5.9 Benzene in air

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Citation for this chapter: Cavanagh, J. (2024). Benzene in air. *In:* Lohrer, D., et al. *Information Stocktakes of Fifty-Five Environmental Attributes across Air, Soil, Terrestrial, Freshwater, Estuaries and Coastal Waters Domains*. Prepared by NIWA, Manaaki Whenua Landare Research, Cawthron Institute, and Environet Limited for the Ministry for the Environment. NIWA report no. 2024216HN (project MFE24203, June 2024). [https://environment.govt.nz/publications/information-stocktakes-of-fifty-five-environmental-attributes]

Preamble: Benzene is volatile organic compound and is associated with gaseous phase in air. Benzene is commonly found associated with toluene, ethylbenzene and xylenes and collectively are referred to as BTEX. Benzene is typically found in the highest concentrations in ambient air.

State of knowledge of the "Benzene in air" attribute: Good / established but incomplete in that studies undertaken agree that elevated benzene can occur across New Zealand, primarily associated with vehicle emissions although concentrations are generally low and below concentrations that might be of concern for human health.

Part A—Attribute and method

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

The primary concern associated with Benzene in air relates to human health. Several comprehensive reviews of the toxicity of benzene have been undertaken (1-6). Benzene exposure affects the central nervous system (CNS), the haematopoietic (blood cell formation) system and immune system. The bone marrow is the target organ for the expression of benzene haematotoxicity and immunotoxicity, which are consistently reported to be the most sensitive indicators of non-cancer toxicity in both humans and experimental animals.

Benzene is a well-established human carcinogen and is classified as a known human carcinogen (Class 1, Group A) by [5]. Epidemiological studies of benzene-exposed workers have demonstrated a causal relationship between benzene exposure and the production of acute myelogenous leukaemia and also suggest evidence for non-Hodgkin lymphoma, chronic lymphoid leukaemia, multiple myeloma, chronic myeloid leukaemia, acute myeloid leukaemia in children, and cancer of the lung.

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 benzene in ambient air on human-health in NZ. However, there are several studies undertaken, primarily in the late 1990's and early 2000's. These studies are reported in [7]. Specifically, [7] reported that reported that benzene concentrations in Auckland, Christchurch, Hamilton, Dunedin, Nelson, the Bay of Plenty and on the West Coast mostly fell within the then current guideline value of 10 µg/m^3 annual as well as the guideline value to meet in 2010 of 3.6 µg/m^3 at most 'residential' sites. Exceedances (i.e., >10 µg/m^3) were recorded at peak traffic sites of Khyber Pass Road in Auckland (2002) and Riccarton Road in Christchurch (2001). Subsequent annual monitoring has been undertaken in Auckland to 2013 [8, 9], and Hamilton to 2021 [10]. [8] reports monitoring at 6 sites across Auckland, mostly annual sampling for 5 years. Of these Khyber Pass Road was the only site with markedly elevated concentrations; the remaining sites all showed annual average concentrations <3.6 µg/m^3 over the duration of monitoring. [9] reported monitoring undertaken at Khyber Pass Road over 2001 to 2013, and at another heavily trafficked site over 2009-2012. Benzene was considered to be elevated above guideline values in 2011. Current monitoring in Auckland comprises monthly passive sampling at three sites (two on Khyber Pass Road, one in Penrose) with benzene concentrations below detection limits at all sites in 2022 [18]. Monitoring in 2020 and 2021 found annual average benzene concentrations of 2 and 2.4 µg/m^3 [19].

Eight sites in Hamilton have been monitored over 2003 to 2020 [10]. Monitoring results show that from 2003 to 2005 benzene measured at two high-density traffic sites in Hamilton, would have breached the current National Ambient Air Quality Guideline for benzene, which is 3.6 µg/m^3 (annual average). From 2006 to 2020 annual average concentrations have been <3.6 µg/m^3 at all eight sites, with all sites being <1 µg/m^3 from 2017.

Monitoring was also undertaken at 20 site across the Taranaki in January 2019 [11]. This study determined 1-hr average benzene concentrations at the sites. The highest concentrations were observed at a petrol station, and an unused industrial site.

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 interest in monitoring benzene was stimulated by the removal of lead from petrol and recognition that lead-free petrol had higher concentrations of aromatic hydrocarbons including benzene [8]. Fuel specification regulations imposed increasingly stringent control on the benzene content of petrol, particularly from 2002, which was attributed to the marked decline in benzene concentration up to 2009 by [8]. After this time, concentrations were considered to have stabilised, with [8] suggesting that the effectiveness of reducing benzene in fuel had reached its limit of effectiveness. Continuing declines in annual average benzene concentrations was observed at 8 sites in Hamilton up to 2020 when monitoring ceased. In 2020, all annual average concentrations were <1 µg/m^3[10].

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?

Auckland Council is the only council that currently monitors benzene (along with toluene, xylene and ethylene) using passive samplers [18,19]. Similarly, annual monitoring had been undertaken in Hamilton using passive samplers until 2021. This monitoring, plus most other studies undertaken have tended to use passive samplers with the 3M organic vapour badges most popular. These badges are then sent to commercial laboratories for analysis using by extraction with carbon disulphide and analysed using Gas Chromatography Flame Ionisation Detection. This method was used in original studies by Stevenson and Narsey 1999 (cited in 10] and was further validated by [12]. However, this method is considered to be a screening method only as it does not conform to methods outlined in the Good Practice Guide [13].

A continuous sampling device – a gas chromatograph with photoionisation detector used in Khyber Pass Rd, Auckland and described in [8] is indicated to be the only method used that does conform with methods specified in [13]. However, monitoring via continuous sampling is no longer undertaken in Auckland (L. Boamponsem, Auckland Council, pers. Comm).

Other methods have also been trialled and evaluated [8, 13]

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

Given the size of the passive samplers, and the likely location of deployment i.e. near roadsides, and hence public space, it is unlikely that there would be any implementation issues associated with land access etc. Sampling may also be undertaken at existing air quality sampling sites for which access is already negotiated.

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).

Indicative monitoring costs for passive sampling were provided by Waikato Regional Council (J Caldwell, WRC, pers. com). Specifically, 3M organic vapour badges (~$90 each, available from Office Max) were exposed in duplicates at monitoring sites (8) for 3 months and then taken to Hill Labs where the volatile organic compounds (BTEX) were extracted using carbon disulphide and analysed using Gas Chromatography Flame Ionisation Detection. Lab analysis typically worked out to about $145 per badge, resulting in an overall cost of around $7000 in total. Additional costs would be incurred for staff time to deploy and collect the samplers.

The sampling and analysis costs advised by Auckland Council for monthly monitoring at two locations were ~$1,600 (L Boamponsem, AC, pers. Com). These analyses are undertaken at Watercare laboratories.

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?

Benzene is correlated with other indicators of vehicle emissions including nitrogen dioxide concentrations, black carbon and other volatile organic compounds (e.g., toluene, xylene).

Part 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 benzene in ambient air in New Zealand. Ongoing monitoring occurs in Auckland, although concentrations were below detection limits in 2022 [18]. Other than this, the most recent monitoring was undertaken in Hamilton in 2020, which showed benzene concentrations at 8 sites were <1 µg/m^3. Monitoring in Auckland includes high-traffic sites, thus, benzene concentrations more generally in New Zealand would be considered very low.

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)

New Zealand ambient air guidelines [6] originally proposed an annual average guideline value for benzene of 10 µg/m^3 with a guideline value of 3.6 µg/m^3 to be achieved by 2010. Internationally, the EU directive 2008/EC/50 provides a limit value for benzene of 5 µg/m^3 to be met from 2010. [14] also provides an overview of additional international 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 1-6). However, there are no known thresholds or tipping points (and no studies undertaken to establish these) associated with benzene 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?

Reduction of the benzene content in petrol is attributed for the main reason for observed decreases in benzene in New Zealand [8-10], with the most marked reductions occurring in the mid-2000s. Whether further changes in benzene concentrations in fuel would influence ambient benzene concentrations is unclear.

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?

Benzene emissions are considered to be primarily associated with petrol vehicle emissions, and with increasingly strict emissions control on vehicle exhaust emissions [15], along with an increasing proportion of electric vehicles, vehicle exhaust emissions could be expected to be continuing to reduce.

While benzene is also recognised to be emitted during wood-burning for residential heating, this does not appear to have a major influence on ambient air concentrations. Nonetheless, given the strong focus on reducing emissions associated with wood burning for home heating (e.g., 16, 17), it might be expected, that concentrations would decrease alongside particulate concentrations.

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

C2-(v). Internationally driven

Engine Fuel Specifications Regulations are the dominant mechanism used to affect this attribute, by specifying the maximum amount of benzene that can be present in petrol (1%).

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

Part D—Impact analysis

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

Not managing this attribute, other than through the existing fuel regulations, is unlikely to result in increased human health impacts.

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?

There are no recognized mechanisms by which benzene concentrations in ambient air in NZ would be affected by climate change.

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