5 February 2019

Ministry of Transport
Via email: maritime@transport.govt.nz

Submission to the consultation on MARPOL Annex VI: treaty to reduce air pollution in ports and harbours

Thank you for the opportunity for Auckland Regional Public Health Service (ARPHS) to provide a submission on the Ministry of Transport's consultation on MARPOL Annex VI: treaty to reduce air pollution in ports and harbours.

The following submission represents the views of ARPHS and does not necessarily reflect the views of the three District Health Boards it serves. Please refer to Appendix 1 for more information on ARPHS.

The primary contact point for this submission is:

Andrew Phillipps
Senior Policy Analyst
Auckland Regional Public Health Service
(09) 623 4600
aphillipps@adhb.govt.nz

Yours sincerely

Jane McEntee
General Manager
Auckland Regional Public Health Service

Dr David Sinclair
Medical Officer of Health
Auckland Regional Public Health Service

1 Overview

The Auckland Regional Public Health Service (ARPHS) supports New Zealand's accession to Annex VI for the following reasons:

- Maritime New Zealand will have the mandate to undertake compliance and enforcement actions around shipping emissions for New Zealand and international ships operating in New Zealand waters;
- Reduced emissions of harmful air pollutants will result in reduced adverse public health effects (and costs), including premature deaths;
- Reduced greenhouse gas emissions are a tangible action to combat climate change. Accession would support New Zealand's credibility on climate change matters, as it would demonstrate that the country takes climate change seriously and is willing to adopt international solutions to reduce greenhouse gas emissions.

ARPHS engaged an external air quality consultant to assess the public health impact for Auckland from the *implementation* of MARPOL Annex VI. Much of this submission draws upon the consultant's work, and is primarily focussed on question five of the Ministry of Transport's consultation document, which is determining the public health benefits (particularly for the Auckland region) of New Zealand acceding to Annex VI.

2 Public health impact from shipping emissions

1. The key public health impacts arising from air emissions from shipping are:
    - Effects from harmful emissions;
    - Effects from climate change caused by greenhouse gas emissions.

Effects associated with harmful emissions

2. Air pollutants emitted from fuel combustion in shipping that can cause adverse human health effects include particulate matter (PM_{10}, $PM_{2.5}$), nitrogen oxides (NO_x), sulphur dioxides (SOx), carbon monoxide (CO), and volatile organic compounds (VOC), heavy metals such as mercury and lead, and dioxins. The effects of harmful air pollutants depend on the:
    - Composition of the pollutant mixture;
    - Level and duration of exposure; and
    - Factors relating to the sensitivity of the exposed population. Based on health reviews, the groups within the population who are more affected by air pollution than others include elderly people, children (including babies, infants and unborn babies), people with pre-existing heart or lung disease, people with respiratory conditions, asthmatics, diabetics, pregnant women and Māori.[1]

[1] MfE, 2011. "Clean healthy air for all New Zealanders". Wellington. August.

3. Long-term exposure to air pollutants may lead to serious adverse health effects, such as increased morbidity (illness) and premature deaths (loss of life), mainly related to respiratory and cardiovascular diseases.
4. Studies worldwide have shown that shipping emissions impact on the air quality of coastal areas adjacent to shipping routes, to the detriment of human health and the local environment.[2] For example, European analysis has calculated that shipping emissions cause about 50,000 premature deaths per year in Europe,[3] out of the estimated 680,000 premature deaths in Europe from air pollution.
5. Shipping emissions impact not only the levels and composition of particulate and gaseous pollutants but may also enhance new particle formation processes in urban areas. Emissions of NO_x contribute to the formation of secondary particles and ozone, resulting in higher levels of respiratory and cardiovascular disease among the population, especially in coastal states. Sulphur dioxide is also known for its role in secondary (fine) particulate formation, which, in turn particulate matter is a known carcinogen.
6. See Appendix 2 for more information on the health impacts from the different air pollutants associated with shipping.

Effects associated with greenhouse gas emissions

7. Greenhouse gases emitted from fuel combustion in shipping include carbon dioxide, methane, nitrous oxide and black carbon. The United Nations estimates that maritime transport is currently responsible for 2.5% of global CO_2 equivalent emissions. While this seems low, if the international shipping industry was treated as a country it would be the sixth largest emitter of CO_2 in the world, and its emissions are projected to grow by up to 250% by 2050 with rising demand.[4]
8. Climate change is expected to have direct and indirect health impacts through a number of areas in New Zealand – see Appendix 3 for more detail. ARPHS therefore strongly supports international regulations that seek to reduce both harmful and greenhouse gas emissions from ships.

3 Calculating the public health benefits for Auckland's population

Potential population exposure for Auckland

9. The Auckland waterfront is at the heart of the central business district and includes a series of wharves servicing local ferries, tourist operators, a hotel and cruise ships as well as the port itself.
10. Auckland is the second largest container port and the most popular cruise destination in New Zealand. Ports of Auckland Limited (POAL) handled 580,351 containers in 2017 (up 3.9% on 2016

[2] Viana M. *et al*, 2014. "Impact of maritime transport emissions on coastal air quality in Europe". June. [Online: Retrieved 19 December 2018]
[3] Brandt J et al, 2013. "Assessment of past present and future health cost externalities of air pollution in Europe and the contribution from international ship traffic using the EVA model system". *Atmos Chem & Physics.* 13(15):7747-7764. August.
[4] United Nations, 2018. "UN Climate Change News". 10 April 2018. [Online: Retrieved 19 December 2018]

and 7.1% on 2010).[5] In addition, Auckland hosted cruise ships on 142 days during the 2016/17 cruising season, with port days projected to increase to 179 in 2017/18 (up 26% on 2016/17) then 185 in 2018/19.[6]

11. At the same time that container volumes and cruise ship movements have increased in Auckland, local populations have also increased. The resident population of the Auckland urban area has increased from 1.33 million as at June 2010 to 1.54 million as at June 2017 (up 15 %).[7]

12. A conservative estimate (i.e. likely underestimate) is that around 100,000 people live and work within three kilometres of the Port of Auckland.[8]

Effects on Auckland's air quality (Auckland Council report)

13. Auckland Council reviewed research and monitoring on the effects of shipping on air quality in Auckland in 2017.[9] The report encompassed studies undertaken between 2006 and 2016 and found:

    - Concentrations of SO_2 are higher in locations close to the Auckland waterfront, particularly when the wind is coming from a north-east direction, with concentrations up to four times higher than at other sites across Auckland;
    - The elevated levels of SO_2 are most likely as a result of emissions from vessels docked at the container port or the cruise ship berthing wharves;
    - Source apportionment investigations have confirmed elevated levels of vanadium and nickel (recognised internationally as being associated with shipping emissions and therefore used as an elemental "ship sulphate" signature) at waterfront and Queen Street locations;
    - Ships have been observed to be emitting visible smoke whilst berthed;
    - Shipping emissions interact with and contribute to Auckland's air pollution while the ships are under propulsion in shipping lanes approaching and leaving the port.

14. The report concludes that shipping emissions from near-port and docked vessels do impact and degrade the air quality of Auckland.

Local topographical effects in central Auckland

15. An additional consideration in central Auckland is that Auckland City Hospital and Starship Children's Hospital are located at the top of Grafton Gully approximately 2.5 kilometres south of

---

[5] Ministry of Transport, 2018. "Annual port container volumes". [Online: Retrieved 13 December 2018].
[6] M.E Consulting, 2017. "Cruise Tourism Contribution to NZ's Economy". August. [Online: Retrieved 19 December 2018]
[7] Statistics New Zealand, 2018.
[8] This figure is based off 2013 Census data, and assumes residents living within 3km of Auckland port might reasonably be affected by shipping emissions. It includes a rough estimate of the CBD working population in Auckland, with the number multiplied by 1/3 to account for city commuters only being exposed for 8 hours out of a possible 24 hours to harmful ship emissions.
[9] Talbot N, Reid N, 2017. "Effects of shipping on Auckland's air quality 2006-2016". Prepared for Auckland Council. Auckland. March. [Online: Retrieved 19 December 2018]

the Auckland container port. The hospitals are downwind of the port during north to northeast winds and sea breezes. Grafton Gully is already affected by high vehicle emissions from the motorway system, and port emissions could be expected to be additive. A 'canyoning' effect is likely. NIWA has undertaken some monitoring of emission plumes from the port, but results for the Grafton area are not yet available.

Future trends in annual shipping emissions for Auckland and the estimated health impact of implementing MARPOL Annex VI

16. ARPHS's air quality consultant has estimated the likely public health benefits for the Auckland region over time from shipping emission reductions through the implementation of MARPOL annex VI. Importantly the emission improvements used to calculate the public health benefits are based on a number of key assumptions. See Appendix 4 for the methodology used.

17. From the implementation of MARPOL, it is estimated that the annual public health benefit for Auckland in 2026 alone will be NZ $58 million (NZD 2015), with this figure rising to NZ $77 million in 2040.

4 What are the public health benefits of acceding to Annex VI?

18. We note the Ministry of Transport states that New Zealand's international trade is almost entirely carried on ships registered to States that have acceded to Annex VI. Assuming these vessels are compliant with Annex VI requirements while in New Zealand waters (i.e. operating as if they are in a Party State) then the main reduction in harmful emissions from New Zealand acceding to Annex VI is likely to be derived from the domestic shipping fleet.

19. Table 1 presents harmful emissions arising from domestic shipping from the recent air domain report (Our Air 2018) published by the Ministry for the Environment and Statistics New Zealand.[10] This is based on a national emissions inventory prepared by Emission Impossible Ltd for the Ministry for the Environment (EIL, 2018).[11]

Table 1 Relative contribution of annual domestic shipping to total anthropogenic emissions 2015 (EIL, 2018)

Emissions (t/yr)	PM_{10}	$PM_{2.5}$	CO	NO_x	SO_2
Domestic shipping	828	748	1,089	11,564	10,114
All anthropogenic sources	46,099	34,504	531,493	121,364	49,946
Relative contribution	**2%**	**2%**	**0%**	**10%**	**20%**

Note: the shipping emissions in the above table assume an average fuel sulphur content of 3.5 %.

[10] Ministry for the Environment (MfE) and Statistics New Zealand, 2018. "Our Air 2018". Wellington. October. [Online: Retrieved 13 December 2018]

[11] Emission Impossible Ltd, 2018. "National air emissions inventory 2015". Prepared for the Ministry for the Environment. Auckland. October. [Online: Retrieved 13 December 2018]

20. The table shows that domestic shipping alone is an appreciable contributor to NO_x and SO_2 emissions relative to other anthropogenic air emission sources.

21. However, New Zealand should not assume that inspection regimes at Port State Control countries that are a party to Annex VI will ensure international ships (either flagged to a Party State or not) operate in line with MARPOL Annex VI regulations while in New Zealand waters. A recent media article[12] noted that cruise ships operating in New Zealand waters had breached Annex VI regulations in Alaska.

22. We understand MARPOL Annex VI regulations allow a ship in port to be inspected by officers for the purpose of verifying whether the ship has emitted any substance that would violate the provisions of Annex VI. The ability to enforce Annex VI provisions would remove any uncertainty around whether ships are complying with the regulations in New Zealand waters. As Marten[13] (2016) states:

    "...in the air pollution context it is port States that are best placed to regulate vessels, as opposed to flag States. A flag State, relying on regular class surveys for example, is in a good position to ensure that vessels have particular equipment fitted, such as the shipboard incinerator requirements of Annex VI. However, given that most vessels operate independently of their flag States for the majority of their voyages, flag States are not well positioned to regulate ongoing operational matters, such as fuel use or ongoing engine emissions. For example, a vessel that was carrying MARPOL-compliant fuel at the time of its most recent flag survey might have switched to a lower-grade fuel shortly afterwards. Only port State control inspections have the capacity to monitor such requirements on a regular basis, which is something that New Zealand should be considering in the context of Annex VI. Vessels are capable of carrying different quality fuels in different tanks, and switching to the lower-quality one where regulation is light or non-existent to save costs. If New Zealand does not adopt Annex VI then there is no guarantee at all that vessels visiting New Zealand – which is of course a considerable distance from other countries – will not switch to lower-quality fuel for voyages to this part of the world. The 'free rider' approach outlined in the Ministry of Transport's advice will therefore be of limited assistance."

23. Also of concern is that some ocean-going ships which visit Auckland are registered in countries with questionable compliance with international shipping regulations and standards (i.e. ships which carry flags of convenience), so compliance monitoring by country of registration should not necessarily be relied on.

24. Finally, we agree with the statement made in the consultation documentation that acceding to Annex VI would align with New Zealand's stated ambition to be a global leader on climate change, and strengthen its credibility and influence in international climate negotiations. Furthermore, accession would also align with the following:

---

[12] Cropp A, 2018. "Cruise ship pollution in the spotlight after vessels busted in Alaska come to NZ". Stuff. 27 October. [Online: Retrieved 25 January 2019]

[13] Marten, B. (2016) Shipping and Air Pollution: New Zealand's Failure to Ratify Marpol Annex VI. 30 Australia and New Zealand Maritime Law Journal 90; Victoria University of Wellington Legal Research Paper No. 3/2018. Available at SSRN: https://ssrn.com/abstract=3059252

- New Zealand is about to implement a Zero Carbon bill that will require us to start addressing emissions wherever opportunities present themselves in order achieve real reductions in emissions by 2050;
- New Zealand has a moral obligation to Pacific Island countries to show leadership and to support them.

25. In summary, ARPHS considers there are three reasons why New Zealand should accede to Annex VI as a means to support better public health outcomes:

    1. Maritime New Zealand will have the mandate to undertake compliance and enforcement actions for New Zealand vessels and for international ships operating in and around New Zealand. This will also provide certainty as to whether the assumed public health benefits (derived from the majority of international ships being flagged to states that have signed up to Annex VI) are realised (possibly more important if ships choose to use scrubbers to achieve compliance with the 2020 sulphur limit requirement);
    2. A reduction in harmful domestic and international shipping emissions would be achieved;
    3. It would support a reduction in greenhouse gas emissions from ships and New Zealand would obtain credibility to advocate for climate change initiatives at an international level.

5 Other questions from consultation document

Question 6: What are the public health costs of acceding to Annex VI?

26. ARPHS has not identified any specific public health costs of acceding to Annex VI.

27. A useful comparison could be made with the change to low sulphur diesel initially in the Auckland region, then to the rest of the country in the 1990s. This change was expected to produce significant public health benefits. The change was supported by health services but opposed by some in the transport industry because of cost. However, the overall cost to industry was relatively low, and there was a fairly rapid displacement of high sulphur diesel fuel.

Question 38: If New Zealand is to accede to Annex VI, is 2021 a reasonable timeframe to bring the requirements into effect? Please provide your reasons for your answer.

28. ARPHS considers this timeframe could be shortened given most international ships that visit New Zealand should have already complied with Annex VI.

29. Further, the Ministry's discussion document identified fewer than 50 ships which will require regulation. This suggests compliance will not be particularly onerous.

30. January 2020, which ties in with the commencement of Annex VI regulations, is a more reasonable date.

Conclusion

31. Thank you for considering our submission on the Ministry of Transport's consultation on MARPOL Annex VI: treaty to reduce air pollution in ports and harbours.

Appendix 1: Auckland Regional Public Health Service

Auckland Regional Public Health Service (ARPHS) provides public health services for the three district health boards (DHBs) in the Auckland region (Counties Manukau Health, Auckland and Waitemata District Health Boards).

ARPHS has a statutory obligation under the New Zealand Public Health and Disability Act 2000 to improve, promote and protect the health of people and communities in the Auckland region. The Medical Officer of Health has an enforcement and regulatory role under the Health Act 1956 and other legislative designations to protect the health of the community.

ARPHS' primary role is to improve population health. It actively seeks to influence any initiatives or proposals that may affect population health in the Auckland region to maximise their positive impact and minimise possible negative effects.

The Auckland region faces a number of public health challenges through changing demographics, increasingly diverse communities, increasing incidence of lifestyle-related health conditions such as obesity and type 2 diabetes, infrastructure requirements, the balancing of transport needs, and the reconciliation of urban design and urban intensification issues.

Appendix 2: Health effects from air pollutants associated with shipping

Different air pollutants produce different health effects (see **Figure 1**):

- Carbon monoxide (CO) is a gas that is readily absorbed from the lungs into the bloodstream. It attaches more readily to haemoglobin in the blood than oxygen and can cause headaches, dizziness, weakness and aggravate heart conditions.[14]

- Nitrogen dioxide (NO_2) is a gas that causes increased susceptibility to infections and asthma. It reduces lung development in children and has been associated with increasingly more serious health effects, including reduced life expectancy.[15]

- Sulphur dioxide (SO_2) is a gas that can aggravate respiratory and cardiovascular conditions. It can trigger bronchospasm in asthmatics and its effects are heightened by exercise. Sulphur dioxide also forms secondary (fine) particulate matter. [16]

- Volatile organic compounds (VOCs) include a wide range of chemicals, some of which are carcinogenic to humans. Of most concern are benzene,[17] formaldehyde,[18] 1-3 butadiene[19] and polycyclic aromatic hydrocarbons (**PAHs**) which include benzo(a)pyrene (**BaP**). VOCs can also react with NO_X in the presence of sunlight to form ozone (**O_3**) which is a lung irritant.[20]

- Particulate matter (PM_{10} and $PM_{2.5}$) impacts predominantly on respiratory and cardiovascular systems. Effects can range from reduced lung function to increased medication use to more hospital admissions through to reduced life expectancy and death.[21]

- Heavy metals such as lead and mercury are a threat to the development of the child in utero and early in life. Lead is a cumulative toxicant that affects multiple body systems and can cause adverse neurological and behavioural effects in children.[22] Mercury may have toxic

---

[14] For further information on health effects, please refer WHO, 2004. "Environmental Health Criteria 213. Carbon Monoxide (Second Edition)".

[15] (UK) Committee on the Medical Effects of Air Pollutants, 2015. "Statement on the evidence of effects of nitrogen dioxide on health". Public Health England. March.

[16] For further information on health effects of sulphur dioxide, please refer WHO, 2006. "Air Quality Guideline Global Update 2005" at page 398. See also WHO, 2013. "Review of evidence on health aspects of air pollution – REVIHAAP Project" at page 142.

[17] For further information on health effects of benzene, please refer WHO, 2010. "Exposure to Benzene: A Major Public Health Concern." See also IARC, 2018. "IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Vol 120 Benzene."

[18] For further information on health effects of formaldehyde, please refer WHO, 2000. "WHO Guidelines for Indoor Air Quality. Selected Pollutants." At page 110. See also IARC, 2012. "IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Vol 100F-29, Formaldehyde."

[19] For further information on health effects of 1,3-butadiene, please refer WHO, 2001. "1,3-Butadiene: Human Health Aspects."

[20] For further information on health effects of ozone, please refer WHO, 2006. "Air Quality Guideline Global Update 2005" at page 314.

[21] For further information on health effects of particulate matter, please refer WHO, 2006. "Air Quality Guideline Global Update 2005" at page 247. See also WHO, 2013. "Review of evidence on health aspects of air pollution – REVIHAAP Project" pp 6-46.

[22] For further information on health effects of lead, please refer WHO, 2010b. "Exposure to lead: A major public health concern."

effects on the nervous, digestive and immune systems, and on lungs, kidneys, skin and eyes.[23]

- Dioxins are highly toxic and can cause reproductive and developmental problems, damage the immune system, interfere with hormones and also cause cancer.[24]

Particulate Matter

Adverse health effects caused by particulate matter are dependent on its size and its ability to act as a carrier for other pollutants. Larger particles (between 2.5 and 10 μm in size) generally deposit in the upper airways but particles 2.5 μm and smaller penetrate more deeply into the lungs. Ultrafine particles ($PM_{0.1}$) with diameters less than 0.1 μm can pass through pulmonary tissue, enter the bloodstream, and circulate throughout the body. In addition, toxic substances can be carried into the lungs attached to the particles or as vapour. One example is mercury which is present in variable amounts in fuel oils.

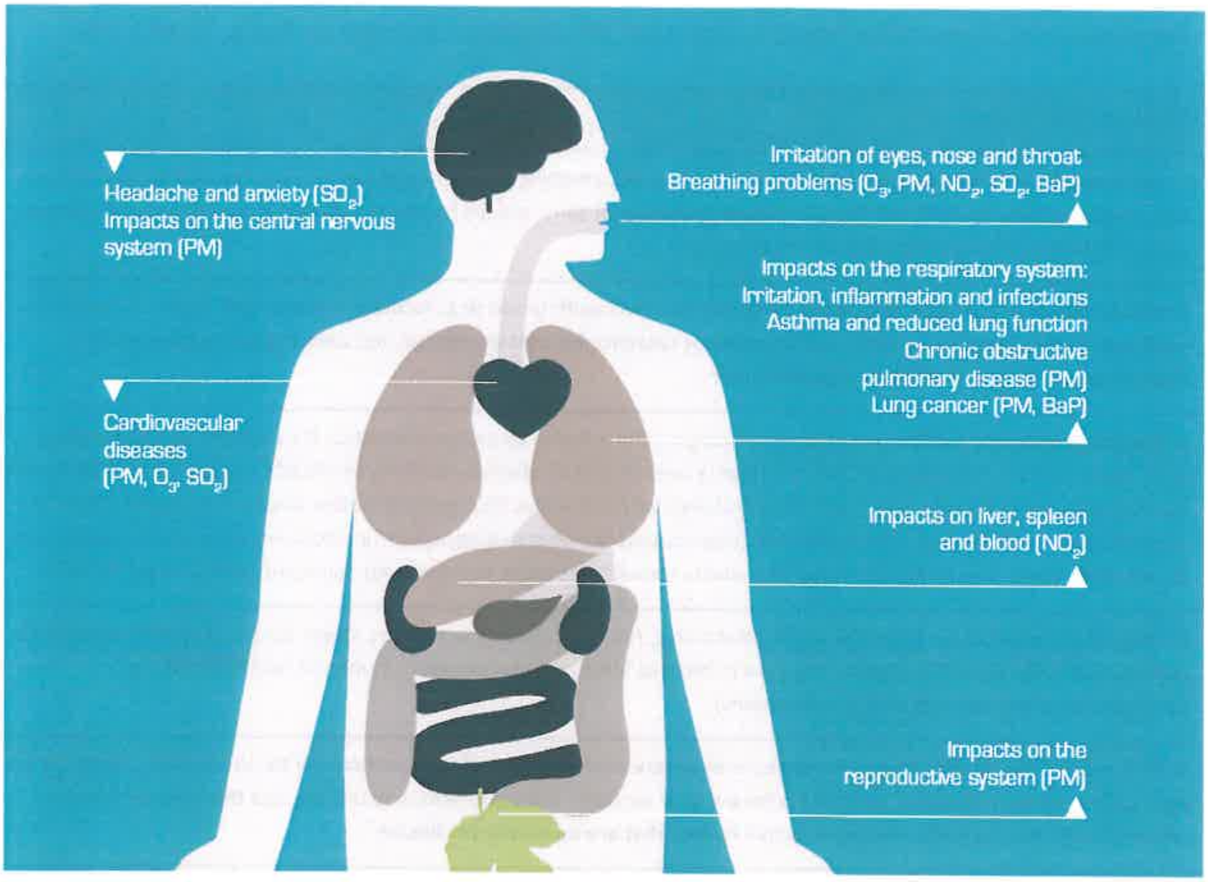
Current estimates suggest that the most significant health impacts, in terms of the burden on the health system and society, arise from particulate matter (PM_{10} and $PM_{2.5}$). However, concern about exposure to NO_2 is increasing. A recent study found nearly 9,500 people die prematurely each year in London due to long-term exposure to air pollution – more than twice as many as previously thought, once both NO_2 and PM effects were accounted for.[25]

---

[23] For further information on health effects of mercury, please refer WHO, 2017. "Mercury and Health." and "Mercury: Most recent WHO evaluation and risk assessment documents".

[24] For further information on health effects of dioxins, please refer WHO, 2016. "Dioxins and their effects on human health".

[25] Kings College London, 2015. "Understanding the health impacts of air pollution in London". Prepared for Transport for London and the Greater London Authority. London. UK. July. [Online: retrieved 19 December 2018]



- Figure 1: Examples of the health impacts associated with air pollution (EEA, 2013)

Note: BaP = benzo(a)pyrene, NO_2 = nitrogen dioxide, O_3 = ozone, PM = particulate matter, SO_2 = sulphur dioxide

The specialised cancer agency of the World Health Organization – the International Agency for Research on Cancer (IARC) – announced in 2013 that it had classified outdoor air pollution as carcinogenic to humans (Group 1), due to evidence linking it to lung cancer and associating it with bladder cancer.[26] In a separate evaluation, particulate matter was also classified as carcinogenic to humans (Group 1). IARC acknowledged that whilst the composition of air pollution and levels of exposure vary dramatically between locations, these classifications apply to all regions of the world. IARC had already classified diesel engine exhaust as carcinogenic to humans (Group 1) in 2012.[27]

---

[26] International Agency for Research on Cancer (IARC), 2013. "Outdoor air pollution a leading environmental cause of cancer deaths". Lyon. France. October.
[27] IARC, 2012. "Diesel engine exhaust carcinogenic". Lyon. France. June.

Appendix 3: Expected health impacts of climate change in New Zealand

Expected health impact
1. Food security and nutrition: Increased global food prices, affecting a large number of locally produced and imported food staples in New Zealand, are likely to reduce the ability of some groups to afford a variety of nutritious foods, further compromising nutritional outcomes for those groups.
2. Mental health and suicide: Increased stress and mental health issues (e.g. farmers with drought, victims of extreme weather). Young people may suffer anxieties about catastrophic climate change, not unlike those experienced by children growing up with the fear of nuclear war.
3. Housing and health: Healthiness of some housing will be affected by extreme weather, for example, indoor moisture (with heavy rainfall, flooding), high indoor temperatures (during heatwaves in poorly insulated houses). It is also likely that people will arrive in New Zealand from climate-change affected areas. This may put further pressure on availability of low income-larger family homes, potentially impacting household overcrowding and the incidence of some infectious diseases. On the other hand, improvements in housing quality through insulation requirements could provide for health benefits.
4. Injury and illness from extreme weather events (e.g. flooding, storms, landslides, storm surges, drought): Immediate trauma, and indirect health impacts in weeks to months after extreme events (e.g. mental health problems, exacerbation of pre-existing medical conditions).
5. Heat-related deaths and illness: Increases in heat-related deaths and illness, particularly for those with chronic illness and those aged over 65 years. Heat stress for outdoor workers. Winter deaths may decline, but this is uncertain as winter deaths may be influenced by seasonal factors that are unrelated to climate.
6. Vector-borne and zoonotic (animal to human) disease: Increased likelihood that mosquito vectors could establish in New Zealand, which could lead to local transmission of mosquito-borne diseases (e.g. dengue, Ross River virus). Also possible impacts on other vector-borne diseases (e.g. tick-borne) and zoonotic diseases.
7. Food- and water-borne disease: Heavy rainfall can lead to contamination of drinking and recreational water/shellfish with faecal pathogens from animals and humans. Both high and low rainfall, and higher temperatures may impact on bacterial and parasitic diseases causing gastroenteritis (e.g. giardiasis, salmonellosis). Dry conditions could affect continuity of household water supplies, impacting diseases influenced by hygiene.
8. Ultraviolet (UV) radiation: Climate change may delay recovery of stratospheric ozone. Warmer temperatures could promote increased or decreased outdoor time, affecting exposure to solar ultraviolent (UV) radiation—with possible impacts on rates of skin cancer, eye disease, and vitamin D levels.
9. Physical activity: Warmer temperatures, and either increases or decreases in outdoor time, may impact on levels of recreational physical activity—an important determinant of health.
10. Cardio-respiratory disease from air pollution: High temperatures can exacerbate photo-chemical air pollution with impacts on respiratory disease. Hot, dry conditions increase potential for bush/forest fires, where smoke impacts on people with cardiorespiratory disease.
11. Allergic diseases, including asthma: Possible impacts on allergic conditions with changes in plant distribution, flowering, and pollen production.
12. Indoor environment: Climate change may affect the healthiness of indoor environments (e.g. overheating of buildings, changes in indoor air pollutants, flood damage and indoor moisture).

Appendix 4: Methodology for calculating public health benefits for Auckland population

Trends in shipping emissions

Shipping emissions have been quantified in an inventory commissioned by Auckland Council (Peeters, 2018).[28] The inventory includes emissions from ships for a base year of 2016, with predictions for 2026, 2036 and 2040.[29]

Table 2 summarises the annual emissions estimates for different shipping sources in the Auckland region.

Table 2 Annual combined emissions from shipping in the Auckland region 2016 to 2040 (Peeters, 2018)

Year	Source	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2
					(tonnes/year)			
2016	OGV at-sea	1,300	125	116	62	133	906	57,474
	OGV at-berth	488	53	48	15	40	472	34,231
	Harbour vessels	46	1	1	5	157	0	3,999
	Ferries	461	9	8	15	116	0	32,668
	Fishing boats	72	5	5	72	284	0	6,118
	Total for 2016	**2,368**	**192**	**178**	**169**	**730**	**1,378**	**134,489**
2026	OGV at-sea	1,462	83	77	82	173	225	74,860
	OGV at-berth	416	25	23	17	45	110	39,377
	Harbour vessels	61	1	1	7	210	0	5,428
	Ferries	536	11	11	19	173	0	41,815
	Fishing boats	57	3	3	38	203	0	6,118
	Total for 2026	**2,532**	**124**	**115**	**162**	**804**	**335**	**167,598**
2036	OGV at-sea	1,767	103	95	101	214	279	92,352
	OGV at-berth	372	17	16	15	40	19	34,336
	Harbour vessels	75	2	2	9	261	0	6,881
	Ferries	549	13	13	24	369	0	50,962
	Fishing boats	59	1	1	15	188	0	6,118
	Total for 2036	**2,822**	**137**	**126**	**163**	**1,072**	**298**	**190,649**

[28] Peeters S, 2018. "Auckland air emissions inventory 2016 - Sea transport". Prepared for Auckland Council. July. [Online: Retrieved 13 December 2018].
[29] *Ibid.*

Year	Source	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2
2040	OGV at-sea	1,878	111	102	109	229	299	99,044
	OGV at-berth	309	15	14	12	33	16	28,546
	Harbour vessels	82	2	2	9	279	0	7,439
	Ferries	588	14	14	25	395	0	54,555
	Fishing boats	59	1	1	15	188	0	6,118
	Total for 2040	**2,916**	**143**	**133**	**171**	**1,126**	**316**	**195,703**

Note: OGV = ocean going vessel

The emissions estimates (in **Table 2**) show the likely improvement in shipping emissions in Auckland due to the implementation of MARPOL Annex VI (as well as the implementation of shore power, also known as hotelling/"cold ironing"). It is important to note these emissions improvements are based on a number of key assumptions (from Peeters, 2018), which follow:

For ocean going vessels (**OGVs**) in 2016:

- an average sulphur content of 2.7% in heavy fuel oil

For OGVs for 2026, 2036 and 2040:

- Cruise ship visits will increase from 99 in 2016 to 150 in 2030, with the number of visits for 2036 and 2040 linearly extrapolated.
- POAL terminal capacity will grow to two million TEU[30] by 2044 from 926,151 in 2016.
- Vehicle imports will grow from 269,939 in 2016 to 341,000 in 2041.
- Bulk carrier, general cargo and tanker activity will experience a similar growth as vehicle carriers.
- Hotelling – shore power infrastructure as follows:
    - 50% of cruise ships will use shore power in 2026.
    - 50% of cruise, container and reefer vessels will use shore power in 2036.
    - 50% of all OGVs will use shore power in 2040.
- OGVs visiting Auckland will be progressively compliant with MARPOL Annex VI NOx emission standards. Compliance will be achieved through using low sulphur fuel and/or other technical implementations such as scrubbers.
- The sulphur content of marine fuels sold worldwide will be capped at 0.5 % from 2020. Sulphur emissions for 2026, 2036 and 2040 are based on a sulphur content of 0.5 %.
- By 2040, all OGVs visiting Auckland will still be powered by engines using petroleum-based fuels.

[30] 1 TEU = 20-foot-long (6.1m) shipping container

Since the development of the Auckland inventory, Ports of Auckland Ltd have set a goal to be a zero emissions port by 2040, which is a world-first. [31] This commitment, undertaken voluntarily by Ports of Auckland Ltd, will significantly reduce both harmful and greenhouse gas emissions to air from cargo and cruise ships. It also provides some certainty for the reductions estimated in **Table 2**, especially for OGVs in port.

Estimated health impacts of shipping emissions

The emissions estimates (shown in **Table 2**) can be combined with damage costs (**Table 5 in Appendix 5**) to indicate the public health *costs* associated with shipping emissions in Auckland. The difference in these values, for different years, can then be used to estimate the likely *benefits* of emissions reductions – for example, from the implementation of MARPOL Annex VI.

Damage costs are a way to value changes in emissions in order to compare the benefits to society of a change in policy/operation versus the cost of implementing the change.

Damage costs are the impact to society as a result of the "emission" under consideration. Exposure to the emission increases the (public health) burden of morbidity (illness) and mortality (death) and results in additional health costs (e.g. from increased medication or hospitalisations) as well as lost social and economic productivity. In the case of greenhouse gases, the damage costs relate to the effects of climate change on the well-being of society (and not the costs associated with complying with any carbon tax or emission trading scheme requirements which would be separate).

New Zealand does not have national published damage cost values. However, air emissions damage costs were developed for Greater Wellington Regional Council (**GW**) as part of their evaluation of transport emissions (refer **Table 5**).[32] These factors were developed from international literature and relevant local data, notably the Health and Air Pollution in New Zealand Update study.[33]

The air emissions damage cost values were reviewed and approved by the NZ Transport Agency (NZTA). In the absence of any other data, these provide a suitable basis for valuing public health benefits of emission reductions associated with New Zealand acceding to Annex VI.

In addition to the damage costs developed for Wellington, we have incorporated a damage cost for SO_2 from the Department for Food and Rural Affairs (**DEFRA**) in the United Kingdom[34] as follows:

- 2015 DEFRA damage costs £1,956 per tonne SO_2 (average across whole UK);
- Converted to NZD using a currency conversion factor of 0.4955 (three-year average for 2013 – 2015); and
- 2015 damage cost of NZD $3,947 per metric tonne SO_2.

The public health costs associated with shipping emissions in Auckland can then be estimated by combining the annual emissions (**Table 2**) with the damage costs (**Table 5**) then applying a discount

[31] Ports of Auckland Ltd, 2018. "Port joins coalition to fight climate change". July. [Online: Retrieved 21 December 2018]
[32] Kuschel et al, 2017. "Evaluating Bus Emissions". Paper by G Kuschel, A Cooper and J Metcalfe presented at the Australasian Transport Research Forum. Auckland. 27-29 November 2017. Available at: https://atrf.info/papers/2017/index.aspx.
[33] Kuschel et al, 2012. "Updated Health and Air Pollution in New Zealand Study". Auckland. New Zealand. March.
[34] Department Environment, Food and the Regions (DEFRA), 2015. "Air quality: economic analysis". London. September. Transport average (Central). [Online: Retrieved 20 December 2018]

rate of 3 % per annum[35] to the various years and all figures are adjusted to New Zealand dollars as at 2015.

Table 3 shows the estimated public health *costs* associated with shipping emissions in Auckland for the four "snap shot" years covered by the Auckland air emissions inventory:

- 2016 - before the fuel sulphur regulations in MARPOL Annex VI come into force; and
- 2026, 2036 and 2046 - after new MARPOL Annex VI regulations take effect.[36]

The public health *benefits* of implementing MARPOL Annex VI in Auckland can then be established relative to 2016 (pre the regulations being in force) by considering the *difference* in estimated annual public health costs for each year (relative to 2016).

Table 3 Estimated annual public health costs associated with shipping emissions in Auckland

Year	NO_x	PM_{10}	VOC	CO	SO_2	CO_2	Total
				(NZD Million 2015)			
2016	38.0	86.6	0.2	0.0	5.4	8.9	
2026	30.2	41.6	0.2	0.0	1.0	8.2	**81**
2036	25.0	34.2	0.1	0.0	0.7	7.0	**67**
2040	23.0	31.7	0.1	0.0	0.6	6.4	**62**

Table 4 Estimated annual public health benefits associated with implementing MARPOL Annex VI in Auckland relative to 2016

Year	NO_x	PM_{10}	VOC	CO	SO_2	CO_2	Total
				(NZD Million 2015)			
2016	0.0	0.0	0.0	0.0	0.0	0.0	**0**
2026	7.8	45.0	0.1	0.0	4.5	0.6	**58**
2036	12.9	52.4	0.1	0.0	4.8	1.9	**72**
2040	15.0	54.9	0.1	0.0	4.8	2.5	**77**

Table 4 shows that if MARPOL is implemented, and then the annual public health benefit in 2026 alone will be NZ $58 million (NZD 2015). This figure rises to NZ $77 million in 2040 (NZD 2015).

NB: These estimates also assume that the assumptions in the Auckland shipping inventory hold true.

[35] A discount rate of 3% per annum is consistent with the discount rate that typically applies year to year with the Ministry of Transport Value of a Statistical Life (VoSL) used for valuing road crash mortality.

[36] NB: The Auckland inventory also incorporates moves to shore power for OGVs while in berth from 2026.

Appendix 5: Damage costs

Table 5 shows the damage costs developed for a Wellington transport emissions evaluation that was reviewed and approved by NZTA. In the absence of any other data, these provide a suitable basis for valuing public health benefits of emission reductions associated with the implementation of MARPOL Annex VI.

Table 5 also provides a comparison with existing (2015) published damage costs for the United Kingdom.

Table 5 Estimated social (damage) costs of emissions in NZD/tonne (2015) used in Wellington compared with UK values adjusted to NZD (2015)

Pollutant	New Zealand Costs in NZD/tonne[1]	United Kingdom Costs in NZD/tonne[2]	Value Base Date
CO_2	$66	-	2015
PM_{10}	$451,123	$126,846	2015
NO_X	$16,031	$55,107	2015
CO	$4.16	-	2015
Hydrocarbons*	$1,318	-	2015
SO_2	-	$3,947	2015

Note:
[1] Kuschel et al, 2017[37].
[2] DEFRA, 2015.[38] £1,956 central value converted to NZD (2015) based on GBP (3-year average 2013-2015) currency conversion 0.4955.
* Essentially equivalent to volatile organic compounds (VOCs)

[37] Kuschel et al, 2017. "Evaluating Bus Emissions". Paper by G Kuschel, A Cooper and J Metcalfe presented at the Australasian Transport Research Forum. Auckland. 27-29 November 2017. Available at: https://atrf.info/papers/2017/index.aspx
[38] Department Environment, Food and the Regions (DEFRA), 2015. "Air quality: economic analysis". London. September. Transport average (Central). [Online: Retrieved 20 December 2018]