# Submission on the proposed variation to the ambient air quality measure standards for ozone, $NO_2$ and $SO_2$

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Healthy planet, healthy people.

National Environmental Protection Council, Department of the Environment and Energy, Australian Government; Proposed variation to the ambient air quality measure standards for ozone, $NO_2$ and $SO_2$.[1]

## Executive summary

Australia's air pollution standards, known as National Environment Protection Measures (NEPM), were set in 1998 and are long overdue for revision. These standards are intended to protect public health, but they have not kept up with new research on the health impacts of air pollution. Health effects occur at lower concentrations than previously thought. Many foreign jurisdictions review their air standards every five or ten years and have progressively lowered permissible levels over time. The particle standards were updated in 2015, and the current review is for sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$) and ozone. These three pollutants are quick acting respiratory irritants, but $NO_2$ and possibly ozone also have long term effects.

Substantial human exposure occurs along busy roads, but until now the NEPM reporting process has excluded these locations. Roadside exposure can be many times higher than urban background exposure, especially for $NO_2$. The NEPM should be expanded to include specified methods and locations for uniform measurement of roadside $NO_2$ in each city because unless it gets measured it will not be managed.

The currently circulated proposal prepared by the Victorian EPA has not properly taken account of current research findings and misses important opportunities to improve health. The proposed 1-day standard for $SO_2$ and annual standard for $NO_2$ appear to be based primarily on what is currently easily achievable rather than aiming for the substantial health benefits from meeting more ambitious standards. DEA supports Australia adopting the World Health Organization (WHO) 1-day $SO_2$ standard of 8 ppb, and a new annual standard for $NO_2$ of 9 ppb. Our proposed $NO_2$ standard of 9bbp is based on research conducted in Australian schools showing substantial effects on children's asthma down to that level.

Nitrogen dioxide has two main sources; vehicle exhaust and burning coal for electricity, while $SO_2$ also has two main sources; metal smelting and burning coal for electricity. Vehicles and electricity generation are areas of technological change where low and zero pollution options are rapidly entering the market. Strong pollution reduction policies based on good standards will assist Australia in reaching the best outcome during this period of change.

# Recommendations

1) That the following standards be adopted for the revised AAQ NEPM.

| Pollutant | Time | Number | Form |
|---|---|---|---|
| **$SO_2$** | 1 hour | 60 ppb | 99th centile of daily worst hour, averaged over 3 years |
| **$SO_2$** | 24 hours | 8 ppb | Maximum value |
| **$NO_2$** | 1 hour | 72 ppb | 99th centile of daily worst hour, averaged over 3 years |
| **$NO_2$** | Annual | 9 ppb | Maximum value |
| **Ozone** | 8 hours | | |

2) Australia should follow the precedents of the US and Canada in adopting the 99th centile of daily worst hour as the form for both 1-hour $SO_2$ and $NO_2$ standards.
3) Part 4 (13) Location of performance monitoring stations have a new paragraph: "In addition to background monitoring sites each jurisdiction must establish some roadside monitoring sites on roads with more than 20,000 vehicles per day, at locations where people live or work."
4) That a program of research be developed to establish, by 2025, air quality standards applicable to locations where people are exposed near busy roads.
5) That future revisions of the NEPM be mandated every 10 years.

**Jargon:**

| | |
|---|---|
| **RIS** | **Regulatory Impact Statement** |
| **NEPM** | **National Environment Protection Measure** |
| **ppb** | **Parts per billion** |
| **pphm** | **Parts per hundred million. (These units are only used in NSW)** |
| **REVIHAAP** | **A review process conducted by World Health Organization (WHO) Europe.** |
| **ACHAPS** | **Australian Child Health and Air Pollution Study, started in 2007.** |
| **US EPA** | **United States Environment Protection Agency** |
| **LUR** | **Land Use Regression model. A method to predict air quality at any location based on local geographic features such as roads and industry, meteorology, and sometimes satellite data.** |
| **IQR** | **Inter Quartile Range. The difference between the 25th and 75th centile.** |
| **TRAP** | **Traffic Related Air Pollution** |
| **99th centile** | **The value in a data set that is exceeded by 1% of data points.** |

## Background

The national ambient air quality standards set in 1998 are out of date and new science since then has demonstrated health impacts at lower levels of exposure, and health impacts that were previously unknown especially for children. The literature review for the regulatory impact statement has documented some of this but failed to discover some of the important child health problems from air pollution.

The objective of the NEPM is to minimise risk to health for Australians wherever they live and the NEPM sets standards for background ambient air. Ambient air is specified to be measured away from any hot spot or busy road, typically in a suburban park. Not all people however are breathing background ambient air. Many people are exposed to poor air quality along roadways which can have pollutants, especially $NO_2$, many times higher than background. It is a failing of the current approach to air quality standards that it does not adequately take account of the common problem of high exposure along busy roads.

For some air pollutants it is unrealistic to talk about a safe level, as there is no lower threshold below which there are no health effects. The best studied such pollutant is the long-term exposure to fine particles. For other pollutants such as short-term exposure to the irritant gases $SO_2$ and $NO_2$ there is evidence from experimental exposure studies of thresholds below which no effect has been detected. When there really is no threshold, regulation has to be based on the trade-off between health gains and the costs of abatement. When there is a threshold however it is realistic to define safe levels that will protect health.

An important feature of well-designed air quality standards is to be able to robustly identify air sheds that are non-compliant, to support strong regulatory action to improve air quality and protect health.

## The approach taken to standard setting

The decision-making process evident in the Regulatory Impact Statement (RIS) proposing the new standards is inadequate. The impact statement has taken the approach that for all pollutants there is no lower threshold below which exposure can be regarded as safe, so the decision about standards is to be made on the basis of what is easily achievable and what might be cost effective. This is a poor basis for decision making. Air quality standards should be set on health grounds, making use of the precautionary principle when necessary. What is achievable by way of improvements in air quality will change rapidly over time with the development of new technological solutions, which will not be developed or implemented if there is no pressure to do so. For example, when the current NEPM standards were set, cars could emit 1.93 g/Km of NOx (vs current 0.06 g/Km) and many power stations did not even have fabric filters. In 2019 we have technologies for zero exhaust pollution vehicles and zero pollution electricity, which could be the dominant technologies within 10 years. Air quality standards should be realistically ambitious about minimising health damage and issues of achievability and cost should be handled by state and federal air quality improvement programs.

The current RIS has abandoned any consideration of safe levels and relied heavily on cost benefit analysis. The range of health benefits from cleaner air for which there are firm dollar valuations are very limited, so the cost benefit analysis documents only a small fraction of the full community benefits of cleaner air. As an example, the input for the value put on a new case of respiratory disease (life-long) is $341. We invite any reader to try explaining that to the parent of a child with asthma.

Excessive weight is given to whether air quality observed in the period 2010 to 2014 would meet or exceed various proposed standards. Why they could not examine more recent years is not explained. Sydney is said to have the highest annual $NO_2$ levels in the country, however the highest annual $NO_2$ observed in Sydney in the period 2014 to 2018 is 13.1 ppb at Chullora in 2014. We know that $NO_2$ causes disease at this level, so why has the annual standard been proposed at 19 ppb?

*QUOTE 7.12.1.2 The historical monitoring data and the model projections indicate that a standard of 19 ppb would be achievable in the Australian airsheds and would align Australia with the tightest international standards.*

*An annual NO2 standard of 10 ppb would not appear to be achievable in several jurisdictions based on the historical monitoring data. Although it has not been assessed in this Impact Statement, an intermediate standard of 15 ppb ought to be achievable, and this is recommended as a longer-term goal to drive further improvement.*

This shows several serious flaws in logic. Firstly, that because the annual level of 19 ppb has already been achieved, that is a suitable standard for Australia to adopt. Secondly, that because current air in some places has greater than 10 ppb $NO_2$, a standard of 10 ppb is ruled out. Thirdly, that the standard we would like to reach should be put off into the future rather than adopted now. These serious flaws expose a quite inadequate decision-making process.

The term exposure reduction framework is misused throughout the document. An exposure reduction framework recognises that lowering pollution has value even when ambient air standards are met. An example would be a pollution fee system which imposes a fee per tonne of pollutant and provides an economic rationale for cleaner production even below a fixed standard. In the RIS exposure reduction framework is taken to mean lowering the standard in the future such as in 2025. It makes far more sense to choose a health-based standard now and work towards compliance by 2025.

## New scientific evidence that was not properly included

The literature review on health effects of gaseous air pollutants makes extensive use of a review done for WHO's Review of evidence on health aspects of air pollution (REVIHAP), published in 2013 so now 6 years old. The REVIHAP review found that even in 2013 there was new evidence about $NO_2$ exposure, and they were expecting both the 1-hour and annual WHO standard to be revised downwards.[2]

Additional critical evidence that has not been properly considered includes:

The Australian Child Health and Air Pollution Study (ACHAPS) first reported in 2012, and further analysis was published in 2018[3]. This was a cross sectional study of 2,630 children at 55 schools across Brisbane, Sydney, Melbourne, Adelaide and Perth, aged between 7 and 11 years. Schools had to be within 2 Kms of an ambient air quality monitoring station. The children did lung function testing and exhaled NO tests and parents completed questionnaires. Mean $NO_2$ exposure was 8.8 (SD 3.2) inter quartile range 4 ppb from monitors. There was a strong association between $NO_2$ exposure and current asthma, with odds ratio 1.24 (1.08-1.43) per 4 ppb from monitor-based exposure and OR 1.54 (1.26-1.87) from Land Use Regression (LUR) based exposure which takes account of both home and school locations. This is strong evidence because it is an Australian study, the design gave good exposure classification as schools were close to monitors, and LUR gave even more geographic specificity of exposure at both home and school. $NO_2$ was regarded as a proxy for the whole of traffic related pollution, so while the asthma may be due to multiple components of traffic related air pollution (TRAP), $NO_2$ serves as a proxy for the mixture in both research and for regulation purposes.

Further strengths of this research are that the effects on lung function were found across all children, even those without asthma, and effects on exhaled NO support the pathogenic mechanism. While ACHAPS does not suggest a safe level of $NO_2$, it does demonstrate that air with $NO_2$ over annual 8.8 ppb causes asthma.

ACHAPS is consistent with international evidence. Khreis et al published a systematic review and meta-analysis of $NO_2$ exposure and incident asthma in children[4]. They found 20 studies at the search date Sept 2016. All this literature should have been identified by the NEPM review. Khreis found a risk estimate for $NO_2$ of 1.05 (1.02-1.07) per 1.95 ppb for incident or lifetime prevalent asthma. This is crucial evidence that should not have been missed.

Further important evidence on the associations of $SO_2$ exposure and low birth weight, and of TRAP and child cognitive development was also not identified by the review. Some of the cognition research is summarised in Appendix A (page 17).

## The form of standards

Every air pollution standard has a time period, a number and a form.

| $SO_2$ | Time | Number | Form |
|---|---|---|---|
| Old NEPM | 1 hour | 200 ppb | Maximum value, not to be exceeded. |
| Proposed in discussion paper | 1 hour | 100 ppb | Maximum value, not to be exceeded. |
| Proposed by DEA | 1 hour | 60 ppb | 99$^{th}$ centile of the daily worst hour. |

We suggest that to regulate hourly $SO_2$ to the worst hour of the year is not an effective form for this standard. There are strong arguments to regulate to the 99$^{th}$ centile of the daily worst hour, and to average this over a rolling 3-year period as has been adopted by the United States Environment Protection Agency (US EPA). The worst hour of the year is in statistical terms always an exceptional event, and whether a region is or is not in compliance with this standard will be influenced to a large degree by chance. The single highest hour may be suspected to be a measurement error, and 'data cleaning' may even remove such values.

The 99$^{th}$ centile could be applied to the 8,760 1-hour values in a year, or to the 365 values for daily 1-hour maximum, which will be referred to here as daily worst hour. Daily worst hour is preferable due to the time profile of asthmatic reactions to the irritant gasses $SO_2$ or $NO_2$. The worst hour of the day will trigger reactions in susceptible people, and levels for the other hours in the day will not make much difference. The 99$^{th}$ centile of daily worst hour permits 4 bad air days, while 99$^{th}$ centile of hourly values potentially allows for 87 bad air days per year. DEA recommends that the form of the standard be the 99$^{th}$ centile of daily worst hour.

The problem of random fluctuation of maximum 1-hour values is illustrated by examining the distribution of hourly $SO_2$ at two sites in NSW, Randwick in Sydney which is the Sydney site with the highest annual average value but still well below any proposed standard, and Beresfield in greater Newcastle which is in the mid-range of Newcastle sites for $SO_2$ and is geographically in the middle of the population centres of Newcastle, Maitland and Port Stephens.

Figures 1 & 2 Histogram of 8,760 hourly average $SO_2$ values at Randwick, 2012 and Beresfield 2015, with an arrow showing the maximum value.

**Figure 1**
(Units pphm on the X axis)

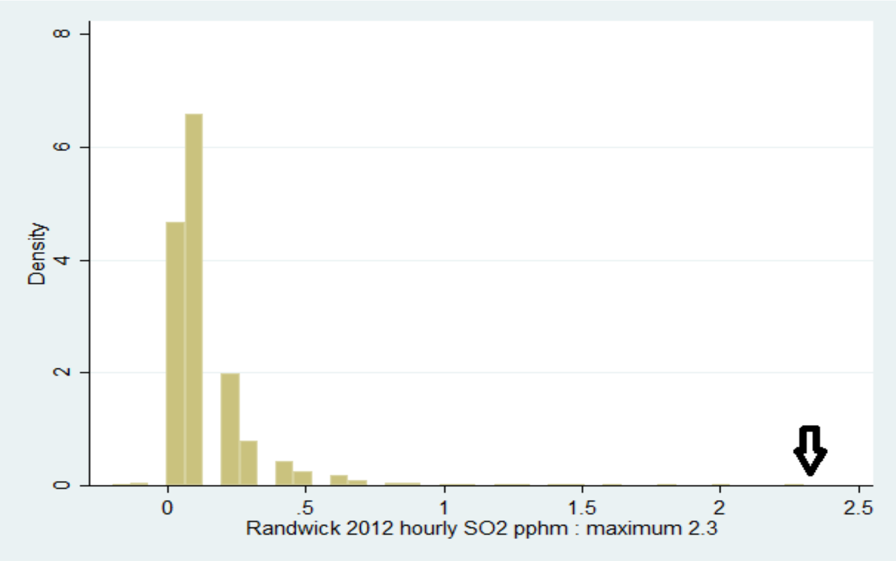
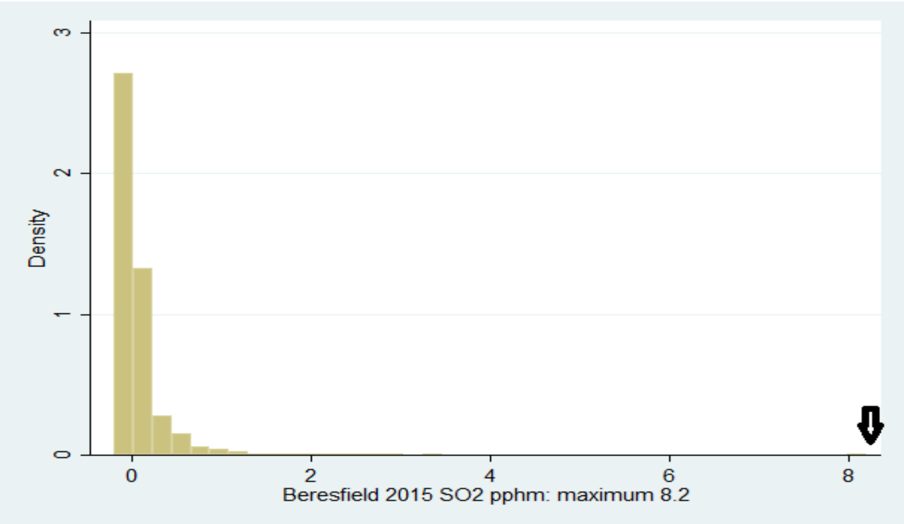



**Figure 2**
(Units pphm on the X axis)



Figures 3 & 4 show hours of the year sorted by $SO_2$ value for 2018.

**Figure 3**
(Units ppb, on the Y axis)

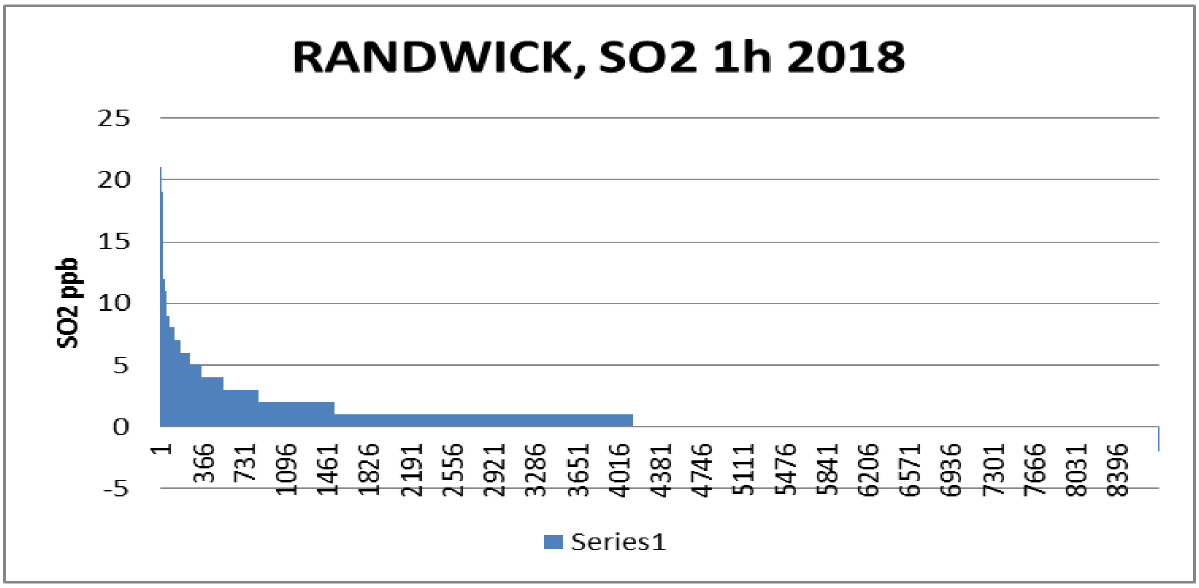
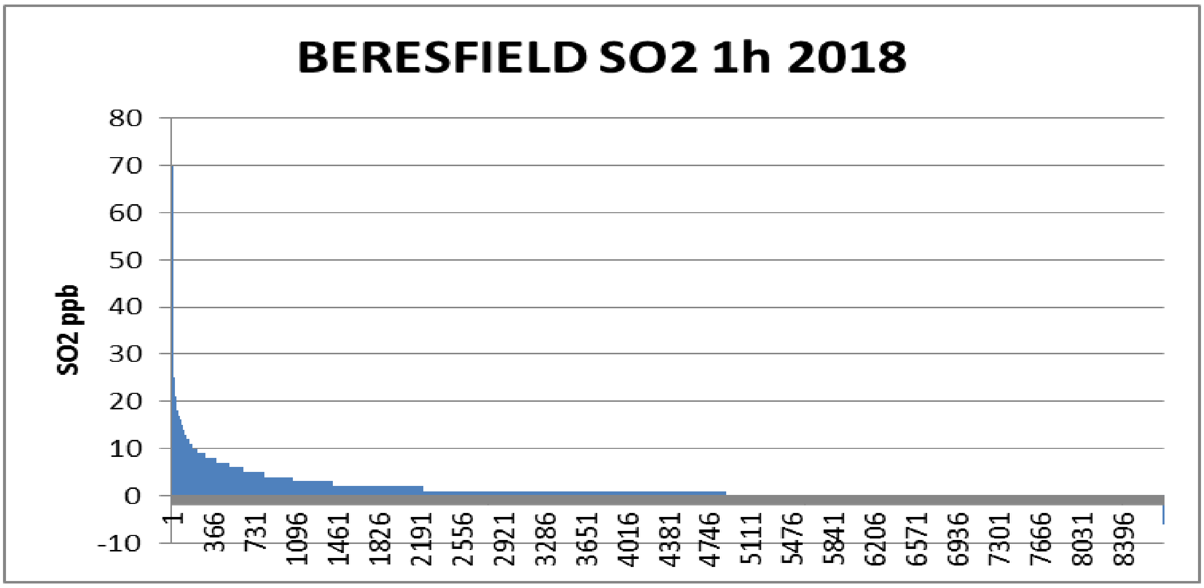



**Figure 4**
(Units ppb, on the Y axis)




The degree to which the maximum value is subject to random variation can be seen in table 1 showing various metrics for hourly $SO_2$ over a seven-year period.

**Table 1**: Comparison for each year of maximum 1-hour value with 99th and 98th centiles of hourly values, and 99th centile of the worst hour of the day.

| ppb | 2012 Randwick | 2013 Randwick | 2014 Randwick | 2015 Randwick | 2016 Randwick | 2017 Randwick | 2018 Randwick |
|---|---|---|---|---|---|---|---|
| Maximum | 23 | 27 | 26 | 31 | 34 | 29 | 21 |
| 99th centile daily worst hour | 16 | 22 | 15 | 15 | 19 | 19 | 19 |
| 99th | 8 | 7.35 | 7 | 7 | 7 | 8 | 8 |
| 98th | 6 | 6 | 6 | 6 | 6 | 6 | 7 |
| Average | 1.27 | 0.89 | 0.93 | 0.84 | 0.86 | 1.00 | 1.01 |
| | **Beresfield** | **Beresfield** | **Beresfield** | **Beresfield** | **Beresfield** | **Beresfield** | **Beresfield** |
| Maximum | 37 | 31 | 31 | 82 | 33 | 54 | 70 |
| 99th centile daily worst hour | 25 | 24 | 25 | 26 | 28 | 30 | 36 |
| 99th | 12 | 11 | 13 | 11 | 13 | 14 | 15 |
| 98th | 9 | 9 | 10 | 9 | 10 | 11 | 11 |
| Average | 1.53 | 1.27 | 1.25 | 1.03 | 1.40 | 1.51 | 1.64 |

This random variation in maximum value is even more obvious in places with an $SO_2$ problem. Table 2 shows the same metrics for Muswellbrook, a town of 25,000 people in the upper Hunter, and Stockton, a suburb of Newcastle. While the maximum varies by a factor of two, the 99th centile of daily worst hour varies by a factor of only 1.4. Muswellbrook exceeded the old NEPM 1-hour standard of 200 ppb in 2016, but this did not lead to any regulatory action.

**Table 2**: Stability over time of various metrics for hourly $SO_2$ in Muswellbrook and Stockton, NSW.

| ppb | 2012 M'brook | 2013 M'brook | 2014 M'brook | 2015 M'brook | 2016 M'brook | 2017 M'brook | 1018 M'brook |
|---|---|---|---|---|---|---|---|
| Maximum | 145 | 148 | 190 | 104 | 210 | 113 | 120 |
| 99th cent daily worst hour | 83 | 108 | 104 | 87 | 117 | 96 | 92 |
| 99th | 37 | 39 | 42 | 36 | 34 | 38 | 39 |
| 98th | 25 | 25 | 32 | 25 | 23 | 27 | 27 |
| Average | 2.29 | 2.26 | 2.86 | 2.30 | 1.98 | 2.54 | 2.60 |
| | **Stockton** | **Stockton** | **Stockton** | **Stockton** | **Stockton** | **Stockton** | **Stockton** |
| Maximum | | | 25 | 50 | 58 | 64 | 54 |
| 99th cent daily worst hour | | | 25 | 40 | 45 | 51 | 44 |
| 99th | | | 13 | 23 | 24 | 27 | 23 |
| 98th | | | 9 | 19 | 20 | 22 | 19 |
| Average | | | 1.11 (2-month Only) | 2.69 | 3.13 | 3.27 | 3.16 |

A standard for the 99th centile averaged over 3 years is a better basis for determining compliance in a region, but clearly the numeric value for a standard based on the 99th centile will be different to one based on the maximum. Table 3 compares the values of a range of metrics across some Sydney and Hunter Valley sites.

**Table 3**: Comparing possible metrics. Centiles of hourly $SO_2$, and the 99th centile of daily worst hour. ppb 2018

| Site ppb | Mean | Median | 90th | 98th | 99th | 99th worst | Max |
|---|---|---|---|---|---|---|---|
| Randwick | 1.0 | 1 | 3 | 7 | 8 | 19 | 21 |
| Liverpool | 0.7 | 0 | 2 | 4 | 5 | 10 | 20 |
| Parramatta North | 0.6 | 0 | 2 | 4 | 6 | 14 | 21 |
| Newcastle | 1.4 | 1 | 4 | 10 | 13 | 30 | 39 |
| Mayfield | 1.5 | 1 | 4 | 10 | 13 | 32 | 43 |
| Stockton | 3.2 | 1 | 9 | 19 | 23 | 44 | 54 |
| Carrington | 2.1 | 1 | 6 | 13 | 17 | 37 | 48 |
| Wallsend | 1.2 | 1 | 3 | 9 | 13 | 29 | 79 |
| Beresfield | 1.6 | 1 | 4 | 11 | 15 | 36 | 70 |
| Singleton | 1.4 | 0 | 4 | 14 | 20 | 47 | 67 |
| Muswellbrook | 2.6 | 0 | 7 | 27 | 39 | 92 | 120 |

The ratio of the 99th centile of daily worst hour to the maximum value ranges from 32% at Wallsend to 90% at Randwick, with an average of 68%. The proposed new 1-hour $SO_2$ NEPM maximum hourly standard is 100 ppb so the equivalent daily worst hour 99th centile value is 68 ppb.

The same arguments apply to the measurement of $NO_2$, as shown in table 4.

**Table 4**: Centiles of hourly $NO_2$ values, and the 99th centile of daily worst hour at 6 NSW sites 2018.

| Site ppb | Mean | Median | 90th | 98th | 99th | 99th worst | Max |
|---|---|---|---|---|---|---|---|
| Liverpool | 12.3 | 10 | 26 | 34 | 37 | 46 | 62 |
| Chullora | 11.8 | 9 | 25 | 33 | 35 | 43 | 57 |
| Parramatta North | 10.7 | 8 | 23 | 31 | 33 | 48 | 64 |
| Rozelle | 9.9 | 7 | 22 | 31 | 34 | 44 | 57 |
| Beresfield | 8.8 | 7 | 19 | 26 | 28 | 36 | 40 |
| Muswellbrook | 10.5 | 9 | 21 | 29 | 31 | 40 | 47 |

The average ratio of 99th centile worst hour to maximum value was 80% in 2018, and 83% over the 5 years since 2014. The proposed value of 90 ppb for worst hour equates to 72 ppb as 99th centile of daily worst hour values.

## Recommendation

The 99th centile of daily worst hour averaged over 3 years still focuses attention on the high levels for the respiratory irritant gases that are most likely to trigger asthma attacks but are statistically more robust and a much stronger basis for taking regulatory action. Australia should follow the precedent of the US and Canada in adopting this approach for both $SO_2$ and $NO_2$. It can be argued that the 3-year averaging means that the effects of a new polluting industry would not be noticed for 3 years so shorter averaging times should be applied in these circumstances.

### Table of current and proposed standards

| **Standard**<br>**All units ppb** | **International standards** | **Current standard** | **DEA proposal** | **RIS proposal** |
|---|---|---|---|---|
| $SO_2$ 1-hour | US - 75 as 99th centile of daily worst hour<br>Canada - 70 as 99th centile of daily worst hour<br>EU - 124 | 200 as yearly worst hour, not to be exceeded | 60 as 99th centile of daily worst hour | 100 as yearly worst hour, not to be exceeded |
| $SO_2$ 24-hour | WHO - 7.6<br>EU - 44<br>UK - 44 | 80 | 8 no exceedances | 20 no exceedances |
| $SO_2$ annual | Canada - 5<br>Elsewhere, no standard | 20 | No standard | No standard |
| $NO_2$ 1-hour | WHO - 97<br>US - 100 (98th centile, daily worst hour)<br>EU - 97 | 120 | 72 as 99th centile of daily worst hour. | 90 as yearly worst hour |
| $NO_2$ annual | WHO - 19<br>US - 53<br>EU - 19 | 30 | 9 | 19 |
| Ozone 1-hour | NZ - 70<br>Japan - 60 | 100 | | |
| Ozone 4-hour | No standard | 80 | | |
| Ozone 8-hour | WHO - 47<br>US - 70 99th centile<br>Canada - 63<br>EU - 56 | No standard | | 65 |

# Detailed support for DEA proposed standards

## SO2- 1 hour

The main acute effect of $SO_2$ is to trigger asthma attacks in susceptible people. This has been demonstrated for people with asthma exercising in exposure chamber studies to occur at levels of 200 ppb over a duration of just 10 minutes. It is backed up by observational studies that more children attend hospital with asthma on days with high $SO_2$, in areas where the 75$^{th}$ centile of daily worst hour is 32 ppb[5]. Limiting the 99$^{th}$ centile of daily worst hour to 60 ppb is expected to prevent any 10-minute period exceeding 200 ppb. The 99$^{th}$ centile of daily worst hour at 60 ppb corresponds to a worst hour value of 88 ppb so our proposal is slightly more stringent than the RIS, and is more robust as it is less subject to random variation.

## SO2- 24 hour

The evidence behind the WHO 1-day standard is convincing, strongly influenced by the evidence from Hong Kong when a policy of low sulphur fuel introduction simultaneously for both transport and electricity led to substantial health improvements. The WHO standard is set as 20µg/m$^3$ which is 7.6 ppb rounding to 8 ppb as the value Australia should adopt.

## NO2- 1 hour

Our proposal is the equivalent of the RIS proposal expressed as a 99$^{th}$ centile of daily worst hour.

## NO2- annual

Our proposed annual $NO_2$ standard is considerably stricter than existing standards, reflecting the strong evidence from ACHAPS of its role in childhood asthma. The role of $NO_2$ in damaging child cognitive development is less certain but of great community importance if it is causative.

## Ozone

Meeting strict standards for $NO_2$ in ambient air will have a beneficial effect on atmospheric ozone as it is one of the ozone precursor pollutants. DEA is not making a recommendation about ozone.

## Road-side air quality

The objective of the NEPM is appropriate, and we support the change in wording from 'adequate protection' to 'minimising the risk' and making clear that this applies to people wherever they live in Australia.

The question of geographic application of air quality standards is important both at the regional level where communities that host polluting industries need protection, and at the intra urban scale where some pollutants have strong gradients of exposure especially around busy roads. The prime example for intra urban heterogeneity is exposure to nitrogen dioxide which has been shown to have steep gradients between roadside and urban background levels. $NO_2$ is often taken to be a surrogate for the mixture of TRAP which includes the black carbon fraction of fine particles, carbon monoxide, and unburned hydrocarbons.

We disagree with the position in the impact statement that the NEPM should avoid monitoring at localised hot spots including roads as these do not represent general population exposure. Major roads are used by large numbers of people every day, and even more people live, work or attend schools along such roads. The high levels along roads are a general population exposure and excluding these sites from monitoring restricts the degree to which air quality standards can protect public health.

Intra urban heterogeneity has been studied in Edinburgh where roadside locations were shown to have average $NO_2$ levels 14 times higher than urban background[6], and Birmingham where roadside locations were up to 2.4 times higher[7]. Less severe gradients typically 1.5 to 2 times higher were found by Cyrys across multiple sites in Europe, however in that work the roadside measurements were further from the kerb side, and background measurements could be within 50 m of roads so may not truly reflect background levels[8].

The issue of road pollution is also demonstrated by epidemiological work showing a health burden from proximity to roads. A large cohort study in Vancouver showed a relative risk of 1.29 (95%ci 1.18-1.41) of death from heart disease in those living less than 150m from a highway or 50m from a major road when compared to those living greater than these distances[9]. This analysis was suitably adjusted for confounders and followed 450,283 people for 9 years. Moreover, for people who moved during follow up, the risk decreased for those who moved away and increased for those who moved towards the roads.

There is strong evidence from Australian and overseas studies for TRAP being associated with childhood incident asthma, and alarming but mixed evidence of effects on children's cognitive development. For childhood asthma it is a large increase in a very common disease, which should be the basis for immediate regulatory action. For cognitive development it is a potentially large effect on a very important community outcome which the precautionary principle suggests should not be ignored.

As considerable human exposure occurs along roadways it is crucial that roadside air quality on busy roads be included in any framework for the minimisation of health risk. It is not adequate to just rely on background measurements, especially as some of the proposed pollution mitigation measures directly address vehicle exhaust pollution.

Australian NEPM air monitoring sites are specified to be located away from any point source including roads. They are typically located in parkland or open space, and while this is valuable to record urban background it misses frequent exposures to potentially high levels of $NO_2$ along roadways. As roadside air is highly variable it is best understood by land use regression modelling, but this requires a selection of roadside air monitoring sites to keep the models correctly calibrated as vehicle emissions change over time. Although a few states currently monitor a small number of roadside locations this should be done in a nationally consistent manner.

We propose that a selection of five sites in each city along busy roads and close to where people live or work be established as NOx and Ozone monitoring stations. This will give valuable information on progress in air quality from interventions such as better fuel standards for on road vehicles, improved vehicle pollution standards, better public transport, and the progressive roll out of electric vehicles. Understanding of roadside air quality will also inform planning decisions such as the location of schools and childcare centres given the particular sensitivity of young children to traffic related air pollution.

Eventually there should be a roadside $NO_2$ standard, but a prior period of nationally consistent roadside measurements of $NO_2$ and Ozone should commence now to inform standard development.

Recommendations:

1) In addition to background monitoring sites each jurisdiction must establish some roadside monitoring sites on roads with more than 20,000 vehicles per day, at locations where people live or work.

2) That a program of research be developed to establish by 2025 air quality standards applicable to locations on busy roads.

## Conclusion

Ambient air quality standards have an important part to play in protecting public health in Australia. The current review process has the potential to lead to important health gains, but these will not be achieved if the currently proposed standards are adopted. As a group of medical professionals committed to improving health in Australia through environmental protection, we call for adoption of the strong evidence-based standards as outlined above.

## References

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# Appendix A

## A brief review of some literature on TRAP and cognitive development in children

The RIS review process pays lip service to the precautionary principle, that where uncertainty exists it is better to protect health than to allow health damage while waiting for further research. It has however failed to apply the precautionary principle to emerging harms from air pollution with the effects on cognitive development being a prime example. There are many examples of epidemiological research, showing adverse effects on brain development from exposure to traffic related air pollution (TRAP), although there are some studies showing no association. There are also supportive findings from experimental animal studies showing inflammatory changes in the frontal cortex in exposed rodents.

Guxens 2014 analysed 9,482 children from 6 European cohorts comparing pregnancy air quality with cognitive and psychomotor development [i]. Cognitive development showed no association, but psychomotor development did. The age at assessment was only 1.5 or 2 years in most of the cohorts. Cognitive effects are easier to study in older children, 8-10 years as they can be much better tested so the lack of a cognitive difference in 2-year olds does not rule out an effect.

Harris 2015 found no such association in 1,100 mother-child pairs in Massachusetts studied at 8 years, and although the raw data showed associations these were no longer present after adjustment for suitable confounders [ii].

Sunyer 2015 in Barcelona showed large effects in a cohort study with 2,715 older kids aged 7-10, who were tested 4 times over a year with a battery of computerised cognition tests measuring their rate of development [iii]. TRAP was assessed as $NO_2$, and also as the elemental carbon sub fraction of $PM_{2.5}$ which reflects diesel exhaust.

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[i] Guxens, M., et al. (2014). "Air Pollution During Pregnancy and Childhood Cognitive and Psychomotor Development Six European Birth Cohorts." Epidemiology **25**: 636–647.

[ii] Harris, M. and D. Gold "Prenatal and Childhood Traffic-Related Pollution Exposure and Childhood Cognition in the Project Viva Cohort (Massachusetts, USA)." Environ Health Perspect **123**: 1072–1078.

[iii] Sunyer, J., et al. (2015). "Association between Traffic-Related Air Pollution in Schools and Cognitive Development in Primary School Children: A Prospective Cohort Study." PLOS medicine **12**(3): e1001792.

Median outdoor $NO_2$ at the Barcelona schools = 23.6 IQR 17.1- 28.0 ppb. The size of the difference between high and low pollution schools showed cognitive 12-month gains after adjustment for confounding :

- Working memory: 12.3 weeks handicap.
- Superior working memory: 23 weeks handicap.
- Inattentiveness:  6.3 weeks handicap in development during the year.
- These are in addition to the fact that the kids in polluted schools started from a worse baseline.

Remaining uncertainty exists in that there could be residual confounding by social class, although analysis looking for this did not demonstrate it. The effects were apparent for TRAP assessed as $NO_2$ and as the elemental carbon component of $PM_{2.5}$. TRAP has to be thought of as a package.

In support that this is a causative association, further analysis showed that the air pollution effects where stronger in those 23% of children who carry the APOE e4 allele, while they were weaker or non-significant in those without this gene[iv]. APOE e4 is a risk factor for dementia in later life.

Cognitive effects this large have to be seen as a substantial threat to community wellbeing if they are due to air pollution exposure. It is not justified to ignore these harms while the conflicting study results are resolved through further research.

[iv] Alemany, S., et al. (2018). "Traffic-Related Air Pollution, APOEe 4 Status, and Neurodevelopmental Outcomes among School Children Enrolled in the BREATHE Project (Catalonia, Spain)." Environmental Health Perspectives **126**(8): 087001.