5.7 Benzo(a)pyrene in air

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Preamble: BaP is a contaminant that occurs ubiquitously with a range of polycyclic aromatic hydrocarbons (PAHs) primarily as a result of incomplete combustion of fossil fuels and wood. BaP is considered to be a marker for PAHs as it is one of the most strongly carcinogenic of the hundreds of PAHs that exist (of which only 16 are on the US EPA list of priority pollutants and therefore routinely analysed). BaP is primarily associated with particulate matter in air, although it is a semi-volatile compound, and a small fraction may be present in gaseous form. Other PAHs may be more or less volatile than BaP.

State of knowledge of "Benzo(a)pyrene (BaP) in air" attribute: Good / established but incomplete in that studies undertaken agree that elevated BaP is recognised to occur across New Zealand, primarily associated with wood burning for residential heating. Excellent and well-established in relation to the effects on toxicity effects of benzo(a)pyrene on people, although poor / inconclusive regarding the extent of the impact of BaP in ambient air on human health.

Section A—Attribute and method

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

The primary concern associated with BaP in air relates to human health. Several comprehensive reviews of the toxicity of benzo(a)pyrene have been undertaken (1-5). Studies in multiple animal species demonstrate that benzo[a]pyrene is carcinogenic at multiple tumour sites (alimentary tract, liver, kidney, respiratory tract, pharynx, and skin) by all routes of exposure. An increasing number of occupational studies demonstrate a positive exposure-response relationship with cumulative benzo[a]pyrene exposure and lung cancer [5]. The toxicity of PAH mixtures is often determined through the use of potency equivalence factors (PEFs), which express the toxicity of individual PAHs that are carcinogenic relative to that of BaP (BaP-equivalents). Non-carcinogenic PAHs are considered separately.

In terms of non-carcinogenic effects, animal studies show that inhalation exposure to benzo[a]pyrene results in developmental and reproductive toxicity, and available human PAH mixtures studies report developmental and reproductive effects that supports the findings from animal studies. [4]

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 BaP in ambient air on human-health in NZ. However, there are multiple studies that have assessed BaP concentrations in ambient air in several New Zealand urban areas. The majority of these studies have been undertaken in Christchurch or other South Island towns [6-9], with studies being undertaken in Hamilton [6], Auckland [6] and Masterton on the North Island [10]. These studies show markedly elevated concentrations over winter, which is primarily associated with wood-burning for residential home heating [6-11], with concentrations also influenced by the formation of winter inversion layers [12]. The biological effect associated with particulates from Christchurch and Auckland was assessed by [13] and showed that the organic extracts of Christchurch PM2.5 and PM10 showed higher mutagenicity and CYP1A1 induction compared with PM10 from Auckland. In contrast, water-soluble extracts of Auckland PM were more cytotoxic and resulted in greater TNF-α release than those from Christchurch PM, although they had a lower metal content. The effect associated with the organic fraction was primarily attributed to PAHs.

Observed average concentrations were around 11-15 times higher than the Ambient Air Quality Guidelines (AAQG) 0f 0.3 ng/m3 in Christchurch in 2008/9 and 2012 [6, 7] and 14-16 times higher in Timaru [6, 8].

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 are limited data available to assess change over time. Studies undertaken in Christchurch show slightly higher annual average BaP concentrations of 4.4. ng/m^3 in 2012 [7], as compared to concentrations of 3.4 ng/m^3 in 2008/9 [6]. This increase follows from an apparent increase in BaP concentrations in Christchurch in 2003/2004 from 3.1 ng/m^3. Studies in Timaru show a slight decrease in concentrations from 6.4 ng/m^3 in 2007 [6] to ~ 5.5 ng/m3 in 2012 [8].

The comparisons are indicative only, as the studies used different sampling techniques (i.e., sampling of gas-phase and particulates-phase PAHs or particulate-phase only), analytical techniques, frequency and duration of sampling [6, 7].

In the context that BaP in NZ air is primarily associated with the incomplete combustion of wood, and there has been a strong focus on reducing emissions associated with wood burning for home heating (e.g., 14, 15), it might be expected, or hoped, that concentrations would decrease alongside particulate concentrations.

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 regular monitoring of this attribute is currently undertaken in New Zealand. As noted in A2, there have been some studies that have assessed BaP in air. Particularly in earlier studies, different sampling techniques (i.e., sampling of gas-phase and particulates-phase PAHs or particulate-phase only) were used, with analysis most commonly undertaken using solvent extraction and gas chromatography-mass spectrometry. More recent studies in Christchurch [7] and Timaru [8] used thermal-desorption/gas chromatography-mass spectrometry, partly because these studies were focussed on using a range of organic compounds to assist with source apportionment studies.

Internationally, 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 15549:2008, which specifies the standard method for analysis of BaP in PM10 aerosol, through sample extraction and analysis by high performance liquid chromatography (HPLC) with fluorescence detector (FLD) or by gas chromatography with mass spectrometric detection (GC/MS).

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 ongoing 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 arsenic concentrations. However, method evaluation is required to determine whether BaP 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 benzo-a-pyrene in particulate matter. However, commercial laboratories have previously been used for the analysis of extracts from filters [6], and the general analysis is similar to that required determining PAHs in soils hence it would seem feasible for commercial laboratories to develop the method if there was sufficient demand.

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

We are not aware of any BaP 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?

There is likely to reasonable correlation with PM2.5 concentrations, given the association of BaP with incomplete combustion of wood and fossil fuels (i.e. wood-burning for home-heating and vehicle exhaust emissions).

B) Current state and allocation options

B1. What is the current state of the attribute?

As noted in A2, there have been various studies of benzo-a-pyrene in New Zealand, with additional studies providing information on biological effects associated with air particulates [13]. However, the most recent study was undertaken over 10 years ago, hence there is a considerable gap in our current understanding of the state of the attribute.

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 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)

New Zealand ambient air guidelines [4] have an annual average guideline value for BaP in 0.3 ng/m^3. [6] also comments that It is unclear as to how the 0.3 ng m-3 value was actually selected; calculation of the increased risk at 0.3 ng/m3 using the WHO unit risk of 8.7 per ng/m3 yields a risk of 1 in 38 300 or ~3 in 100 000 and that it is unclear why the value of 0.12 ng/m3, which is associated with a risk level of 1 in 100 000, was not adopted as this risk level is consistent with that nominally associated with ambient air quality guidelines for As and other New Zealand documents (e.g., [1]).

Internationally, the EU directive 2004/107/EC provides a target value for BaP of 1 ng/m^3, which is based on the total content in the PM10 fraction averaged over a calendar year. Arsenic is not included in Australian or US air quality standards (but lead is).

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 1-5). However, there are no known thresholds or tipping points (and no studies undertaken to establish these) associated with benzo(a)pyrene concentrations in 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 existence of lag times and legacy effects for this attribute is unknown/uncertain.

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). Māori are often disproportionately affected by poor air quality (Telfar Barnard et al 20XX). 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.

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?

It is recognised that BaP is primarily associated with incomplete combustion fossils fuels and biomass burning e.g., wood, with particulate emissions from wood-burning for residential home-heating considered to be the primary source of particulates in New Zealand air e.g., [6, 11]. Given there has been a strong focus on reducing emissions associated with wood burning for home heating (e.g., 14, 15), it might be expected, or hoped, that concentrations would decrease alongside particulate concentrations.

BaP is also derived from incomplete combustion of fossil fuels e.g., petrol, diesel, coal. With increasingly strict emissions control on vehicle exhaust emissions [21], along with an increasing proportion of electric vehicles, vehicle exhaust emissions could be expected to be reducing in relative significance. Reductions in industrial burning of coal to meet greenhouse gas emission targets will also act to reduce BaP concentrations in NZ air.

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

Councils have campaigns to raise awareness good practices to reduce emissions associated with home-heating.

C2-(ii). Central government driven

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.

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 this attribute could result in increased human health impacts, although it is difficult to gauge the potential magnitude of this increase, or indeed if an increase would occur. As noted in C1, there are a number of current interventions to generally reduce particulate emissions that would also be expected to reduce BaP concentrations in NZ air. Provided those interventions are maintained, it is unlikely that separate interventions to manage BaP are required. However, verification that BaP concentrations are declining alongside any reductions in particulate emissions would be valuable – particularly given the historically comparatively high concentrations of BaP in at least some New Zealand cities.

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)

Where and who economic impacts would be felt is largely unknown for this attribute, although 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?

Indirectly through primarily through changed winter temperatures, which may result in more or less winter heating, and changes in electricity demand which may influence the extent to which coal-fired power stations are required.

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