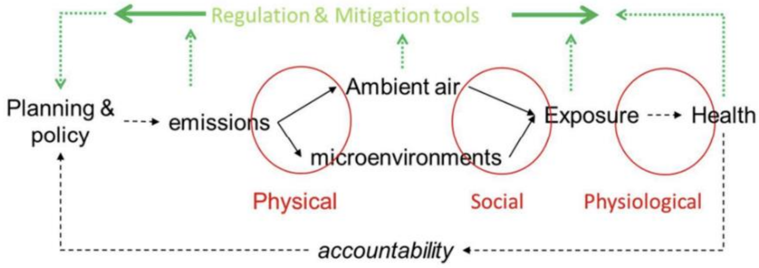

Figure 1. links in the chain from pollutant emissions to health effects

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

The National Environmental Standards design criteria for wood burners was established for the purpose of reducing concentrations of particulate in urban areas. However, the emission limit and efficiency criteria are likely to also result in improvements in CO concentrations. The impact of this legislation is ongoing in the near future as households replace older more polluting and less efficient burners with compliant models over time.

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

National Environmental Standards for air contaminants include two limit values for CO. These standards 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

Part D—Impact analysis

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

If the air were to become degraded and CO concentrations increased to level in excess of standards and guidelines then not managing concentrations of CO in the air could result in increased health impacts including dizziness, weakness, nausea, confusion and disorientation. If extreme short-term concentrations were experienced health impacts could include loss of consciousness and death.

If concentrations became elevated for a period of days, then there would be increased risk of myocardial infarction and associated hospitalisation. Māori are disproportionately affected by cardiovascular disease (Mason et al., 2019) and will be more susceptible to the health impacts of daily CO exposure.

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 cardiovascular hospitalisations in New Zealand has been estimated in the HAPINZ model as around $36,666 per admission (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 of CO 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.

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 CO 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.

References:

Bluett, J., Aguiar, M., & Smit, R. (2016). *Understanding trends in roadside air quality September 2016*. NZ Transport Agency research report 596.

Kuschel, G., Metcalfe, J., Sridhar, S., Davy, P., Hastings, K., Mason, K., Denne, T., Berentson-Shaw, J., Bell, S., Hales, S., Atkinson, J., & Woodward, A. (2022). *Health and air pollution in New Zealand 2016 (HAPINZ 3.0)*. Report prepared for Ministry for Environment, Ministry of Health, Te Manatu Waka Ministry of Transport and Waka Kotahi NZ Transport Agency.

Lee, K. K., Spath, N., Miller, M. R., Mills, N. L., & Shah, A. S. V. (2020). Short-term exposure to carbon monoxide and myocardial infarction: A systematic review and meta-analysis. *Environment International*, *143*, 105901. https://doi.org/10.1016/j.envint.2020.105901

Mason, K., Toohey, F., Gott, M., & Moeke-Maxwell, T. (2019). Māori: Living and dying with cardiovascular disease in Aotearoa New Zealand. *Current Opinion in Supportive & Palliative Care*, *13*(1), 3–8. https://doi.org/10.1097/SPC.0000000000000404

Metcalfe, J., & Sridhar, S. (2018). *National air emissions inventory: 2015*. Emission Impossible.

Ministry for Environment. (2021). *Our Air 2021*. Ministry for the Environment, Wellington.

Sobieraj, K., Stegenta-Dąbrowska, S., Luo, G., Koziel, J. A., & Białowiec, A. (2022). Carbon Monoxide Fate in the Environment as an Inspiration Biorefinery Industry: A Review. *Frontiers in Environmental Science*, *10*, 822463. https://doi.org/10.3389/fenvs.2022.822463

World Health Organization. (2021). *WHO global air quality guidelines: Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. World Health Organization. https://apps.who.int/iris/handle/10665/345329