IN THE ENVIRONMENT COURT
AT AUCKLAND **ENV: 2023-AKL-00160**

I TE KŌTI TAIAO O AOTEAROA
TĀMAKI MAKAURAU ROHE

IN THE MATTER	of the Resource Management Act 1991 (the Act)
AND	
IN THE MATTER	A resource consent application by way of direct referral under s 87G of the Act
BETWEEN	**ALLIED ASPHALT LIMITED**
	Applicant
AND	**BAY OF PLENTY REGIONAL COUNCIL**
	TAURANGA DISTRICT COUNCIL
	Consenting Authorities

STATEMENT OF EVIDENCE OF CHARLIE LOU WICKHAM
NATIONAL PUBLIC HEALTH SERVICE – TOI TE ORA PUBLIC HEALTH
11 April 2024

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STATEMENT OF EVIDENCE OF CHARLIE LOU WICKHAM

INTRODUCTION

1. My full name is Charlie Lou Wickham, and I am referred to as Lou Wickham.

2. I am a Director and Senior Air Quality Specialist at Emission Impossible Ltd. I am subcontracted by the Institute of Environmental Science and Research (**ESR**) to provide independent air quality advice to Te Whatu Ora Health New Zealand. National Public Health Service - Toi Te Ora Public Health (**Toi Te Ora**), in turn, have engaged me through ESR to provide independent air quality advice on the application by Allied Asphalt Limited for resource consent for discharge of contaminants to air from an asphalt plant at 54 Aerodrome Road, Mount Maunganui.

Qualifications and Experience

3. I hold the academic qualifications of Bachelor of Chemical and Materials Engineering from the University of Auckland and a Master of Environmental Law from the University of Sydney. I am a certified Resource Management Act decision maker and am in my third term of appointment to Auckland Council's panel of independent commissioners. I am a member of the Institute of Directors New Zealand, the Resource Management Law Association and the Clean Air Society of Australia and New Zealand.

4. I have 30 years experience in air pollution engineering and nine years experience as a decision maker under the Resource Management Act 1991. My air quality experience is from working in New Zealand, Australia and the United Kingdom in both the private and public sectors. From 2004 to 2011, I was the Ministry for the Environment's senior adviser on air quality. During this time, I was

the Ministry's technical lead on air quality matters and played a key role in the introduction, implementation and (first) review of the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 (**NESAQ**). Since 2011, I have provided technical air quality advice to both government and private clients and published articles on air quality issues.[1] I have also continued to author, and co-author, a number of national good practice air quality guidance documents.[2]

5. To date I have acted as a commissioner for Auckland Council, Waikato Regional Council and Hawke's Bay Regional Council. These consent decisions were mostly on applications for resource consents with discharges to air and include a wide range of industries (e.g., from New Zealand Steel to a landfill and a pyrolysis plant).

6. I am familiar with air quality in the Mount Maunganui area having undertaken studies and provided advice to Toi Te Ora and the Bay of Plenty Regional Council (**BOPRC**). This most recently includes:

    a. An air pollution health risk assessment (**HRA**) for the Mount Maunganui area (ESR 2023) prepared for Toi Te Ora.[3]

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1 For example: Wickham L., 2017. New Zealand air quality case law review: what stinks and why. Resource Management Journal. April.

2 For example:

MfE, 2016. Good Practice Guide for Assessing and Managing Odour. (Lead author). Wellington. November. Available at [Online]

MfE, 2016b. Good Practice Guide for Assessing Discharges to Air from Industry. (Co-author). Wellington. November. [Online]

MfE, 2005. Updated Users Guide to Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins and Other Toxics) Regulations 2004 (Including Amendments 2005) (second draft). (Lead author). Wellington. October. [Online]

3 ESR, 2023. Air Pollution: Health Risk Assessment Mount Maunganui. Prepared for Toi Te Ora Public Health. 1 June 2023. [Online]

b. Independent reporting on (BOPRC's) ambient air quality monitoring in the Mount Maunganui Airshed for Toi Te Ora since 2016. My most recent report (ESR 2023b)[4] summarises and reviews Bay of Plenty Regional Council ambient air quality monitoring data from the Mount Maunganui Airshed for the years 2019 through 2022.

c. Preparation of independent dust audits of all industrial and commercial sites in the Mount Maunganui Airshed (including the Higgins and Allied Asphalt plants) in 2020 and the Port of Tauranga in 2016 for BOPRC (EIL 2020, EIL 2016).[5]

7. I am familiar with asphalt manufacture, having assessed multiple plant in my career, most recently providing expert advice regarding the Higgins asphalt plant application for consent.

Expert witness and air quality professional code of conduct

8. I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court of New Zealand Practice Note 2023 and that I have complied with it when preparing my evidence. Other than when I state I am relying on the advice of another person, this evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

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[4] ESR, 2023b. *Mount Maunganui Air Quality Monitoring Review 2022*. Prepared for Toi Te Ora Public Health. 22 June 2023. [Online]

[5] Emission Impossible Ltd (EIL), 2016. 2016 Dust Audit: Port of Tauranga. Prepared for Bay of Plenty Regional Council. April. [Online]

EIL, 2020. *Mount Manganui Dust General Industrial Survey* [CONFIDENTIAL]. Prepared for Bay of Plenty Regional Council. Auckland. April. NB: To maintain commercial confidentiality for the audited industries this report is not publicly available.

9. I have read the Code of Ethics and Professional Conduct for members of the Clean Air Society of Australia and New Zealand and I agree to comply with it.[6] This requires me *inter alia* to remain objective and truthful in all statements or testimony and to uphold the safety and health of the community above private or business interests in the performance of my professional duties.

Documents considered and opinions relied on

10. For the purposes of my opinion evidence, apart from my own knowledge, I have also relied on the following:

    a) Updated Air Quality Assessment (**AQA**) for existing and proposed asphalt plants, Mt Maunganui. Prepared for Allied Asphalt Ltd by Tonkin & Taylor Ltd dated January 2024, hereafter referred to as the **Allied AQA**.

    b) Health Risk Assessment (**HRA**) for existing and proposed asphalt plants, Mt Maunganui. Prepared for Allied Asphalt Ltd by Tonkin & Taylor Ltd dated January 2024, hereafter referred to as the **Allied HRA**.

    c) Statements of evidence of Ms Jenny Simpson and Dr Denison dated 29 February 2024 on behalf of Allied.

    d) Statements of evidence of Mr Robert Murray dated 21 March 2024 and Dr Emily Wilton dated 22 March 2024 on behalf of BOPRC.

    e) Air pollution health risk assessment for the Mount Maunganui area (ESR 2023), hereafter referred to as the **Mount Maunganui HRA**. This is attached as Annexure 1.

[6] https://www.casanz.org.au/certified-air-quality-professional/#code-of-ethics

f) Mount Maunganui air quality monitoring review 2022 (ESR 2023b), hereafter referred to as the **Mount Maunganui air quality review**. This is attached as Annexure 2.

g) Bay of Plenty Regional Council air quality update 2023 (BOPRC 2023).[7]

11. I participated in two expert conferences both held on 28 March 2024 and signed joint witness statements dated 5 April 2024 (Air Quality) and 7 April 2024 (Health Risk).

SCOPE OF EVIDENCE

12. My evidence will address the following:

a) Overview of the proposal and requirement for best practicable option and mitigation to the greatest extent possible.

b) Receiving environment – Mount Maunganui air quality monitoring review and Mount Maunganui health risk assessment.

c) Allied air quality assessment – emissions estimates, matters of agreement and disagreement with other experts.

d) Allied health risk assessment – matters of agreement and disagreement with other experts

e) Social costs of pollutants

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[7] Bay of Plenty Regional Council, 2023. *Ambient Air Quality Data Update 2023*. Prepared by Shane Iremonger. BOPRC Environmental Publication 2023/07. [Online]

f) Conclusions

g) Recommended conditions of consent

OVERVIEW

13. Allied Asphalt Limited (**Allied**) have significantly amended their application to Bay of Plenty Regional Council (**Council**) for consent to discharge to air since its referral to the Environment Court. The new proposed plant will have a different design, different fuel, better emissions control and a higher stack. I consider the new proposed plant is largely consistent with best practice, except for enclosed load-out and low NOx burners which are not proposed. Discharges to air from the new plant will, however, depend on the fuel employed with some pollutants being higher than others compared with the existing plant.

14. In my opinion:

    a) The existing Allied asphalt plant is 27 years old and has discharges to air that are likely causing adverse health and objectionable odour effects downwind.

    b) The new proposed Allied asphalt plant will be a significant improvement compared to the existing operation, however, the proposed increase in throughput reduces the overall benefits that could be achieved. Considering the pollutant social costs of the proposal affords an alternative way of weighing up the various options under consideration.

    c) The receiving environment is currently polluted due to the presence of existing industry (including the existing Allied plant), traffic and the Port of Tauranga. I consider this warrants the adoption of best practicable option for the existing plant seeking renewed consent. For the proposed new plant seeking new consent, I consider the receiving environment warrants mitigation to the greatest extent possible and I have recommended conditions of consent accordingly.

BACKGROUND AIR QUALITY

15. I consider the Mount Maunganui air quality review, the Mount Maunganui HRA (ESR 2023b, ESR 2023) and the 2023 ambient air quality update (BOPRC 2023), provide helpful context for the Allied application as they robustly characterise the receiving environment.

16. The Mount Maunganui HRA selected the year 2019 as the base year for quantitative risk assessment of particulate matter (**PM_{10}** and **$PM_{2.5}$**) and nitrogen dioxide (**NO_2**). At the time of preparation this was the most recent year for which there was comprehensive ambient air quality monitoring data, but which excluded step changes in emissions due to mitigation, regulatory changes and/or any changes due to activity restrictions from COVID-19. Importantly, it also avoided significantly underestimating public exposure in previous and future years.[8]

17. The Mount Maunganui air quality review shows that long-term concentrations of PM_{10} in the Mount Maunganui Airshed (**MMA**) vary spatially, being influenced by proximity to shipping activities and industrial sources. In 2019 annual concentrations of PM_{10} measured in the MMA exceeded the WHO guideline at all monitoring locations except Sulphur Point (predominantly upwind of the airshed), with higher levels recorded near the Port and/or in more industrial locations. As noted by Dr Wilton, there is not yet ten years of data on which to make a statistically valid trend analysis, but I am pleased to note that long-term concentrations of PM_{10} have

[8] Additional discussion of the base year is provided ESR, 2023. At Section 3.2.3.

declined significantly at Whareroa Marae (only) in the period 2019 – 2022.

18. The introduction of MARPOL Annex VI in January 2020, which *inter alia* mandated reductions in emissions of sulphur dioxide (**SO_2**) from ships, resulted in a step-change reduction in short-term concentrations of SO_2 at all bar two monitoring locations in the Mount Maunganui Airshed. In my opinion short-term concentrations of SO_2 at these two locations, Whareroa Marae and Tauranga Bridge Marina, remain influenced primarily by SO_2 emissions from the neighbouring fertiliser manufacturer.

19. SO_2 is a precursor pollutant[9] that contributes to the formation of $PM_{2.5}$. It is very likely that long-term concentrations of $PM_{2.5}$ also vary spatially in the MMA, however, monitoring is only carried out at one location (Totara Street) so this cannot be investigated further. In 2019 $PM_{2.5}$ measured at Totara Street complied with the WHO daily guideline but exceeded the WHO annual guideline. My trend analysis (ESR, 2023b) suggests the introduction of MARPOL Annex VI in early January 2020 may have supported reductions in $PM_{2.5}$ in the Mount Maunganui Airshed between 2019 and 2022. The use of modifiers in that sentence (suggests, may) reflect four years of BOPRC monitoring data being insufficient for statistical validity.

20. The Mount Maunganui air quality monitoring review concluded that ambient concentrations of NO_2 in Mount Maunganui warranted additional monitoring and investigation so it is pleasing to see Mr Murray's new monitoring data for NO_2 at Whareroa Marae. The new site has recorded one (minor) exceedance of the daily WHO NO_2

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[9] Precursor pollutants are substances that react chemically to form other pollutants.

guideline[10] but the limited available data suggest long-term concentrations of NO_2 at Whareroa Marae is likely to comply with the WHO annual NO_2 guideline.

21. However, given Whareroa Marae's location predominantly upwind of the key source of NO_2 in the MMA (traffic), the new data do not give me confidence that daily NO_2 concentrations in the MMA and in the Omanu residential area will be below the WHO daily guideline, particularly near the roadside. Waka Kotahi passive monitoring reports that annual NO_2 concentrations in the MMA exceed the WHO annual guideline (ESR 2023b). I therefore, consider that annual NO_2 concentrations in the Omanu residential area may also exceed the WHO guideline near roadside locations. NB: This is not reflected in the annual average in Table 1 which provides a census-area-unit average (i.e., not at the roadside where NO_2 levels will be highest).

22. Table 1 summarises the long-term concentrations for particulate and NO_2 used for quantitative risk assessment in the Mount Maunganui HRA.

[10] 3 – 4 exceedances are permitted in a year (WHO, 2021). It should be noted that exceedance of a WHO (global) air quality guideline has no regulatory status in New Zealand (which is different to a 'breach' of a national environmental standard).

Table 1 Background Concentrations Assumed in Mount Maunganui Air Pollution Health Risk Assessment (ESR, 2023)

Pollutant	Time Average	Mt M HRA 2019 Omanu Concentration ($\mu g/m^3$)	WHO Air Quality Guideline ($\mu g/m^3$)
PM_{10}	Annual	20	15
$PM_{2.5}$	Annual	6.4	5
NO_2	Annual	6.2	10

23. The Mount Maunganui HRA estimated that, compared with Otūmoetai, in Mount Maunganui there were:

    a) Around five additional premature deaths in adults (>30 years) each year associated with exposure to long-term concentrations of $PM_{2.5}$ and NO_2. For context, the total mortality from all non-external causes[11] in Mount Maunganui for the year 2019 was 145 so this estimate represents around 3% of deaths in that year.

    b) An additional four cardiovascular and six respiratory hospitalisations per year associated with long-term exposure to $PM_{2.5}$ and NO_2.

    c) An additional 1,256 restricted activity days per year across the population associated with long-term exposure to $PM_{2.5}$.

    d) Two additional cases of asthma per year in under 18-year-olds associated with long-term exposure to NO_2.

    e) Estimated social costs due to additional mortality and morbidity of $22 million (NZ$2019).

[11] i.e., deaths excluding accidents and violence

24. The Mount Maunganui HRA also presented single-pollutant modelling for PM_{10} (only) which estimated that the Mount Maunganui area had 13 additional premature deaths in adults (> 30 years) each year (95% confidence interval 11 to 15) when compared with Otūmoetai. This estimate represents around 9% of total mortality from all non-external causes in Mount Maunganui that year, which is higher than the estimates associated with long-term exposure to $PM_{2.5}$ and NO_2. It should be noted that the PM_{10} modelling is not additive to the estimate of effects associated with $PM_{2.5}$ and NO_2, rather it is a separate estimate.

25. Based on the Mount Maunganui air quality review and HRA, I consider that existing air quality in the Mount Maunganui area is degraded in comparison with other residential areas of Tauranga, with associated adverse health effects.

26. I note Dr Wilton has independently reviewed the Mount Maunganui HRA (Environet 2023)[12] and raised a number of criticisms but overall concurs that the estimates provide information on the potential scale of adverse health effects from air quality in the MMA.[13] I am comfortable with the different views expressed and, given the carefully stated limitations of the Mount Maunganui HRA, I do not consider Dr Wilton's critique material to the findings.

27. A valid concern of Dr Wilton's is that some of the analyses imply a level of accuracy that exceeds the scale of adverse effect. Overall, however, I consider the Mount Maunganui HRA serves its purpose which is to provide indicative numbers quantifying the simple

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[12] Environet, 2023. *Health risks of exposure to air pollution in the Mount Maunganui Airshed – a technical review*. Prepared for Tauranga City Council and Bay of Plenty Regional Council by Emily Wilton. March. [Appendix A to Statement of Evidence of Dr Emily Wilton dated 26 March 2024]

[13] Statement of Evidence of Dr Emily Wilton dated 26 March 2024. At [3]

premise that air pollution causes serious adverse health effects including premature mortality. In doing so, I agree with Dr Wilton's conclusion that it "supports the need to manage and minimise emissions of all contaminants in the MMA".

28. Based on the Mount Maunganui qualitative risk assessment I also consider that:

a) people living at Whareroa Marae and the Tauranga Bridge Marina may have been, and continue to be, adversely affected by SO_2 emissions.

b) industrial emissions of hydrogen sulphide (**H_2S**) regularly exceed the national guideline set to prevent against offensive odours at Whareroa Marae. This would reduce the quality of life and impact adversely on the wellbeing of Marae users, including manuhiri, and Whareroa Marae residents.

c) odour is a well-established issue in Mount Maunganui, with more than 500 complaints to the regional council each year. Based on the frequency of complaints it is apparent that offensive and objectionable odours are reducing the quality of life and adversely impacting on the wellbeing of residents in and around the Mount Maunganui Airshed.

Recent literature suggests that industrial odours are often associated with adverse health impacts in surrounding communities (Government of Alberta 2017, Guadualupe-Fernandez *et al.* 2021)[14,15]. Some chemicals, such as

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[14] Government of Alberta, 2017. *Odours and Human Health*. Environmental Public Health Science Unit, Health Protection Branch, Public Health and Compliance Division, Alberta Health. Edmonton, Alberta. [Online]

[15] Guadalupe-Fernandez et al., 2021. Industrial Odour Pollution and Human Health: a systematic review and meta-analysis. *Environmental Health*. 20:108. doi.org/10.1186/s12940-021-00774-3.

benzene, can be harmful even when present below their respective odour thresholds. This suggests that, in addition to negative impacts on wellbeing, odorous emissions may also be adversely impacting residents' health.

29. I acknowledge the concerns of Ms Awhina Ngātuere as expressed in the Joint Witness Statement (Air Quality) at the inferiority of technical assessments that neglect to consider public exposure to *all* contaminants (compared with a more holistic Te Ao Māori approach). This is a stated limitation of the Mount Maunganui HRA that bears repeating.

ALLIED AIR QUALITY ASSESSMENT

Emissions Estimates

30. The proposal has been well described by Ms Simpson in her statement of evidence dated 29 February 2024. In summary, Allied are seeking renewal of consent for their existing, 80 tonnes per hour (**tph**) waste oil-fired, continuous drum asphalt plant for two years. Following this, Allied are seeking consent for a period of 35 years for a new, 200 tph, natural gas-fired batch asphalt plant. The new plant will have improved particulate and odour mitigation and a higher stack. Allied are also seeking consent to operate the new plant on diesel if the use of natural gas becomes untenable.

31. Emissions of particulate matter (**PM**), heavy metals, sulphur dioxide (**SO_2**) and greenhouse gases from the new plant will be lower than from the existing plant despite a proposed increase in throughput from 80 tph to 200 tph. However, as noted by Dr Wilton, the actual benefits of the new plant will be less than the modelling suggests because the modelling adopts a conservative approach of assuming maximum throughput for continuous operation and this artificially inflates the difference between the two scenarios.

32. Table 2 summarises maximum emissions vs likely actual emissions for both existing and proposed plant on all proposed fuels. I understand the proposed consent limit of 300,000 tonnes per year (**tpy**) is based on the possibility of a number of very large projects in the region that require asphalt, or the Allied Plant increasing production to cover a possible closure of the Higgins plant.

33. Also included in Table 2 are annual emissions of oxides of nitrogen estimated using the US EPA AP-42 emission factor for batch asphalt plants.[16] The Allied AQA estimated emission rate of nitrogen dioxide (estimated using emission factors for drum mix plant) is not supported and an underestimate. I note AP-42 specifically states, "*As with any combustion process, the design, operation and maintenance of the burner provides opportunities to minimise emissions of NOx, CO and organic compounds*." This reflects my understanding that NO_X emissions can and will vary significantly with different types of combustion processes. Notwithstanding the lower quality rating, I consider the batch plant emission factor more appropriate for estimating emissions from a batch plant (than the lower emission factor from a drum mix plant employed in the Allied AQA).

34. When reviewing Table 2 it is important to acknowledge the relationship between emissions and downwind concentrations will change between the existing and proposed plant. This is because the higher stack in the new plant will increase downwind dispersion and reduce downwind concentrations compared to the existing plant. However, from an overall airshed management perspective, I consider it helpful to compare the existing and proposed annual emissions for the various scenarios under consideration.

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[16] US EPA, 2004. AP 42, Fifth Edition, Volume I Chapter 11: Mineral Products Industry. Chapter 11.1 Hot Mix Asphalt Plants. April. [Online]

Table 2 Estimates of Maximum Modelled and Actual Annual Emissions from Existing and Proposed Plants (my estimates in bold blue font)[17]

Plant / Scenario [a]	**PM_{10} (tpy)**	**NO_x (tpy) US EPA Drum Plant Emission Factor**	**NO_x (tpy) US EPA Batch Plant Emission Factor**
Existing Drum Plant – waste oil			
Maximum (80 tph,700,800 tpy)	29	20	–
Actual (50 tph, 68,000 tpy)	3.3	1.9	–
Proposed Batch Plant – natural gas			
Maximum (200 tph, 1,752,000 tpy)	8.8	23	23
Proposed (120 tph, 300,000 tpy)	2.0	3.9	**3.9**
Actual (120 tph, 75,000 tpy)	0.5	1.0	**1.0**
Proposed Batch Plant – diesel			
Maximum (200 tph, 1,752,000 tpy)	[As above for natural gas]	49	102
Proposed (120 tph, 300,000 tpy)		8.4	**17**
Actual (120 tph, 75,000 tpy)		2.1	**4.4**

[a] Maximum emissions are hypothetical consent limits for modelling only and do not apply in practice.

35. Based on a comparison of the existing production with proposed (i.e. 68,000 tpy existing v 300,000 tpy proposed) Table 2 indicates:[18]

a) The proposed plant would reduce annual emissions of PM_{10} by 1.3 tonnes per year.

[17] Full calculations in Appendix 1

[18] These estimates do not include any emission reductions gained by the closure of the Higgins plant (which is one assumption for the 300,000 tpy scenario).

b) The proposed plant would increase annual emissions of NO_x by 2.0 tonnes per year when running on natural gas.

c) The proposed plant would increase annual emissions of NO_x by 16 tonnes per year when running on diesel.[19]

36. This highlights that operating the proposed plant on diesel is much more significant for emissions of NOx.

37. In addition to combustion emissions, the increased throughput of the proposed new plant will increase emissions of benzene, dioxins, and possibly odour (depending on throughput and the addition of resin or reclaimed asphalt pavement).

Air Quality Assessment – Areas of Agreement

38. At expert conferencing Ms Simpson agreed to undertake more dispersion modelling with additional meteorology (2021) and residential locations at Kittyhawk Way and Dakota Way. I have not yet reviewed this modelling so the following views are based on evidence filed to date.

39. I agree with Ms Simpson and Mr Murray that the Resource Management (National Environmental Standards for Air Quality) Regulations 2004 pose no regulatory barriers to grant of consent for discharges to air of PM_{10}, oxides of nitrogen, SO_2 and volatile organic compounds (**VOCs**) with one important caveat – that emissions of particulate do not increase above those currently consented (Regulations 17(1)). This is discussed further at [79]-[80].

[19] Based on my calculations

40. I support the Allied AQA conservative approach of modelling with CALPUFF for continuous operation at maximum load for assessment of annual average exposure. I agree with Ms Simpson that probabilistic scenario development is not needed.

41. I support the Allied AQA selected air quality criteria for assessment purposes. Whilst the WHO guidelines are not standards or legally binding criteria in New Zealand, they do provide up to date, evidence-informed recommendations on air quality levels that "*pose important risks to public health*" (WHO 2021). I think it important to point out a significant limitation of the air quality assessment of toxic discharges to air (benzene, dioxins) is that it is incremental only in the absence of any understanding of background concentrations.

42. I support the Allied AQA use of odour emissions data estimates based on measurements undertaken at a similar plant. This means we can be confident the data are representative. I further support the Allied AQA approach of odour dispersion modelling for comparative purposes (only). This estimates the reductions afforded by a higher stack and reduced odour emissions on predicted nearfield locations (50x less odour) and at residential locations further afield (10x less odour). This comparative approach is consistent with good practice (MfE 2016).[20]

Air Quality Assessment – Areas of Disagreement

Particulate

43. As outlined in the Joint Witness Statement (Air Quality) I disagree with the exclusion of the existing available particulate monitoring data within the Mount Maunganui Airshed from the assessment. Using this more conservative data, suggests both the existing and

[20] Ministry for the Environment, 2016. *Good Practice Guide for Assessing and Managing Odour.* Wellington. November. [Online]

proposed plants add fractional increases to an airshed that already exceeds the WHO guideline as shown in the Table 3 (Allied column is from Table 2-1 of Ms Simpson's evidence dated 29 February 2024).

Table 3 Cumulative Assessment of Predicted Maximum PM_{10} Concentrations

Scenario	Allied Contribution (µg/m^3)	Background Concentration (µg/m^3)	Cumulative Concentration (µg/m^3)	WHO AQG (µg/m^3)
Existing Plant				
Daily PM_{10} (4th highest)	3.5	35-43	39-47	45
Annual PM_{10}	0.7	18-19	19-20	15
Proposed Plant				
Daily PM_{10} (4th highest)	0.76	35-43	36-44	45
Annual PM_{10}	0.16	18-19	18-19	15

44. It is well established that the Mount Maunganui Airshed is polluted for PM_{10} and the Environment Court has issued strong directions to improve air quality as soon as reasonably practicable with all industries doing their share (paraphrased).[21] Of note, the Court has directed that:[22]

Future management must require that PM_{10} emissions from all existing emitters of PM_{10} in the MMA be minimised to the greatest extent reasonably practicable until the objectives of PC13 are met.

45. The proposed plant will reduce annual emissions of PM_{10} by 1.3 tonnes/year. This reduction would be higher (i.e. even less

[21] [2023] NZEnvC 001 *Swap Stockfoods Ltd v BOPRC* at [256]

[22] *Ibid.*

emissions in total) if a lower throughput was adopted. For example, a realistic scenario of the proposed new plant producing 75,000 tpy would result in a reduction of 2.8 tonnes of PM_{10} into the airshed when compared with an existing plant operation of 68,000 tpy.[23]

Nitrogen Dioxide

46. Nitrogen dioxide is a secondary pollutant formed downwind from oxides of nitrogen. This complex chemistry prohibits me from pro-rating my own emission estimates of NOx onto Ms Simpson's (multiple methods of) assessment of nitrogen dioxide downwind.

47. What I can say is that a realistic comparison of the existing plant running at 68,000 tpy with the proposed new plant running at 75,000 tpy would result in:

    a) A reduction of 0.9 tonnes of NO_x emitted into the airshed when running on natural gas.

    b) An increase of 2.4 tonnes of NO_x into the airshed when running on diesel.

48. The air quality experts agreed unanimously that the best practicable option emissions control is the use of low NOx burners. These would further reduce NOx emissions and I recommend this be adopted as a condition of consent.

Odour

49. Mr Murray has noted that it appears that emissions of odour with reclaimed asphalt paving have not been assessed, despite tests showing that manufacturing with reclaimed asphalt plant has higher

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[23] Refer Table 2, full calculations in Appendix 1

odour emissions. If it has not been assessed, then it should not be consented. I recommend conditions of consent prohibiting the use of reclaimed asphalt paving to give greater confidence that the projected odour improvements predicted from the new plant will be achieved in practice.

50. Fugitive emissions (benzene, VOCs, odour) from up to 100 loadouts per day are not included the modelling in the Allied AQA. Odour from load-out is a common source of odour complaint (i.e. a cause of offensive and objectionable odour offsite) and good practice is to fully enclose the load-out activity. I am unclear on the health and safety issues that render this mitigation option non-viable. If it is because people inside the load-out area will be exposed to elevated concentrations of contaminants and odour, then this demonstrates the need to enclose, extract and treat emissions.

Toxics

51. There is an absence of ambient air quality monitoring data for benzene in the industrial Mount Maunganui Airshed to inform cumulative assessment. Similarly, the use of emission factors and the exclusion of fugitive emissions (which may be significant in the near field, particularly for workers in the industrial area) go some way to offsetting the conservatism provided by assuming continuous operation at maximum throughput.

52. As noted by Mr Murray that there will be an increase in the emission rates of benzene and dioxins from the proposed plant in comparison to the current plant, which is a result of the proposed plant's greater operating capacity.

53. Given their carcinogenic nature, the focus with respect to benzene and dioxins should be on the best practicable option, which I

consider the new proposed plant is – when operating on natural gas (emissions of benzene will be higher when operating on diesel).

AIR QUALITY HEALTH RISK ASSESSMENT

54. The applicant is to be commended on the preparation of a quantitative health risk assessment of discharges to air.

55. I support Dr Wilton's evidence on the adverse health effects of PM_{10}, $PM_{2.5}$ and NO_2. I was the lead author for summaries of the science behind the World Health Organisation (**WHO**) global air quality guidelines for these contaminants in factsheets published by ESR that may also be helpful (refer Appendix 2). Important things to note are:

    a) The major impacts of air pollution occur due to chronic exposure. Depending on the circumstances (e.g., duration and magnitude of exposure) the health burden due to chronic exposure to air pollution may be 10 times greater than that for acute exposure, based on the relative risk ratios (WHO 2021).[24]

    b) Whilst air pollution impacts many New Zealander's health, these adverse health impacts are not always evenly distributed. Susceptible groups include elderly people, children, people with pre-existing heart or lung disease, people with respiratory conditions (such as asthmatics), diabetics and pregnant women.

    c) There is also an environmental justice aspect to these unevenly distributed health impacts. Lower socio-economic

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[24] WHO, 2021. *WHO air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. Geneva: World Health Organization, 2021. [Online]

groups also tend to have housing close to significant emission sources such as arterial transport routes and industry. The Health and Air Pollution in New Zealand (HAPINZ 3.0) exposure model (Sridhar *et al*. 2022)[25] suggests that lower socio-economic groups are disproportionately exposed to higher concentrations of nitrogen dioxide. A preliminary investigation into social inequity of air quality exposure and associated impacts in New Zealand found that people in areas of higher socioeconomic deprivation are adversely affected more strongly by air pollution (ESR, 2023c).[26]

56. Appendix 2 includes a lay guide on the epidemiology of air pollution that may be helpful for the discussion on concentration response functions (**CRF**) which follows. (NB: The factsheets refer to CRFs as risk ratios – they are the same thing).

57. A CRF relates exposure to ambient concentrations with the risk of a specified health outcome. CRFs may be described as the ratio of the probability of an outcome in an exposed group to the probability of an outcome in an unexposed group. For relationships that are known to be causal (such as air pollution and adverse health effects), values of CRFs can be interpreted as follows:

CRF=1 means that exposure does not affect the outcome

CRF<1 means that the risk of the outcome is *decreased* by the exposure

CRF>1 means that the risk of the outcome is *increased* by the exposure

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[25] Sridhar S. et al., 2022. Health and Air Pollution in New Zealand 2016 (HAPINZ 3.0). He rangi hauora he iwi ora. Health effects model – Users' Guide. Prepared for Ministry for the Environment, Ministry of Health, Te Manatū.

[26] ESR, 2023c. Air Quality and Social Inequity in Aotearoa. A Preliminary Investigation. 14 November. [Online]

58. It is important to note that CRFs are relative (to non-exposure). This means that to understand a CRF, the range of exposure needs to be clearly stated. The standard increment in air quality epidemiology (including all CRFs referred to by Dr Denison, Dr Wilton and myself) is 10 micrograms per cubic metre ($\mu g/m^3$).

59. A CRF of 1.08 (95% Confidence Interval (**CI**) 1.06 – 1.09) means that for every 10 $\mu g/m^3$ increase in annual $PM_{2.5}$, there was an 8% increase in all-cause mortality where 95% of the data for the CRF lay between 6% and 9%.

60. Dr Wilton raises good points with respect to the selection of CRFs. The HAPINZ 3.0 study (Kuschel *et al.* 2022)[27] estimates air pollution health impacts in New Zealand using CRFs developed for New Zealand based on New Zealand exposure and health statistics (Hales *et al*. 2021).[28] Specifically:

a) The HAPINZ 3.0 study CRF for all-cause mortality associated with annual $PM_{2.5}$ is 1.105 (95% CI 1.065 – 1.145)[29] which is higher than that published by WHO; 1.08 (95% CI 1.06 – 1.09) (Chen & Hoek 2020).[30]

b) Similarly, the HAPINZ 3.0 CRF for all-cause mortality associated with annual NO_2 of 1.097 (95%CI 1.074 – 1.120)

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[27] Kuschel et al., 2022. Health and Air Pollution in New Zealand 2016 (HAPINZ 3.0). Report prepared for Ministry for the Environment, Ministry of Health, Te Manatū Waka Ministry of Transport and Waka Kotahi NZ Transport Agency. Auckland. New Zealand. March. [Online]

[28] Hales S., Atkinson J., Metcalfe J., Kuschel G. and Woodward A., 2021. Long term exposure to air pollution mortality and morbidity in New Zealand: Cohort study. Sci Tot Env. Vol 801. 20 Dec. 149660. doi.org/10.1016/j.scitotenv.2021.149660.

[29] All CRFs are for increases in mean annual concentrations of 10 $\mu g/m^3$

[30] Chen J., Hoek G., 2020. Long-Term exposure to PM and all-cause and cause-specific mortality: A systematic review and meta-analysis. *Env Int*. Vol 143. October 2020. 105974. doi.org/10.1016/j.envint.2020.105974.

is significantly higher than that published by WHO; 1.02 (95% CI 1.01 – 1.04) (Huangfu & Atkinson 2021)[31].

61. I note that although the HAPINZ 3.0 CRFs are higher than those published by WHO, they are not inconsistent with the WHO epidemiological evidence:

a) Chen & Hoek (2020) noted the CRF for five studies included in their meta-analysis with all-cause mortality associated with annual mean $PM_{2.5}$ concentrations below 10 mg/m^3 was 1.17 (95% CI: 1.12 – 1.23). This is double the published CRF from their meta-analysis; 1.08 (95% CI 1.06 – 1.09). The HAPINZ 3.0 study CRF for all-cause mortality associated with $PM_{2.5}$ in New Zealand, which also has a population weighted annual mean $PM_{2.5}$ concentration below 10 µg/m^3, was 1.105 (95% CI 1.065 – 1.145).

b) Huangfu & Atkinson (2020) did not include any cities with mean annual NO_2 below 10 µg/m^3 when they developed a CRF for all-cause mortality associated with annual NO_2 of 1.02 (95% CI 1.01 – 1.04). However, I note the CRF from five studies with mean annual NO_2 below 25 µg/m^3 was 1.04 (95% CI 1.0 – 1.18) in their study which is double the published CRF from their meta-analysis.[32] The HAPINZ 3.0 study CRF for all-cause mortality associated with annual $PM_{2.5}$ in New Zealand was 1.097 (95% CI 1.074 – 1.120). Commentary published by other researchers since the effects estimate in HAPINZ 3.0

[31] Huangfu P., Atkinson R., 2020. Long-Term exposure to NO_2 and O_3 and all-cause and respiratory mortality: A systematic review and meta-analysis. *Env Int*. Vol 144. November 2020. 105998. doi.org/10.1016/j.envint.2020.105998.

[32] Calculated from supplementary data using only studies with statistically significant risk ratios. Crouse et al., 2015, Weichenthal et al., 2017, Carey et al, 2013, Yorifuji et al., 2013 and Turner et al., 2016.

were published supports the HAPINZ 3.0 findings being robust (Forastiere & Peters 2021).[33]

Put simply, CRFs tend to be higher in areas with lower air pollution. New Zealand's higher CRF is consistent with this trend.

62. I also agree with Dr Wilton's characterisation of the tension between increased discharges to air of some pollutants from increased production potentially undermining improvements in reductions of other pollutants from the improved technology in use.

63. Importantly, and as noted by Dr Wilton, the RMA requires an assessment of cumulative effects rather than an assessment of the effects of discharges to air in isolation. This is a critical matter for Dr Denison's risk assessment, which is an incremental assessment that does not acknowledge the Allied site being located within a polluted airshed.

64. During expert conference, Dr Denison undertook to address potential health effects on the approximately 10,000 workers present in the Mount Maunganui Airshed each day but I have yet to see these calculations.

Quantitative Risk Assessment

65. Dr Denison has used the CRFs developed by the WHO (Chen and Hoek, 2020; Huangfu and Atkinson, 2020; Orellano et al., 2020) in the first instance to assess incremental risk from identified health outcomes associated with long-term and short-term exposure to PM_{10}, $PM_{2.5}$, NO_2 and SO_2. The WHO CRFs offer the advantage of

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[33] Forastiere F., Peters A., 2021. Invited Perspective: The NO_2 and Mortality Dilemma Solved? Almost There! *Environ. Health Perspect*. 129 (12). December. doi.org/10.1289/EHP10286

covering both long-term *and* short-term effects compared with the New Zealand-specific CRFs developed for HAPINZ 3.0 (Hales et al. 2021), which only address long-term effects of PM_{10}, $PM_{2.5}$ and NO_2. However, good practice is to adopt country specific CRFs in the first instance, where available (WHO, 2016).[34] This is because CRFs extrapolated from studies in other parts of the world may not accurately describe the concentration-response relationship in the region to be assessed, leading to uncertainties in the results.[35]

66. The HAPINZ 3.0 CRFs are, in my opinion, superior for a risk assessment in New Zealand. I acknowledge Dr Denison's use of the HAPINZ 3.0 CRFs for a sensitivity analysis but consider it should be the other way around (i.e., use the WHO CRFs for sensitivity analysis).

67. I do not support the use of health incidence statistics averaged for the wider Bay of Plenty population when census area unit specific data are available (in HAPINZ 3.0). I consider the choice of 2020 for baseline health statistics to be unfortunate as this was the first year of the COVID-19 pandemic. New Zealand was one of only two countries in the world in which annual mortality *improved* in 2020 (Kung *et al.* 2020).[36] The implication is that baseline statistics for this year may underestimate risk (as CRFs are applied relative to baseline health incidence). I consider it would be more appropriate to use 2 or 3-year averaged nationally published statistics, and to avoid the years 2020-2021.

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[34] WHO, 2016. *Health Risk Assessment of Air Pollution. General Principles.* WHO Regional Office for Europe. Copenhagen. [Online]

[35] A stated limitation of the Mount Maunganui Air Quality Risk Assessment is the uncertainty of applying a New Zealand CRF to the Mount Maunganui Airshed, noting the infeasibility of developing a localised CRF for such a small population (ESR, 2023 At 3.2.4).

[36] Kung *et al*., 2020. Reduced mortality in New Zealand during the COVID-19 pandemic. *The Lancet.* 14 December. [Online]

68. These are technical differences in risk assessments prepared for different purposes that do not materially detract from the calculations undertaken. Both the Allied HRA and Mount Maunganui HRA employ an overall similar approach to quantifying risk.

Carcinogenic Risk Assessment

69. Dr Denison has combined predicted concentrations of arsenic, benzene, benzo(a)pyrene (**BaP**), cadmium, chromium VI, formaldehyde and lead with unit risk factors to give an estimate of the probability of excess cancer. The New Zealand *Good Practice Guide for Assessing Discharges to Air from Industry* notes (MfE 2016):

Historically air quality assessments in New Zealand have adopted an acceptable environmental risk for exposure by residential receptors to individual environmental pollutants of 1 in 1,000,000. This is still recommended when assessing discharges to air from industry.

70. Dr Denison has noted general agreement by international agencies including the WHO and United States Environmental Protection Agency (**USEPA**) that acceptable incremental risk levels fall between 1 in a million and 1 in 100,000,[37] preferring to characterise risk of less than 1 in 100,000 as acceptable and less than 1 in a million as negligible. I support assessment against the more health protective criterion of 1 in a million for exposure by residential receptors to carcinogenic risks.

71. I note Dr Denison's incremental carcinogenic risk estimate for benzene for children (9×10^{-6}) is predicted to exceed this more

[37] Statement of Evidence of Dr Denison dated 29 February 2024. At [52].

protective criterion when modelling the proposed plant running on both diesel and natural gas at De Havilland Way.[38] This estimate assumes an artificially high annual throughput (1,752,000 tpy) that would not be realised in practice. Assuming the risk estimate is proportional to throughput it would reduce to:

a) 1.5×10^{-6} for 300,000 tpy; or

b) 0.4×10^{-6} for 75,000 tpy.

72. Thus, Dr Denison's estimated incremental risk for children associated with benzene would exceed 1×10^{-6} at De Havilland Way for 300,000 tpy, but not 75,000 tpy production.

Hazard Quotient Risk Assessment

73. Dr Denison has used the predicted concentrations from dispersion modelling for toxics and metals in combination with health-based air quality guidelines for non-cancer effects to establish hazard quotients. This considers only the effects of the Allied discharge and ignores the other sources of air pollution the Mount Maunganui airshed. I do not agree with Dr Denison's statements regarding "acceptability", or otherwise, when comparing only the Allied discharges to the full risk envelope for a particular hazard. For example, ten dischargers could be discharging at 10% of a health-based air quality guideline, so individually each would be judged to be acceptable, whereas the overall risk is not (acceptable).

SOCIAL COST OF POLLUTANTS

74. An alternative approach to the complexities of risk assessment, is to consider pollutant emissions in terms of costs to society, where

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[38] *Ibid*. [At Table 6]

social costs are the burden to society arising from increased health costs and productivity losses. The Treasury has published *damage* costs (social costs per tonne of pollutant) developed from the Health and Air Pollution in New Zealand (HAPINZ 3.0) study that are specific for New Zealand conditions (The Treasury 2023).[39]

75. This approach is not as accurate as the air quality assessment and detailed risk assessments (which assess *absolute* burden) undertaken by the application, but it is robust for indicating *relative* burden between options – as is under discussion here. This approach further does not account for the increased stack height of the proposed plant, or even account for the emissions being from any stack – they are social costs averaged from all sources in New Zealand (i.e. primarily domestic home heating and traffic as outlined in HAPINZ 3.0). I have not discussed this approach with the other experts at conferencing. It is offered to the Court purely to assist with comparative analysis.

76. Table 4 presents the harmful pollutant damage costs updated to $NZD 2024 (Treasury 2023) for $PM_{2.5}$ and NO_x emissions for the various scenarios under consideration (full calculations in Appendix 1).

77. Based on a comparison of the existing actual production with proposed (i.e. 68,000 tpy existing v 300,000 tpy proposed) Table 4 indicates (all costs in $NZD 2024):[40]

    a) The proposed plant would increase total social costs for $PM_{2.5}$ and NO_x by $1.4 M per year when running on natural gas.

[39] Treasury, 2023. *CBAx Spreadsheet Model*, The Treasury, New Zealand, 21 December 2023. [Online]

[40] These estimates do not include any emission reductions gained by the closure of the Higgins plant (which is one assumption for the 300,000 tpy scenario).

b) The proposed plant would increase total social costs for $PM_{2.5}$ and NO_x by $15.6 M per year when running on diesel.

78. Of note, a more modest throughput of 75,000 tpy in the proposed plant would *reduce* total social costs for $PM_{2.5}$ and NO_x by $2.4 M per year when running on natural gas. This comparative analysis supports emissions reductions, where practical and reasonable, for the new plant.

Table 4 Damage Costs (NZD $2024) for Annual Emissions from Existing and Proposed Plants[41]

Plant / Scenario	**Production**	**$PM_{2.5}$**	**NO_x**	**$PM_{2.5}$ + NO_x**	**Δ**
	(tpy)	**Social Cost (NZD $2024)**			
Existing Drum Plant – waste oil					
Actual	68,000	$1,691,467	$2,001,051	$3,692,518	–
Proposed Batch Plant – natural gas					
Proposed	300,000	$1,036,438	$4,098,791	$5,135,229	+$1,442,711
Actual	75,000	$259,110	$1,024,698	$1,283,807	-$2,408,711
Proposed Batch Plant – diesel					
Proposed	300,000	$1,036,438	$18,286,914	$19,323,352	+$15,630,834
Actual	75,000	$259,110	$4,571,728	$4,830,838	+$1,138,320

Regulation 17 of NESAQ

79. Ms Simpson's evidence indicates that the existing plant would exceed the significance criterion in Regulation 17(1) (i.e. the discharge increases daily PM_{10} by more than 2.5 μg/m^3 in a polluted airshed).[42] I understand this means:

[41] Full calculations in Appendix 1.

[42] Statement of Evidence of Ms Simpson dated 29 February 2024. At Table 2-1 in Attachment Two

a) production of the existing plant may not increase above 68,000 tpy because then Regulation 17(2)(b) wouldn't apply and consent is prohibited under Regulation 17(1); and

b) the new plant may not be run at the same time as the existing plant for the same reason.

80. In practice there is a difference between the *daily* emission rate (at 80 tph) assumed in the modelling that would exceed the daily criterion in Regulation 17(1) and the *annual* emissions (for 68,000 tpy) I have described above as needing to remain below existing levels in Regulation 17(2)(b). However, any increase in daily or annual PM_{10} emissions would breach the intent of Regulation 17(2)(b) which seeks to provide a consenting pathway for existing industry, whilst mandating emissions of PM_{10} do not increase the *amount* (annual) *and rate* (daily).

CONCLUSIONS

81. Allied Asphalt Limited (**Allied**) have significantly amended their application to Bay of Plenty Regional Council (**Council**) for consent to discharges to air since its referral to the Environment Court. The new proposed plant will have a different design, different fuel, better emissions control and a higher stack. I consider the new proposed plant is largely consistent with best practice, except for enclosed load-out and low NOx burners which are not proposed. Discharges to air from the new plant will, however, depend on the fuel employed with some pollutants being higher than others compared with the existing plant.

82. Existing air quality in Mount Maunganui is degraded and poor relative to other residential areas in Tauranga. The Mount Maunganui air quality review and HRA show adverse effects have

previously, and are currently, occurring in some part of the MMA. These effects range from offensive and objectionable odours, to short-term, transient bronchoconstriction to more serious, chronic conditions including cardiovascular disease, lung cancer and premature mortality.

83. The increase in throughput from the proposed new plant will increase overall emissions of some pollutants (NOx, benzene, dioxins) even as other pollutants reduce. There is no safe level for these pollutants and a cautious approach would include mitigation to the greatest extent possible. I have provided annual emissions estimates and estimated associated social costs for New Zealand to inform a comparative approach.

RECOMMENDED CONDITIONS OF CONSENT

84. I agree with Mr Murray's recommendations for conditions of consent for both the existing and new plant except for his proposal to remove the constraint on daily hours of operation of the existing plant. The plant is known to cause offensive and/or objectionable odours offsite and operating earlier than 7 am will likely increase the risk of this occurring.

85. I also agree with Mr Murray's recommendations for emissions testing of the new proposed plant. As noted in the Joint Witness Statement (Air Quality) I consider emissions testing of PAHs may be beneficial.

86. I consider a consent limit of 10 years to be appropriate. Air quality science has advanced rapidly in the last decade, and it is important that discharges to air are well regulated considering their known adverse effects on health. The limitations of a review condition as compared with a consent renewal, whereby consent may be or may not be granted, are clear.

87. I further recommend the following conditions of consent:

a) Fully enclosed load out

b) Low NOx burners

c) Site boundary monitoring for PM_{10} using an approved method (consistent with Environment Court directives for other sites with fugitive discharges of PM_{10} in the Mount Maunganui Airshed).

d) Annual production limit of 75,000 tpy on the proposed plant running on natural gas in preference to diesel.

Lou Wickham
11 April 2024

Appendix 1

EMISSION CALCULATIONS FOR DIFFERENT FUEL AND THROUGHPUT

PM_{10} EMISSIONS

Plant/Fuel/Scenario	Production			Emission		Δ
	tph	tpy	hr/yr	kg/hr	tpy	tpy
Existing Plant – waste oil						
Maximum	80	700,800	8,760	3.36	29	
Actual	50	68,000	1,360	2.4	3.3	
Proposed – all fuels						
Maximum	200	1,752,000	8,760	1	8.8	
Proposed	120	300,000	2,500	0.8	2.0	-1.3 [a]
Proposed actual	120	75,000	625	0.8	0.5	-2.8 [b]

[a] Proposed cf existing actual
[b] Proposed actual cf existing actual

NOx EMISSIONS

Plant/Fuel/Scenario	Production			Emission		
	tph	tpy	hr/yr	kg/t*	kg/hr	tpy
Existing Plant – waste oil						
Maximum	80	700,800	8,760	0.028	2.2	20
Actual	50	68,000	1,360	0.028	1.4	1.9
Proposed – natural gas						
Maximum	200	1,752,000	8,760	0.013	2.6	23
Proposed	120	300,000	2,500	0.013	1.6	3.9
Proposed – diesel						
Maximum	200	1,752,000	8,760	0.028**	5.6	49
Proposed	120	300,000	2,500	0.028**	3.4	8.4

* US EPA AP-42 Emission Factor in units of kilograms of pollutant emitted per tonne of asphalt produced

** For drum mix asphalt plant (but a batch plant is proposed)

NO_x EMISSIONS (Corrected for Batch Mix Plant)

Plant/Fuel/Scenario	Production			Corrected Emission			Δ
	tph	tpy	hr/yr	kg/t*	kg/hr	tpy	tpy
Existing Plant – waste oil							
Maximum	80	700,800	8,760	0.028	2.2	20	
Actual	50	68,000	1,360	0.028	1.4	1.9	
Proposed – natural gas							
Maximum	200	1,752,000	8,760	0.013	2.6	23	
Proposed	120	300,000	2,500	0.013	1.6	3.9	+2.0 [a]
Proposed actual	120	75,000	625	0.013	1.6	1.0	-0.9 [b]
Proposed – diesel							
Maximum	200	1,752,000	8,760	0.058	11.6	102	
Proposed	120	300,000	2,500	0.058	7.0	17	+16 [a]
Proposed actual	120	75,000	625	0.058	7.0	4.4	+2.4 [b]

Notes

* US EPA AP-42 Emission Factors in units of kilograms of pollutant emitted per tonne of asphalt produced

[a] Proposed cf existing actual
[b] Proposed actual cf existing actual

SOCIAL COST ANALYSIS

Plant / Scenario	PM_{10} (tpy)	$PM_{2.5}$ (tpy)*	NOx (tpy)	$PM_{2.5}$ Social Costs $NZD2024	NOx Social Costs $NZD2024	$PM_{2.5}$ + NO_x Social Costs $NZD2024	Δ
Existing Drum Plant – waste oil							
Maximum (80 tph,700,800 tpy)	29	15	20	$15,253,055	$20,622,594	$35,875,649	
Actual (50 tph, 68,000 tpy)	3.3	1.6	1.9	$1,691,467	$2,001,051	$3,692,518	
Proposed Batch Plant – natural gas							
Maximum (200 tph, 1,752,000 tpy)	8.8	4	23	$4,539,600	$23,936,940	$28,476,539	
Proposed (120 tph, 300,000 tpy)	2.0	1.0	3.9	$1,036,438	$4,098,791	$5,135,229	$1,442,711
Actual (120 tph, 75,000 tpy)	0.5	0.3	1.0	$259,110	$1,024,698	$1,283,807	-$2,408,711
Proposed Batch Plant – diesel							
Maximum (200 tph, 1,752,000 tpy)	8.8	4	23	$4,539,600	$23,936,940	$28,476,539	
Proposed (120 tph, 300,000 tpy)	2.0	1.0	17	$1,036,438	$18,286,914	$19,323,352	$15,630,834
Actual (120 tph, 75,000 tpy)	0.5	0.3	4.4	$259,110	$4,571,728	$4,830,838	$1,138,320

*Assumes $PM_{2.5}$ is 50% of PM_{10}
Harmful emission social costs taken from Table 9 in MBCM (NZTA 2023)
Costs updated from $2021 to $2024 using update factor from Impacts Database in CBAx tool (Treasury 2023) for increase in NZ average damage cost = 1.2139

Emission damage costs - urban ($/tonne - 2021)

Pollutant	Costs in $2021/tonne Urban	Costs in $2021/tonne NZ average	Costs in $2024/tonne NZ average*	CBAx Update Factor	Costs in $2024/tonne Urban
$PM_{2.5}$	$853,824	$530,676	$644,176	1.2139	$1,036,438
NO_X	$865,797	$325,312	$394,889	1.2139	$1,050,972

*CBAx tool utilises greater than 4 decimal places as shown here. (This creates slight differences with scenario emissions costs above)

Impacts Database

Take note of the row number (column A) for the relevant impact(s) values you want to use in the Impact Inputs tab. Or you can enter your own in the yellow cells at the bottom of this table. See the CBAx Tool User Guidance for more information about entering your own impacts.

Row Number	Wellbeing Domain	Description	Value adjusted to 2024	Value	Unit	Government/Non-Government	Sector	Year of data	Source (1)
205	Environmental amenity	Shadow Emissions Value CO2 - lower price path (Present – 2030)	-121	-114	Per tonne	Government	Environment	2023	Treasury, 2023
206	Environmental amenity	Shadow Emissions Value CO2 - central price path (Present – 2030)	-181	-171	Per tonne	Government	Environment	2023	Treasury, 2023
207	Environmental amenity	Shadow Emissions Value CO2 - higher price path (Present – 2030)	-241	-228	Per tonne	Government	Environment	2023	Treasury, 2023
208	Environmental amenity	Shadow Emissions Value CO2 - lower price path (2030 – 2050)	-218	-206	Per tonne	Government	Environment	2023	Treasury, 2023
209	Environmental amenity	Shadow Emissions Value CO2 - central price path (2030 – 2050)	-327	-309	Per tonne	Government	Environment	2023	Treasury, 2023
210	Environmental amenity	Shadow Emissions Value CO2 - higher price path (2030 – 2050)	-435	-411	Per tonne	Government	Environment	2023	Treasury, 2023
211	Environmental amenity	Shadow Emissions Value CO2 - lower price path (2050 – onwards)	-266	-251	Per tonne	Government	Environment	2023	Treasury, 2023
212	Environmental amenity	Shadow Emissions Value CO2 - central price path (2050 – onwards)	-590	-557	Per tonne	Government	Environment	2023	Treasury, 2023
213	Environmental amenity	Shadow Emissions Value CO2 - higher price path (2050 – onwards)	-1,156	-1,092	Per tonne	Government	Environment	2023	Treasury, 2023
214	Health	Health loss from air emissions (PM2.5)	-644,176	-530,676	Per tonne	Non-Government	Private Impact	2021	Waka Kotahi - Monetised Benefits and Costs
215	Health	Health loss from air emissions (NOx)	-394,889	-325,312	Per tonne	Non-Government	Private Impact	2021	Waka Kotahi - Monetised Benefits and Costs
216	Health	Health loss from air emissions (CO)	-4	-3	Per tonne	Non-Government	Private Impact	2021	Waka Kotahi - Monetised Benefits and Costs
217	Health	Health loss from air emissions (Volatile organic compounds [Hydrocarbons])	-1,152	-949	Per tonne	Non-Government	Private Impact	2021	Waka Kotahi - Monetised Benefits and Costs

References

Waka Kotahi NZ Transport Agency, 2023. *Monetised Benefits and Costs Manual*, Version 1.6.1. June. [Online]
Treasury, 2023. *CBAx Spreadsheet Model*, The Treasury, New Zealand, 21 December 2023. [Online]

Appendix 2

LAY GUIDES TO EPIDEMIOLOGY OF AIR POLLUTION

Attached:

a) Wickham L., Cridge B., Nicoll R., Powell J., 2022g. ***Health Effects of Air Pollutant Factsheets: Supporting Information**.* Factsheet prepared by Emission Impossible Ltd for Ministry of Health. October. [Online]

b) Wickham L., Cridge B., Nicoll R., Powell J., 2022h. ***Health Effects of Air Pollution**.* Factsheet prepared by Emission Impossible Ltd for Ministry of Health. October. [Online]

NB: Also available online:

Wickham L., Cridge B., Nicoll R., Powell J., 2022a. ***Health effects of long-term exposure to PM***. Factsheet prepared by Emission Impossible Ltd for Ministry of Health. October. [Online]

Wickham L., Cridge B., Nicoll R., Powell J., 2022b. ***Health effects of short-term exposure to PM, NO_2 & O_3***. Factsheet prepared by Emission Impossible Ltd for Ministry of Health. October. [Online]

Wickham L., Cridge B., Nicoll R., Powell J., 2022c. ***Health effects of long-term exposure to NO_2 & O_3***. Factsheet prepared by Emission Impossible Ltd for Ministry of Health. October. [Online]

Wickham L., Cridge B., Nicoll R., Powell J., 2022d. ***Effects of short-term exposure to NO_2, O_3 and SO_2 on asthma***. Factsheet prepared by Emission Impossible Ltd for Ministry of Health. October. [Online]

Wickham L., Cridge B., Nicoll R., Powell J., 2022e. ***Health effects of short-term exposure to SO_2***. Factsheet prepared by Emission Impossible Ltd for Ministry of Health. October. [Online]

Wickham L., Cridge B., Nicoll R., Powell J., 2022f. ***Effects of CO exposure on heart attacks***. Factsheet prepared by Emission Impossible Ltd for Ministry of Health. October. [Online]

Health Effects of Air Pollution

October 2022

Air pollution is a major hazard to human health and a leading cause of illness and death worldwide. After reviewing the best available scientific knowledge, in September 2021 the World Health Organisation (WHO) published revised recommendations for air quality levels to protect human health (WHO 2021). Informed by epidemiological evidence, the new guidelines are significantly lower than previous guidelines (WHO 2006).

Key Facts

- Clean air is fundamental to health. The World Health Organisation (WHO) estimates that air pollution – both ambient (outdoor) and household (indoor) – is the biggest environmental risk to health, carrying responsibility for about one in every nine deaths annually (WHO 2016a).

- In May 2015, the World Health Assembly endorsed a resolution recognising air pollution as a risk factor for noncommunicable diseases such as ischaemic heart disease, stroke, chronic obstructive pulmonary disease, asthma and cancer and stating the need for Member States and WHO to intensify efforts to protect populations from the health risks of air pollution (WHA, 2015).

- In July 2022, the United Nations adopted resolution A/RES/76/300 recognising the human right to a clean, healthy and sustainable environment (UN 2022). This includes the right to breathe clean air (Human Rights Council 2019).

- To reduce air pollution mortality (death) and morbidity (disease), the World Health Organisation (WHO) reviewed the best available scientific knowledge and in September 2021 released revised global air quality guidelines (WHO 2021).

- In New Zealand, the HAPINZ 3.0 study (Kuschel *et al.* 2022), estimates that in 2016, the health outcomes attributable to anthropogenic (human-generated) air pollution resulted in:
  - the premature deaths of more than 3,300 adult New Zealanders
  - more than 13,100 hospital admissions for respiratory and cardiac illnesses, including 845 asthma hospitalisations for children
  - over 13,200 cases of childhood asthma

- Of the more than 3,300 deaths approximately 60% (2,000) were associated with nitrogen dioxide (NO_2) pollution – which is largely from motor vehicles – whilst the rest (nearly 1,300) were associated with fine particulate ($PM_{2.5}$) pollution – largely from domestic fires. For context, 30,422 New Zealanders died in 2016 from natural causes (Ministry of Health 2022). [1]

- To improve air quality in New Zealand concerted action will need to be taken in sectors like transport, energy (particularly home heating), urban planning and industry. Reducing emissions from these sectors will also reduce New Zealand's greenhouse gas emissions.

Background

Air pollution is a major environmental hazard to human health and a leading cause of illness (morbidity) and death (mortality) worldwide.

WHO has identified air quality as the world's largest environmental health risk and among the largest global health risks – comparable with 'traditional' health risks such as smoking, high cholesterol, and obesity. The WHO estimates that indoor and outdoor air pollution exposure currently kills about seven million people worldwide every year due to cardiovascular diseases, such as strokes and ischaemic heart disease, as well as respiratory diseases including acute respiratory infections, chronic obstructive pulmonary diseases and lung cancer. According to the World Bank, the global health cost of mortality and morbidity attributed to air pollution was $8.1 trillion in 2019 (World Bank 2022).

Most air pollution related deaths are from non-communicable diseases such as stroke, lung cancer and chronic respiratory disease. However, air pollution also has other impacts – including damaging natural ecosystems, biodiversity and crops, limiting enjoyment of the outdoors and harming our quality of life. Health impacts from air pollution can also be exacerbated for certain portions of the population due to proximity to air pollution sources, sensitivity to health effects or the resilience of that population to respond to these effects. The impacts of air pollution are assessed through short-term (acute) or long-term (chronic) exposure. Short-term exposures cover minutes, hours, or days. Long-term exposures are usually over months or years. The major impacts of air pollution occur due to chronic exposure. Depending on the circumstances (e.g., duration and magnitude of exposure) the health burden due to chronic exposure to air pollution may be 10 times greater than that for acute exposure, based on the relative risk ratios (WHO 2021).

[1] Excludes motor vehicle accidents, intentional self-harm & assault

WHO 2021 Global Air Quality Guidelines

The 2021 WHO Global Air Quality Guidelines (the Guidelines) note "*compared to 15 years ago, when the previous edition of these guidelines was published, there is now a much stronger body of evidence to show how air pollution affects different aspects of health at even lower concentrations than previously understood*" (WHO 2021). The Guidelines provide global guidance on thresholds and limits for key air pollutants that pose health risks and offer quantitative, health-based recommendations for air quality management derived from epidemiological evidence.

To support the Guidelines update, WHO published a series of systematic reviews, using meta-analyses to evaluate the best available evidence on the effects of air pollutants on human health (Whaley *et al*. 2020-21). Brief plain English summaries of these review papers are available (Wickham *et al*. 2022a-g) on the ESR website.

The Guidelines apply worldwide to both outdoor and indoor environments and are expressed as long-term or short-term concentrations.

WHO noted that the new Guidelines do not identify 'safe' levels and are not based on a defined level of acceptable risk (i.e., the guidelines are not "no adverse effect levels"). WHO advises that the risks of long-term exposure to elevated concentrations of air pollutants are significantly (an order of magnitude) higher than the risks of short-term exposure. This means that long-term air quality guideline levels for most health outcomes are more protective of health than short-term air quality guideline levels. However, both short-term and long-term guidelines are needed to protect against different health effects for different pollutants that can occur over different exposure periods.

The Guidelines also include qualitative good practice recommendations for black carbon/elemental carbon, ultrafine particles (<1 μm) and particles derived from sand and dust storms. Not all the air pollutant's averaging times were considered in the Guidelines update; some averaging times were carried over from previous publications (WHO 2000, WHO 2006, WHO 2010).

The classical air pollutants

WHO's new guidelines recommend air quality levels for six pollutants where evidence has advanced the most on health effects from exposure. WHO refers to these pollutants as 'classical' air pollutants. They are particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2) sulfur dioxide (SO_2) and carbon monoxide (CO).

Particulate matter (PM)

Worldwide (and in New Zealand), the worst human health impacts from poor air quality are estimated to be caused by particulate matter (PM) (Health Effects Institute 2020). PM is a collective term for solid and liquid particles suspended in the air and small enough to be inhaled. The major components of PM are sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water.

PM is classified by particle size defined through aerodynamic diameter:

- **PM_{10}** – particulate matter less than 10 micrometres;
- **$PM_{2.5}$** – particulate matter less than 2.5 micrometres;
- **$PM_{0.1}$** – particulate matter less than 0.1 micrometres.

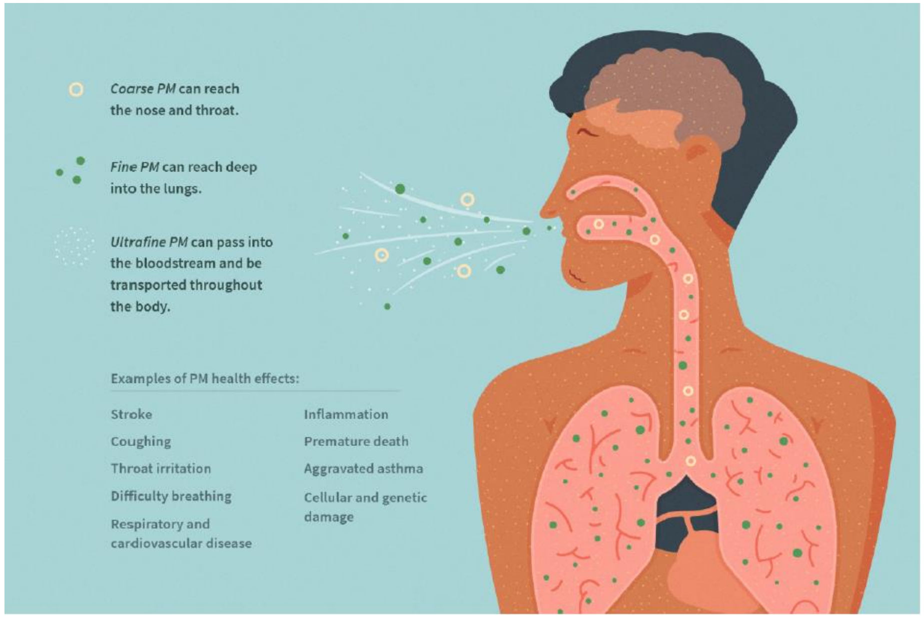
In general, $PM_{2.5}$ (fine particulate) and smaller tends to be more closely associated with anthropogenic activities, whereas the $PM_{10-2.5}$ fraction (coarse particulate matter) can have a substantial natural source component. The main sources of PM in New Zealand are home heating, industry, agricultural practices, road dust and sea salt. The main anthropogenic (human caused) sources of PM in New Zealand are domestic fires, motor vehicles and industry.

Health effects of PM

Different sizes of PM can result in different health effects. This is because they deposit in different parts of the respiratory tract, they have diverse sources, and they can interact through different biological mechanisms (WHO 2013). In general, the smaller a particle is, the farther into the respiratory tract it can penetrate (to interact and cause adverse health effects).

There is scientific consensus that exposure to particulate pollution causes predominantly respiratory and cardiovascular effects, ranging from subclinical functional changes (e.g. reduced lung function) to symptoms (increased cough, exacerbated asthma) and impaired activities (e.g. school or work absenteeism) through to doctors' or emergency room visits, hospital admissions and death (WHO 2006). The effects, in terms of escalating severity, are described as increased visits to doctors for many individuals, hospital admission for some individuals and death for a few individuals. People with pre-existing heart or lung disease, young children, and the elderly, are most likely to suffer adverse health effects. The exposure-response relationship is essentially linear and there is no 'safe' threshold; adverse health effects are observed at all measured levels (USEPA 2020a; WHO, 2021).

The impact of particulate matter on the human body



[Source: Ministry for the Environment and Stats NZ 2018]

In 2013, the International Agency for Research on Cancer (IARC) classified particulate matter (as a component of outdoor pollution) as carcinogenic based on an increased risk of lung cancer (IARC 2013). Additional research further indicates particulate matter is associated with atherosclerosis, adverse birth outcomes, childhood respiratory disease (WHO 2013) as well as Alzheimer's disease and other neurological endpoints, cognitive impairment, diabetes, systemic inflammation and aging (WHO 2016b).

More recently, WHO has concluded that chronic exposure to PM is causal, or likely to be causal, for (WHO 2021):

- All-cause mortality
- Cardiovascular mortality (all, cerebrovascular, ischaemic heart disease)
- Respiratory mortality (any, chronic obstructive pulmonary disease, acute lower respiratory infections)
- Lung cancer

WHO Guidelines for PM

Pollutant / Time Average	Guideline ($\mu g/m^3$)	Permitted Exceedances per year
$PM_{2.5}$		
Annual	5	n/a
24-hours	15	3-4
PM_{10}		
Annual	15	n/a
24-hours	45	3-4

Additional reading

- Health effects of long-term exposure to PM (Wickham *et al*. 2022a) – A plain English summary of the paper evaluating the health effects of long-term exposure to PM for the Guidelines update (Chen and Hoek 2020)
- Health effects of short-term exposure to PM and NO_2 (Wickham *et al*. 2022b) – A plain English summary of the paper evaluating the health effects of short-term exposure to PM and NO_2 for the Guidelines update (Orellano *et al.* 2020)
- Supporting Information for Air Quality Factsheets (Wickham *et al*. 2022g) – supporting technical information for the plain English summaries.

Nitrogen dioxide (NO_2)

Nitrogen dioxide (NO_2) is a reddish brown coloured acidic gas with a characteristic pungent odour. The main sources of NO_2 worldwide are combustion processes such as motor vehicles, domestic heating, industrial combustion sources, electricity generation, shipping and construction machinery. NO_2 is both a primary and secondary pollutant i.e., it is both emitted and forms downwind from other pollutants.

Nitrogen dioxide is the main source of nitrate aerosols, which form an important fraction of $PM_{2.5}$ and, in the presence of sunlight, ozone. It is also a major component of brown haze. In New Zealand the main source of nitrogen dioxide is motor vehicles.

Health effects of nitrogen dioxide

Long-term exposure to NO_2 increases the risk of premature death (mortality) and respiratory illnesses (morbidity) (Huangfu & Atkinson 2020). Epidemiolocal studies have also shown that symptoms of bronchitis in asthmatic children increase with long-term exposure to NO_2 (Orellano *et al*. 2020). Short-term exposure to high concentrations of nitrogen dioxide (NO_2) causes significant inflammation of the airways and respiratory problems and can also trigger asthma attacks (WHO 2021).

Reduced lung function is linked to measured levels within cities of Europe and North America (WHO 2005). There is also evidence that suggests exposure may increase the risk of premature death and trigger heart attacks (Orellano 2020, USEPA 2016).

WHO Guidelines for nitrogen dioxide

Time Average	NO_2 Guideline (µg/m³)	Permitted Exceedances per year
Annual	10	n/a
24-hours	25	3-4
1-hour	200	-

Additional reading

- Health effects of long-term exposure to NO_2. (Wickham *et al*. 2022c) – A plain English summary of the paper evaluating the best available evidence on the health effects of long-term exposure to NO_2 for the Guidelines update (Huangfu & Atkinson 2020)
- Health effects of short-term exposure to PM and NO_2 (Wickham *et al*. 2022b) – A plain English summary of the paper evaluating the best available evidence on the health effects of short-term exposure to PM and NO_2 for the Guidelines update (Orellano *et al*. 2020)
- Effects of short-term exposure to NO_2 and SO_2 on asthma (Wickham *et al*. 2022d) – A plain English summary of the paper evaluating the best available evidence on the effects of short-term exposure to nitrogen dioxide and sulphur dioxide and asthma exacerbations (Zheng *et al*. 2021)
- Supporting Information for Air Quality Factsheets (Wickham *et al*. 2022g) – supporting technical information for the plain English summaries.

Sulphur dioxide (SO_2)

Sulphur dioxide (SO_2) is a colourless gas with a sharp odour. It is produced from the combustion of fossil fuels and natural geothermal processes. SO_2 is both a primary and secondary pollutant i.e., it is both emitted and forms downwind from other pollutants. SO_2 is also a known precursor for PM formation.

In New Zealand the major anthropogenic sources are industrial processes (aluminium manufacture, fertiliser manufacturing) and the combustion of fossil fuels that contain sulphur (coal fired boilers).

Health effects of sulphur dioxide

Sulphur dioxide can cause respiratory problems, such as bronchitis, and it can irritate the nose, throat and lungs. This is because inhaled sulphur dioxide readily reacts with the moisture of mucous membranes to form sulphurous acid (which is a severe irritant). It may cause coughing, wheezing, phlegm and asthma attacks (MfE 2014).

Studies have shown that asthmatics and people with lung disease are particularly sensitive to sulphur dioxide. Children may also be more sensitive to the effects of sulphur dioxide due to their relatively higher respiration rate and smaller body mass. Key points to note are (WHO 2006):

- There appears to be a continuous spectrum of sensitivity to sulphur dioxide. This means that some people will be completely unaffected by concentrations that lead to severe bronchoconstriction in others. Asthmatics are particularly sensitive.
- The maximum effect is usually reached within a few minutes. Effects are generally short-lived. Lung function returns to normal after some minutes to hours, varying with the individual and the severity of the response.

Levels of 500 µg/m³ should not be exceeded for averaging periods of 10 minutes as asthmatics can experience changes in pulmonary function and respiratory symptoms (WHO 2006).

The association between short-term SO_2 and asthma hospital admissions and emergency room visits was judged to be causal for respiratory effects (WHO 2021).

WHO Guidelines for sulphur dioxide

Time Average	SO_2 Guideline (µg/m³)	Permitted Exceedances per year
24-hours	40	3-4
10-minutes	500	-

Additional reading

- Health effects of short-term exposure to SO_2 (Wickham *et al*. 2022e) – A plain English summary of the paper evaluating the best available evidence on the health effects of short-term exposure to SO_2 for the Guidelines update (Orellano *et al*. 2021)
- Effects of short-term exposure to NO_2 and SO_2 on asthma (Wickham *et al*. 2022d) – A plain English summary of the paper evaluating the best available evidence on the effects of short-term exposure to nitrogen dioxide and sulphur dioxide and asthma exacerbations (Zheng *et al*. 2021)
- Supporting Information for Air Quality Factsheets (Wickham *et al*. 2022g) supporting technical information for the plain English summaries.

Ozone (O_3)

Ozone (O_3) is a reactive gas that exists in two layers in the atmosphere: the stratosphere and the troposphere (at ground level and up to 15 km). Stratospheric ozone protects life on Earth from UV radiation, but tropospheric ozone is an air pollutant affecting human and ecosystem health.

Ozone is a secondary gas and is produced by a chemical reaction between hydrocarbons, including methane, and nitrogen oxides in the presence of sunlight. Because sunlight is required to form ozone, concentrations are usually highest in mid to late afternoon in summer. Ozone is also a major component of photochemical smog. Ozone is widely considered to be at very good (i.e., relatively low) levels in New Zealand.

Health effects of ozone

People most at risk from breathing air containing ozone include people with asthma, children, older adults, and people who are exercising outdoors. Breathing ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and airway inflammation. It also can reduce lung function and harm lung tissue. Ozone can worsen bronchitis, emphysema, and asthma, leading to increased medical care. People with lung or cardiovascular diseases are particularly at risk (USEPA 2020b).

WHO Guidelines for ozone

Time Average	O_3 Guideline (µg/m³)	Permitted Exceedances per year
8-hour daily maximum	100	3-4
8-hour mean, peak season [a]	60	-

[a] Peak season is defined as an average of daily maximum 8-hour mean ozone concentration in the six consecutive months with the highest six-month running average ozone concentration (usually summer)

Carbon monoxide (CO)

Carbon monoxide (CO) is a colourless, odourless and tasteless toxic gas. It is produced by the incomplete combustion of carbonaceous fuels such as wood, petrol, coal and natural gas.

Levels of ambient carbon monoxide in New Zealand are relatively low.

Health effects of carbon monoxide

In the human body carbon dioxide reacts with haemoglobin to form carboxyhaemoglobin. Short term exposure to high concentrations of carbon monoxide can cause acute ischaemic heart attacks (myocardial infarction) and damage the foetuses of non-smoking pregnant women due to untoward hypoxic effects (WHO 2010).

WHO Guidelines for carbon monoxide

Time Average	CO Guideline (mg/m³)	Permitted Exceedances per year
24-hours	4	3-4
8-hour	10	-
1-hour	35	-
30-minute	60	-
15-minute	100	-

Additional reading

- Effects of CO exposure on heart attacks (Wickham *et al*. 2022f) – A plain English summary of the paper evaluating the best available evidence on the effects of short-term exposure to carbon monoxide (CO) and myocardial infarction (Lee *et al*. 2021)
- Supporting Information for Air Quality Factsheets (Wickham *et al*. 2022g) – supporting information for the plain English summaries.

Air Pollution in New Zealand

New Zealand is fortunate in having relatively low levels of air pollution compared with other countries. Despite this, in some parts of New Zealand, ground level concentrations of particulate matter (PM) can be elevated in winter due to build-up of emissions from home heating and motor vehicles in cold, calm, weather conditions. In addition, levels of nitrogen dioxide (NO_2) can concentrate around transport corridors in urban environments.

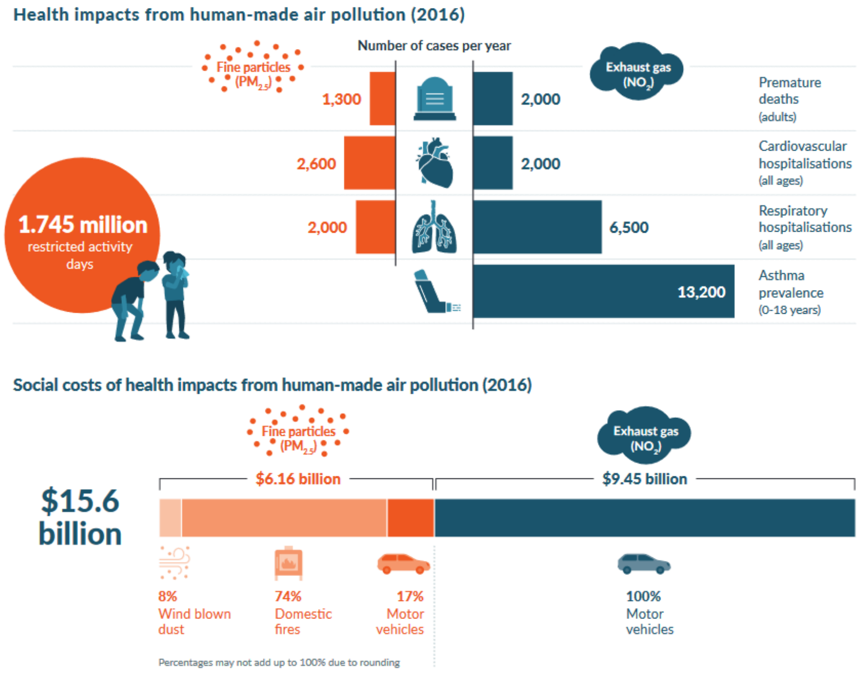
New Zealand's latest research, the HAPINZ 3.0 study (Kuschel *et al*. 2022), estimated that in 2016, the health outcomes attributable to anthropogenic (human-generated) air pollution resulted in:

- the premature deaths of more than 3,300 adult New Zealanders
- more than 13,100 hospital admissions for respiratory and cardiac illnesses, including 845 asthma hospitalisations for children
- over 13,200 cases of childhood asthma
- approximately 1.745 million restricted activity days (days on which people could not do the things they might otherwise have done if air pollution had not been present).

Of the more than 3,300 deaths approximately 60% (2,000) were associated with NO_2 pollution which is largely from motor vehicles, whilst the rest (nearly 1,300) were associated with fine particulate ($PM_{2.5}$) pollution largely from domestic fires. For context, 30,422 New Zealanders died in 2016 from natural causes (Ministry of Health 2022).

Whilst air pollution impacts many New Zealander's health, these adverse health impacts are not always evenly distributed. Susceptible groups include elderly people, children, people with pre-existing heart or lung disease, people with respiratory conditions (such as asthmatics), diabetics and pregnant women (Ministry for the Environment 2011).

Health impacts and social costs of air pollution in New Zealand



[Source: Ministry for the Environment 2022]

There is also an environmental justice aspect to these unevenly distributed health impacts. Lower socio-economic groups also tend to have housing close to significant emission sources such as arterial transport routes and industry. The HAPINZ 3.0 exposure model (Sridhar *et al*. 2022) indicates that lower socio-economic groups are disproportionately exposed to higher concentrations of nitrogen dioxide with corresponding disproportionate adverse health effects.

New Zealand has various air quality standards and guidelines for a range of pollutants and a range of time periods. Both short-term and long-term limits are set for each pollutant to provide a minimum level of health protection for all New Zealanders. The Ministry for the Environment has more information on the air quality standards and guidelines for New Zealand (MfE 2022).

Glossary

Acute exposure	Short-term exposure, typically hours or days.
Aerodynamic diameter	Airborne particles have irregular shapes, and how they behave in the air is expressed in terms of the diameter of an idealised spherical particle known as aerodynamic diameter. This is the size of a unit-density sphere with the same aerodynamic characteristics as the particle of interest. Particles having the same aerodynamic diameter may have different dimensions and shapes.
Aerosol	An aerosol is a suspension of fine solid particles or liquid droplets in air.
All-cause mortality	Death from all causes except external causes (such as accidents, intentional self-harm and homicide). Also referred to as natural mortality.
Bias	Any systematic error in an epidemiological study that results in an incorrect estimate of the true effect of an exposure on the outcome of interest.
Coarse particles	This typically refers to the fraction of particulate matter that is smaller than 10 micrometres in diameter but larger than 2.5 micrometres in diameter ($PM_{10-2.5}$). These particles are small enough to be inhaled into the thoracic region but too large to reach the alveolar region of the lungs. Coarse particles are composed largely of crustal material, sea salt and biological material.
Chronic exposure	Long-term exposure, typically months or years.
Epidemiology	The study and analysis of the distribution (who, when and where), patterns and determinants of health and disease conditions in defined populations.
Fine particles	This typically refers to particulate matter less than 2.5 micrometres in diameter. These are small enough to reach the alveolar region of the lungs where inhaled gases can be absorbed by the blood. Fine particles originate primarily from combustion sources.
Meta-analysis	A survey in which the results of the studies included in the review are statistically similar and are combined and analysed as if they were one study.
microgram (µg)	One millionth of a gram (1×10^{-6} g)
micrometre (µm)	One millionth of a metre (1×10^{-6} m)
Morbidity	Illness and disease, e.g., hospitalisations
Mortality	Death
Particulate matter (PM)	Particulate matter is a complex mixture of suspended particles and aerosols with components having diverse chemical and physical characteristics. It is generally classified by aerodynamic diameter (a summary indicator of particle size) because this determines dispersion and removal processes in the air and deposition sites and clearance pathways within the respiratory tract. The smaller the particle, the longer it remains suspended in the air. Particles larger than 50 micrometres (µm) in diameter will settle out quickly. However, for fine particles of 1 µm any settling due to gravity is negligible (i.e. they will stay suspended in the air).
PM_{10}	Particulate matter smaller than 10 micrometres (µm) in diameter. PM_{10} is so small that it behaves like a gas, travelling for significant distances once emitted to air. PM_{10} includes inhalable particles that are sufficiently small to penetrate to the thoracic region of the lung. The coarse fraction of PM_{10} (i.e., $PM_{10-2.5}$) is primarily produced by mechanical processes such as construction activities, road dust resuspension and wind-blown dust, however, it also includes natural sources such as sea salt, pollen, mould and plant parts.
$PM_{2.5}$	Particulate matter smaller than 2.5 micrometres (µm) in diameter, also called fine particulate. $PM_{2.5}$ has a high probability of deposition in the smaller conducting airways and alveoli of the lungs where inhaled gases can be absorbed by the blood (WHO, 2006). $PM_{2.5}$ is mainly produced by combustion of fossil fuels and through secondary particle formation from nitrate, sulphate and organic aerosols and particles.

$PM_{0.1}$	Particulate matter smaller than 0.1 micrometres (µm) in diameter, also called ultrafine particulate. These particles are small enough to cross into the blood and circulate through the body.
Systematic review	Literature review designed to provide a complete, exhaustive summary of current evidence that is methodical, comprehensive, transparent, and replicable.
Time average	The length of time over which exposure is measured. This is an important element of understanding air pollution and air pollution effects. For example, a concentration of PM_{10} as a 24-hour average, is the concentration of PM_{10} when averaged out over a whole day. The hourly concentrations of PM_{10} may increase overnight then rise in the morning with peak hour traffic but drop off in the afternoon and evening. However, the daily concentration will reflect the average concentration over the full 24-hour period from midnight to midnight. Similarly, an annual average PM_{10} concentration is the concentration of PM_{10} when averaged out over all 365 days (or 8,760 hours) in a year. Typical urban areas of New Zealand have elevated daily concentrations of PM_{10} in winter (due to high emissions from domestic heating combining with still wind conditions). However, spring and summer winds typically result in much lower daily PM_{10} concentrations and the annual average is reduced accordingly when averaged over all the seasons.
µg/m³	microgram per cubic metre. This is the mass measured in millionths of a gram per unit of (cube) space comprising 1 metre x 1 metre x 1 metre. In New Zealand concentrations are typically specified at 0°C (MfE, 2009).

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Health Effects of Air Pollutant Factsheets: Supporting Information

October 2022

Air pollution is a major hazard to human health and a leading cause of illness and death. In 2021, the World Health Organisation (WHO) published revised global air quality guidelines to offer quantitative, health-based recommendations for air quality management (WHO 2021). To support this update, WHO published a series of review papers evaluating the best available evidence on the effects of air pollutants on human health (Chen and Hoek 2020; Huangfu and Atkinson 2020; Lee et al. 2020; Orellano et al. 2020, Orellano et al. 2021; Zheng et al. 2021).

This factsheet provides additional technical detail on how the systematic reviews informed the development of WHO's revised global air quality guidelines.

Background

A *systematic review* is a type of literature review that uses systematic methods to collect secondary data, critically appraise research studies and synthesise findings to answer the review question. For example, in Zheng *et al*. 2021, the systematic review question was:

> *"What is the effect of short-term exposure to NO_2 and SO_2 on emergency room visits and hospitalisations due to asthma?"*

Zheng and fellow researchers undertook a *meta-analysis* of current air pollution epidemiology studies for short-term air pollution exposure to NO_2 and SO_2. A meta-analysis is a survey in which the results of the studies included in the review are statistically similar and are combined and analysed as if they were one study. The meta-analysis thus pools together risk ratios from many, similar studies, to establish a new *risk ratio*.

Risk Ratios

A risk ratio *(RR)* is the ratio of the probability of an outcome in an exposed group to the probability of an outcome in an unexposed group. For relationships that are known to be causal (such as air pollution and adverse health effects), values of RR can be interpreted as follows:

- RR = 1 means that exposure does not affect the outcome
- RR < 1 means that the risk of the outcome is decreased by the exposure
- RR > 1 means that the risk of the outcome is increased by the exposure

It is important to note that RR are relative (to non-exposure). This means that to understand a RR, the range of exposure needs to be clearly stated. The standard increment in air quality epidemiology (including Zheng *et al*. 2021) is 10 micrograms per cubic metre (μg/m^3).

Long-term vs short-term effects

The health effects of exposure to air pollution depend on the duration of exposure as well as the concentration of the pollutant. For example, exposure may trigger the occurrence of an acute event (e.g., asthma attack or myocardial infarction) leading to death (short-term effects) and/or increase the underlying frailty of the population due to chronic exposure (long-term effects).

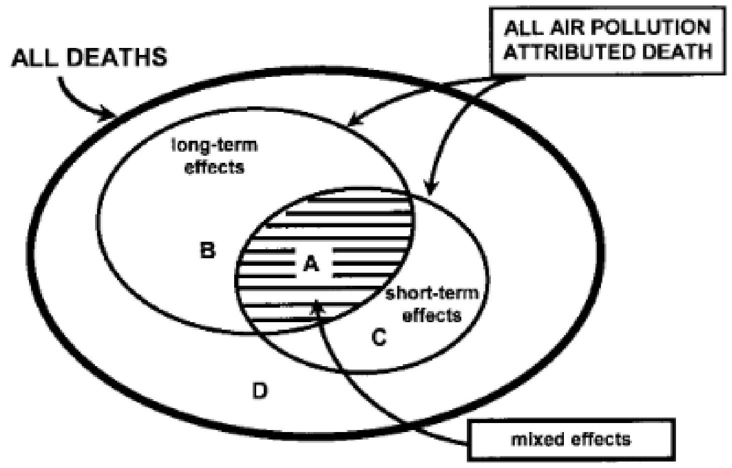

Figure 1: Illustration of deaths due to ambient air pollution in a population, including cases related to both long term and short-term air pollution (Künzli et al. 2001)

To explain the difference between short-term effects and long-term effects, Künzli *et al*. (2001) describes four different categories of mortality effects A, B and C and D. These are illustrated in **Figure 1** and categorised as follows.

- For deaths in **category A**, air pollution may have played a role both in increasing the persons underlying susceptibility or frailty and in triggering the event. For example, patients with chronic bronchitis that has been aggravated by long term air pollution exposure may be hospitalised with an acute, air pollution-related exacerbation of their illness, leading to death shortly afterward.

- For cases in **category B**, the underlying frailty is again related to (among other factors) long term air pollution, but the event or the occurrence of death itself is unrelated to the levels of air pollution shortly before death. For example, suffering from chronic bronchitis may be made worse by long term ambient air pollution exposure but the person may die of acute pneumonia acquired during a clean air period. Therefore, long term cumulative exposure to air pollution contributed to shortening of survival time, whereas air pollution during the final days of life had no further life-shortening effect.

- Among deaths in **category C**, reduced health status or frailty is not related to air pollution, but ambient air pollution experienced before death may trigger the terminal event. For example, a person with diabetes mellitus may be susceptible to heart attacks due to long-standing coronary disease; in such a case, an air pollution episode may trigger the fatal infarction leading to hospital admission, arrhythmia, or death.

- Finally, in **category D**, neither disease history nor the event of death are related to air pollution. In reality (unlike **Figure 1**) category D is much larger than all other categories.

The calculation of air pollution attributable deaths ought to include categories A, B and C.

The policy outcome of this is that air quality guidelines are needed for different exposure periods to protect against different health effects.

Setting WHO 2021 Air Quality Guidelines

The WHO 2021 air quality guidelines (AQG) were developed using the protocol outlined in WHO, 2021, with extensive internal and external review.

Long-term (annual mean, or for ozone, highest six-month average) AQG levels are defined as the lowest exposure level of an air pollutant above which WHO is confident that there is an increase in adverse health effects. This confidence is primarily based on there being moderate or high certainty of evidence for an association between a specific pollutant and a specific health outcome.

Short-term AQG levels are typically defined as a high percentile (e.g., 98^{th} or 99^{th}) of concentrations empirically observed in distributions with a mean equal to the long-term AQG level.[1] The reasoning behind this is that for locations in which concentrations are below the long-term AQG, days with such high daily mean concentrations will be rare and a large proportion of days will have concentrations below the long-term AQG level. This means that the health burden related to a few days with higher concentrations corresponds to a very small fraction of total air pollution-related burden. The rationale for choosing a high percentile and not the maximum is that the maximum of daily values for a given year is a less stable statistic than the high percentiles.

It is important to note that the approach to setting guidelines does not identify safe levels and is not based on a defined level of acceptable risk (i.e., the guidelines are not "no adverse effect levels").

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[1] For SO_2 there is no long-term AQG so the approach has been to select a high percentile daily value consistent with other pollutants, whereby the estimated excess mortality at days with concentrations at the proposed 24-hour guideline is roughly comparable across all pollutants.