5.11 Cadmium in air

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Preamble: This attribute stocktake has been prepared assuming the greatest focus is on ambient air, although it should be noted that cadmium is typically associated with particulate matter in air.

State of knowledge of 'Cadmium in air' attribute: Poor / inconclusive

Poor/inconclusive ranking mainly arising from the limited data available to assess state in New Zealand. However, the motivation for collection of that data is minimal as there is low risk associated with this attribute. There may be some value in expanding the national pollution inventory to include cadmium emissions to build a greater understanding of the magnitude of potential emissions and to understand potential points of intervention.

Part A—Attribute and method

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

The primary concern associated with cadmium in air relates to human health. Cadmium is considered as a class 1 carcinogen, with the strongest evidence for carcinogenicity arising from studies indicating occupational cadmium exposure is associated with lung cancer [1]. For non-occupational exposed people, smoking is a significant greater contributor to exposure via the inhalation pathway than ambient air. For non-smokers, dietary sources of cadmium is the primary route of exposure,

Overviews of the toxicological effects associated with exposure to cadmium are provided by multiple sources [e.g., 2-6] with accumulation in kidneys and renal failure the primary health effect of concern [2].

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

There is no evidence of impact of cadmium in ambient air on human-health in NZ. As noted above, the main source of exposure to cadmium is dietary exposure rather than air emissions.

Internationally, one epidemiological study undertaken in Belgium on people in close proximity to a zinc smelter found an increased incidence of lung-cancer associated with exposure to cadmium [7]. The primary source of exposure was suggested to be house-dust arising from the transfer of contaminated soil into houses.

An assessment of metal concentrations in house-dust across NZ, highlighted cadmium as a potential contaminant of concern – based on comparison of house-dust concentrations with NZ soils contaminant standards for rural residential land use of 0.8 mg/kg [8]. Concentrations ranged from 0.08 mg/kg to 15 mg/kg, with a median concentration of 0.6 mg/kg. An earlier study found a geometric mean cadmium concentration of 4.2 mg/kg in house dust from 120 houses in Christchurch in 1993 with no one dominant source of cadmium identified [9].

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)?

There is an unknown historical trajectory of change since cadmium in air has rarely been measured. Only two studies were found that reported cadmium concentrations in NZ air. The first study undertaken in 1994 reported mean cadmium concentrations of 0.814 ng/m3 in Christchurch with the primary source indicated to be from coal combustion [10], while a study undertaken in Richmond in 2017 found no cadmium concentrations above the limit of detection of 17 ng/m3 [11].

The primary sources of cadmium to the NZ air are unknown. There are no recognised industrial sources of cadmium emissions, although there is ongoing scrutiny of industrial emissions thus it is unlikely any such emissions would increase. The primary source of cadmium in ambient air might be expected to be from suspensions of soil particles. These may contain naturally occurring cadmium from weathered rock, or cadmium derived from anthropogenic sources such as phosphate-fertilisers.

It seems likely there would be minimal change over the next 10-30 years.

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?

No monitoring of this attribute is currently undertaken in New Zealand.

A recent study that reported cadmium concentrations in NZ air used X-ray fluorescence spectroscopy (XRF) to determine elements in particulate matter collected on teflon filters using a Partisol sampler [11]. The limit of detection specified in this study was 17 ng/m3, with an uncertainty of 22 ng/m3- this contrasts with the target value of 5 ng/m3 specified for cadmium in the EU directive 2004/107/EC (see also A6). The earlier NZ study [10] used a hi-volume sampler for the collection of particulate matter and acid-extraction and analysis by Graphite Furnace Atomic Absorption Spectroscopy and measured much lower concentrations.

The European directive 2004/107/EC outlines the requirements for monitoring arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air. Associated with this directive are European Standards that specify the determination of particulate matter concentrations in ambient air (EN1241:2023), and EN 14902:2005, which specifies the standard method for analysis of Pb, Cd, As and Ni in PM10 aerosol, through microwave digestion of the samples and analysis by graphite furnace atomic absorption spectrometry or by inductively coupled plasma (quadrupole) mass spectrometry.

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

Monitoring for this attribute would most sensibly be co-located at existing air-quality monitoring sites, thus there are unlikely to be any additional access issues. However, space to fit equipment, if additional is required, may be an issue at some locations.

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).

Currently there is no existing monitoring of this attribute. Where existing air quality sampling includes the use of instruments that collect particulate matter on filters e.g., Partisol samplers, these filters may be able to be used for analysis to determine cadmium concentrations. However, method evaluation is required to determine whether cadmium can be detected in the particulate mass typically captured by these instruments or whether a higher volume sampler is required; for example, Partisol samplers can sample at between ~0.6-1.2 m3/hr with the USEPA specifying 1m3/hr (16.7 L/min) for regulatory sampling, however other instruments can sample at different rates, higher or lower.

Currently there is no commercially available method for the determination of cadmium in particulate matter. The general method outlined in the European standard EN 14902:2005 is similar to that used for determining cadmium in soils hence it would seem feasible for commercial laboratories to develop the method if there was sufficient demand.

As noted above, XRF used by [11] in New Zealand appears unlikely to be sufficiently sensitive for the determination of cadmium.

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

We are not aware of any monitoring of this attribute 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?

There may some correlation with PM2.5 concentrations – but the association will be dependent on the source of cadmium. Many sources e.g., tyre-wear, soil dust will fall into larger particulate size fractions – hence measurement of cadmium will depend on particle size being measured. Regardless of particulate size, any relationship with particulate mass is still likely to be variable depending on the contribution of different sources.

Vapour-phase cadmium is only likely to be present in a small number of workplaces and should be managed through workplace safety.

Part B—Current state and allocation options

B1. What is the current state of the attribute?

The state of this attribute in New Zealand is largely unknown. Available studies are reported in A2 (house-dust) and A3 (cadmium in ambient air)

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

To our knowledge, there are no known natural reference states 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)

In New Zealand, the only standards related to cadmium in air are provided under Worksafe, which provides a time-weighted average exposure standard for an 8-hr day of 0.004 for respirable dust NZ WES 0.004 mg/m3, which was adopted in 2020 [12].

Internationally, the EU directive 2004/107/EC provides a target value for cadmium of 5 ng/m3, which is based on the total content in the PM10 fraction averaged over a calendar year. Cadmium is not included in Australian or US air quality standards.

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

From toxicological data there are various thresholds that have been identified as leading to different effects (see 2-6). However, there are no known thresholds or tipping points (and no studies undertaken to establish these) associated with cadmium concentrations in ambient air. As noted above, cadmium exposure via dietary sources will be far greater than exposure via ambient air.

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?

The only potentially relevant lag time or legacy effects arguably arises from cadmium accumulation in soils as a result of historical application of phosphate fertilisers and suspension of those soil particulates in the ambient air.

From a human health perspective, the effects of cadmium typically arise from chronic exposure over time with accumulation in kidneys and renal effects – although as noted previously inhalation is considered to be a minor route of exposure.

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?

There are a wide range of natural and anthropogenic sources of cadmium in ambient air, with soil particles suggested to be the predominant source of natural emissions to the atmosphere, followed by forest and bush fires, sea salt, volcanic emissions and meteoric dust [13]. Other sources of natural Cd emissions are weathering of rocks, airborne soil particles, e.g., from deserts, sea spray, forest fires, biogenic material, volcanoes, and hydrothermal vents [13].

The key anthropogenic emissions of cadmium are fossil fuel and coal combustion, mining and smelting of metals, with additional sources related to the production, use, disposal and recycling of cadmium and cadmium containing products (including phosphate fertilisers with cadmium as impurities) [6, 13, 14]. Cadmium may also be found in vehicle non-exhaust emissions – primarily associated with brake-pad wear [15], with some studies indicating that due to increasingly strict emissions control on vehicle exhaust emissions, non-exhaust emissions are increasing as a proportion of total vehicle emissions [16]. Similarly, an increasing proportion of electric vehicles will also increase the relative significance of vehicle non- exhaust emissions.

The National Pollutant Inventory from Australia [17] provides some perspective on sources of cadmium emission – in this case bushfires as the dominant source, followed by paved and unpaved roads (Table 1).

Source	Air (kg)[1]
Burning(fuel red., regen., agric.)/ Wildfires [*]	20,000
Paved/ Unpaved Roads [*]	13,000
Basic Non-Ferrous Metal Manufacturing [213]	5,100
Motor Vehicles [*]	5,800
Metal Ore Mining [080]	1,800
Windblown Dust [*]	630
Solid fuel burning (domestic) [*]	630
Waste Treatment, Disposal and Remediation Services [292]	540
Electricity Generation [261]	350
Fuel Combustion - sub reporting threshold facilities [*]	270
Coal Mining [060]	220
Aeroplanes [*]	210
Basic Ferrous Metal Manufacturing [211]	180
Glass and Glass Product Manufacturing [201]	140

Table 1. Screenshot of the key sources of cadmium emissions in Australia from the National Pollutant Inventory. (http://www.npi.gov.au/npidata/action/load/emission-by-source-result/criteria/destination/ALL/substance/18/source-type/ALL/subthreshold-data/Yes/substance-name/Cadmium%2B%2526%2Bcompounds/year/2022)

The National Air Emissions Inventory methodology [18] could be extended to include Cd emissions from the various sources, drawing on international data to provide a perspective on key sources of cadmium to ambient air in New Zealand. Many industrial sources do not exist in NZ, and bushfires are much less common than in Australia, so it would be expected that soil -derived sources – including unpaved roads, and motor-vehicles may be primary sources.

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

To our knowledge, there are no interventions beyond general industrial emissions controls, and requirements for monitoring particulate matter under the National Environmental Standard for Air Quality are being used to affect this attribute. Cadmium is included in Worksafe standards and thus should be being managed in industrial workplaces.

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

Internationally, the Geneva convention on long-range transboundary air pollution requires parties to reduce emissions of cadmium (and lead and mercury) from industrial sources, combustion processes and waste incineration. The protocol on heavy metals was amended in 2012 to introduce more stringent emission limit values (ELVs) for emissions of particulate matter and of cadmium, lead and mercury applicable for certain combustion and other industrial emission sources that release them into the atmosphere. The emission source categories for the 3 heavy metals were also extended to the production of silico- and ferromanganese alloys. New Zealand does not appear to be a signatory to this convention and hence has no obligations in this regard.

Part D—Impact analysis

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

There is likely negligible impact on human health of not managing cadmium in ambient air. Dietary intake and smoking will dominate people's exposure to cadmium with inhalation a negligible route of exposure for non-smokers. Cadmium is included in Worksafe standards and thus should be being managed in industrial workplaces.

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)

Although uncertain, the expectation is that managing or not managing this attribute will have minimal economic impacts.

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

This attribute may be indirectly affected through changes primarily associated with changes in dust generated from soil as a result of climate related events.

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