Opportunity to reduce paediatric asthma in New South Wales through nitrogen dioxide control

Ben Ewald,[1] Luke Knibbs,[2] Guy Marks[3,4]

Abstract

Objective: The main sources of nitrogen dioxide (NO_2), road vehicles and electricity generation, are currently in a period of technological change. We assessed the number of cases of childhood asthma in New South Wales that could be avoided by lowering exposure to NO_2 by 25% from current levels.

Methods: Health impact assessment calculations for each of the 128 local government areas were based on the population of children aged 2 to 14, the prevalence of asthma derived from the 2017 NSW health survey, NO_2 exposure from a land-use regression model using satellite data, and risk estimates derived from two meta-analyses and one Australian study.

Results: A 25% reduction in NO_2 below current exposure would lead to between 2,597 and 12,286 fewer children with asthma in NSW. The wide range in these estimates reflects the variation in concentration-response functions used.

Conclusions: Even the lowest of these estimates would be a worthwhile reduction in this common childhood illness.

Implications for public health: A 25% reduction in NO_2 is ambitious, but it is achievable through improved vehicle exhaust standards, increasing electric vehicle numbers, and reform of the electricity sector. Current Australian ambient air quality standards for annual NO_2 should be revised downwards.

Key words: nitrogen dioxide, asthma, air pollution

Nitrogen dioxide (NO_2) is an irritant gas that has adverse respiratory effects, especially on children. NO_2 dissolves in the airway lining fluid, where the formation of nitration products and direct oxidative effects cause tissue inflammation.[1] Based on an extensive review, the US EPA Integrated Science Assessment concluded, in 2016, that "… evidence for asthma attacks supports a causal relationship between short-term NO_2 exposure and respiratory effects. Evidence for development of asthma supports a likely to be causal relationship between long-term NO_2 exposure and respiratory effects".[2] There is, however, uncertainty about the degree of asthma risk increase for a given exposure to NO_2.

Several meta-analyses have examined this question. Favarato et al. found 18 studies published before 2013 using a 12-month period prevalence definition for asthma and estimated that for each 4 ppb increase in annual average NO_2 concentration, there was a 4% (95%CI: 0–8%) increase in the prevalence of asthma in children.[3] Khreis et al. found 20 studies published before 2016 using a more inclusive definition of lifetime prevalence of doctor-diagnosed asthma but a stricter definition of exposure, and found that for each 4 ppb increase in NO_2 there was a 10% (95%CI: 4–14%) increase in asthma.[4] These international data were supported by a recently published cross-sectional survey of 2630 children aged 7–11 years living in 12 Australian cities. This study estimated that, for each 4 ppb increase in NO_2 concentration in the ambient environment, there was a 24% (95%CI: 8–43%) or 54% (95% CI: 26–87%) increase in the prevalence of current asthma, depending on the method for assessing NO_2 exposure.[5] Exposure to NO_2 also occurs indoors, however, these are the best estimates of the outdoor ambient exposure effects.

The prevalence of asthma among children in Australia is higher than in many other countries. Among children aged 2 to 14 years the 2017 prevalence of asthma was 12% in boys and 8% in girls.[6] Asthma has been estimated to be the largest contributor to disease burden in children aged 14 years and under[7] and is a common reason for presentation to general practice. The BEACH survey of general practice estimated that asthma accounts for 11.1% of all consultations.[8] Hence, we have a reason to focus on the prevention of asthma through population-level strategies.

Until 2015, NO_2 concentrations measured at urban background locations in Australian cities were trending down, however, since then the trend has flattened or even risen slightly. Given this adverse trend, the current review of the Australian Standard[9] and the importance of asthma in Australia, we believe it is timely to assess the potential impact of a reduction in NO_2 exposure that might be achieved by setting a lower National Environment Protection Measure standard for NO_2. The objective of this analysis was

1.School of Medicine and Public Health, University of Newcastle, New South Wales
2. School of Public Health, University of Queensland
3. Faculty of Medicine and Health, University of New South Wales
4. Ingham Institute of Applied Medical Science, Liverpool, New South Wales
Correspondence to: Dr Ben Ewald, School of Medicine and Public Health, University of Newcastle NSW, HMRI building, Kookaburra Close, NSW 2305; e-mail: Ben.ewald@newcastle.edu.au
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to measure the impact of an ambitious but achievable 25% reduction in the current annual average NO_2 on the prevalence of asthma in NSW children. Such reductions have been achieved elsewhere, for instance, annual average urban background NO_2 in the UK decreased by two-thirds between 1992 and 2018, albeit from a higher level than experienced in Australia.[10]

Methods

We performed a health impact assessment following the methods of Fann et al.[11] For each of the 128 local government areas (LGA) in NSW, we estimated the current prevalence of asthma and the current annual average NO_2 concentration. Applying concentration-response coefficients for NO_2 and asthma, we estimated the impact of a 25% reduction in annual average NO_2 concentration on prevalence. Finally, we summed the impacts across all LGAs to estimate the impact for all of NSW.

For each LGA, we retrieved the prevalence of asthma in children aged 2 to 14 years from the 2017 NSW Health Survey[12] and the population in this age range from the Australian Bureau of Statistics (ABS) Estimated Resident Population. We estimated annual average NO_2 concentrations for 2017 at all ABS mesh blocks (smallest census unit, 30–60 households) in each LGA using a validated satellite-based land-use regression model to give a population-weighted average NO_2 value for each LGA.[13] We assumed the NO_2 concentration applied to all residents of the LGA and applied the several risk estimates from the two meta-analyses and the Australian study mentioned above. Based on these risk estimates we calculated the number of prevalent cases of asthma that would be averted if the annual average NO_2 concentration in the LGA was 25% lower than the current concentration. We used the following formula:

$$P \times D \times \left(1 - \frac{1}{r^c}\right)$$

where

P is the population aged 2–14 years in each LGA

D is the prevalence of asthma among persons aged 2–14 years in each LGA

r is the relative risk of the concentration-response function per 4 ppb

C is the 25% reduction in NO_2 for each LGA (units ppb/4).

The estimated number of cases averted in each LGA was summed across NSW to estimate the total number of prevalent cases of asthma in children aged 2 to 14 years that would be averted with a 25% reduction in the annual average concentration of NO_2.

Results

Based on the NSW Health Survey, there were 162,040 (13% of 1.25 million) children aged 2 to 14 years in NSW who have a history of wheezing illness or used asthma medication in the past 12 months. The satellite LUR model estimated that the population-weighted annual mean (±SD) NO_2 concentration for NSW was 6.3 (±2.5) ppb.

Applying the risk estimate from the Favarato meta-analysis the number of cases of asthma in children aged 2 to 14 averted by a 25% reduction in the annual average concentration of NO_2 was 2,597 (95%CI: 0–4613). Using the risk estimate from the Khreis meta-analysis the result was 5,475 (95%CI: 2247–7530) and applying the risk estimate from the Australian cross-sectional study the result was that 12,286 (95%CI:4527–19,823) cases could be averted. This represents 1.6%, 3.4% and 7.6% of the total asthma burden, respectively. Using the Favarato risk estimate some of the small LGAs in the far west of the state had less than one averted case, while the large Canterbury-Bankstown LGA had 198 (Table 1).

Discussion

Lowering NO_2 exposure by 25% would lead to fewer children with prevalent asthma. It is a feature of the health impact assessment method that it relies on a concentration-response function derived from research conducted across a wide range of settings that give different risk estimates. We have based this analysis on three credible estimates of the risk, each with its own strengths and weaknesses. While there is a wide range between our three estimates, achieving even the smallest would be an important health gain.

The Southern California Children's Health Study followed three cohorts of children between 1993 and 2014, during which time average NO_2 decreased from 24 ppb to 18 ppb.[14] A modelled 20% decrease in NO_2 beyond the decline that actually occurred was predicted to decreased asthma incidence by a further 19.6%. This is a higher proportion than we have predicted for NSW, but not unexpected as California has a higher baseline level of NO_2 exposure.

A recently published global study based on the Khreis meta-analysis showed that, for Sydney, approximately 13% of asthma incidence could be attributed to total NO_2 exposure, congruent with our estimate of 3.4% from one-quarter of current exposure.[15] A strength of our analysis is the statewide scope and the use of geographically specific values for NO_2 exposure and asthma prevalence.

Reductions in NO_2 exposure could be pursued through more stringent national ambient air quality standards, and low or zero emissions vehicles as a population-level approach to reduce asthma in NSW. One positive development is the serious attention being paid to the construction of Metro rail lines in both Sydney and Melbourne that will make train transport the quick, easy and cheap option. Reducing the number of car trips improves both air quality and safety.

Opportunities to achieve health gains through the current review of Australia's air quality standards have been further discussed in a companion paper.[16]

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Table 1: Population numbers, asthma prevalence, modelled NO2 exposure and the results of health impact calculations for the number of asthma cases potentially averted by a 25% reduction in annual NO_2 exposure for selected Local Government Areas of NSW.

Local Government Area	Population of children aged 2 to 14 years	Prevalence of asthma(%)	Annual average NO_2 concentration (ppb)	Number of cases of asthma averted by a 25% reduction in NO_2*
Canterbury-Bankstown	63,492	13.4	8.6	198
Northern Beaches	45,560	15.6	7.0	135
Liverpool	41,648	13.4	7.5	113
Penrith	36,900	18.5	5.7	105
Fairfield	34,501	13.4	8.4	105
Central Coast	54,952	12.1	5.4	97
Lake Macquarie	32,844	17.2	5.9	90
Inner West	24,961	11.7	10.7	84
Newcastle	23,561	17.2	7.6	84
Hornsby	25,481	15.6	6.4	69
Blacktown	68,289	5.1	6.9	65
Campbelltown	30,343	13.4	5.8	63
Sutherland Shire	37,670	9.3	6.6	62
Ku-Ring-Gai	22,376	15.6	6.5	62
Wollongong	33,286	11.5	5.6	59
Ryde	16,925	15.6	8.1	58
Bayside	22,610	9.3	10.1	57
Sydney	12,275	11.7	14.0	54
Willoughby	12,998	15.6	9.2	50
Cumberland	38,962	5.1	9.0	48
Parramatta	36,400	5.1	9.3	47
Georges River	22,135	9.3	8.3	46
Randwick	18,884	9.3	9.6	46
Maitland	15,248	17.2	5.2	37
North Sydney	7,462	15.6	11.2	35
Canada Bay	12,644	11.7	8.6	34
Camden	16,703	13.4	4.8	29
Wagga Wagga	11,492	24.6	3.6	28
The Hills Shire	30,938	5.1	6.1	26
Lane Cove	5,937	15.6	10.4	26
Waverley	9,596	9.3	10.7	26
Blue Mountains	12,877	18.5	3.9	25
Albury	8,607	24.6	4.3	25
Port Stephens	11,467	17.2	4.6	25
Hawkesbury	11,672	18.5	4.1	24
Cessnock	10,270	17.2	4.8	23
Woollahra	7,856	9.3	10.6	21
Remaining 91 LGAs with less than 20 cases averted	322,590			414

Note:

** based on meta-analysis estimate that relative risk of asthma is 1.04 per 4 ppb increase in NO_2*

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