Traffic Related Air Pollution and Pediatric Asthma

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Global, national, and urban burdens of pediatric asthma incidence attributable to ambient NO$_2$ pollution: estimates from global datasets

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Motivation: Traffic-related air pollution (TRAP)

Traffic influence zones (<500m from highway or <100m from major road)
- 32% of Canadian population (~10 M)
- 36% of primary schools in large Canadian cities

Motivation: Traffic-related air pollution (TRAP)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log(Odds Ratio)</th>
<th>SE</th>
<th>Weight</th>
<th>Odds Ratio IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carlsten et al. 2010 - at 7 y.o.</td>
<td>0.2253</td>
<td>0.1448</td>
<td>0.6%</td>
<td>1.25 [0.94, 1.66]</td>
</tr>
<tr>
<td>Clark et al. 2010 LUR - at mean age of 4 y.o.</td>
<td>0.0489</td>
<td>0.0171</td>
<td>9.5%</td>
<td>1.05 [1.02, 1.09]</td>
</tr>
<tr>
<td>Dell et al. 2014 LUR - 5 to 9 y.o.</td>
<td>0.039</td>
<td>0.04</td>
<td>5.0%</td>
<td>1.04 [0.96, 1.12]</td>
</tr>
<tr>
<td>Deng et al. 2016 - 3 to 6 y.o.</td>
<td>0.1374</td>
<td>0.0689</td>
<td>2.4%</td>
<td>1.15 [1.00, 1.31]</td>
</tr>
<tr>
<td>Gehring et al. 2015 b - BAMSE birth to 16 y.o.</td>
<td>0.0397</td>
<td>0.0498</td>
<td>3.8%</td>
<td>1.04 [0.94, 1.15]</td>
</tr>
<tr>
<td>Gehring et al. 2015 b - PIAMA birth to 14 y.o.</td>
<td>0.0665</td>
<td>0.0246</td>
<td>7.8%</td>
<td>1.07 [1.02, 1.12]</td>
</tr>
<tr>
<td>Gehring et al. 2015b - GINI&amp;LISA North birth to 15</td>
<td>-0.0679</td>
<td>0.1235</td>
<td>0.8%</td>
<td>0.93 [0.73, 1.19]</td>
</tr>
<tr>
<td>Gehring et al. 2015b - GINI&amp;LISA South birth to 15</td>
<td>-0.0252</td>
<td>0.0602</td>
<td>2.9%</td>
<td>0.98 [0.87, 1.10]</td>
</tr>
<tr>
<td>Jerret et al. 2008 - 10 to 16 y.o.</td>
<td>0.0874</td>
<td>0.033</td>
<td>6.1%</td>
<td>1.09 [1.02, 1.16]</td>
</tr>
<tr>
<td>Kim et al. 2016 - 6 to 7 y.o.</td>
<td>-0.0214</td>
<td>0.0219</td>
<td>8.4%</td>
<td>0.98 [0.94, 1.02]</td>
</tr>
<tr>
<td>Krämer et al. 2009 - 4 to 6 y.o.</td>
<td>0.0698</td>
<td>0.069</td>
<td>2.3%</td>
<td>1.07 [0.94, 1.23]</td>
</tr>
<tr>
<td>Liu et al. 2016 - 4 to 6 years old</td>
<td>0.0877</td>
<td>0.0215</td>
<td>8.5%</td>
<td>1.09 [1.05, 1.14]</td>
</tr>
<tr>
<td>Macintyre et al. 2014 - CAPPS&amp;SAGE only birth to 8</td>
<td>0.1111</td>
<td>0.1268</td>
<td>0.8%</td>
<td>1.12 [0.87, 1.43]</td>
</tr>
<tr>
<td>McConnell et al. 2010 - 4th to 6th grade</td>
<td>0.0698</td>
<td>0.0281</td>
<td>7.1%</td>
<td>1.07 [1.01, 1.13]</td>
</tr>
<tr>
<td>Möller et al. 2014 b - MAAS only birth to 8 y.o.</td>
<td>0.574</td>
<td>0.2374</td>
<td>0.2%</td>
<td>1.78 [1.11, 2.83]</td>
</tr>
<tr>
<td>Nishimura et al. 2013 - 8 to 21 y.o.</td>
<td>0.0632</td>
<td>0.0269</td>
<td>7.3%</td>
<td>1.07 [1.01, 1.12]</td>
</tr>
<tr>
<td>Oftedal et al. 2009 - birth to 10 y.o.</td>
<td>-0.0359</td>
<td>0.0196</td>
<td>8.9%</td>
<td>0.96 [0.93, 1.00]</td>
</tr>
<tr>
<td>Ranzi et al. 2014 - birth to 7 y.o.</td>
<td>0.0289</td>
<td>0.0701</td>
<td>2.3%</td>
<td>1.03 [0.90, 1.18]</td>
</tr>
<tr>
<td>Shim et al. 2014 - 6 to 12 y.o.</td>
<td>0.1136</td>
<td>0.0534</td>
<td>3.5%</td>
<td>1.12 [1.01, 1.24]</td>
</tr>
<tr>
<td>Tèbreault et al. 2016 - birth to 12 y.o.</td>
<td>0.0153</td>
<td>0.0048</td>
<td>11.6%</td>
<td>1.02 [1.01, 1.03]</td>
</tr>
</tbody>
</table>

Total (95% CI)

Heterogeneity: Tau² = 0.00; Chi² = 54.38, df = 19 (P < 0.0001); I² = 65%
Test for overall effect: Z = 3.76 (P = 0.0002)

Motivation

- First estimates published in EHP in October 2018

Research

Estimates of the Global Burden of Ambient PM$_{2.5}$, Ozone, and NO$_2$ on Asthma Incidence and Emergency Room Visits

Susan C. Anenberg,¹ Daven K. Henze,² Veronica Tinney,¹ Patrick L. Kinney,³ William Raich,⁴ Neal Fann,⁵ Chris S. Malley,⁶ Henry Roman,⁷ Lok Lamsal,⁷ Bryan Duncan,⁷ Randall V. Martin,⁸,⁹ Aaron van Donkelaar,⁸ Michael Brauer,¹⁰,¹¹ Ruth Doherty,¹² Jan Eiof Jonson,¹³ Yanko Davila,² Kengo Sudo,¹⁴,¹⁵ and Johan C.I. Kuylenstierna⁶

- Demonstrated potentially large impacts, but also many uncertainties and methodological refinements needed.
- For **asthma incidence**, strongest evidence for associations with **traffic-related NO$_2$ and for children**, but our methods were unable to capture realistic near-roadway exposures.
Methods: Estimating asthma burden attributable to NO$_2$
Exposure: Global high resolution (100m) NO$_2$ model

Exposure: Global high resolution (100m) NO$_2$ model

Bangkok, Thailand

NYC, USA

New Delhi, India

Exposure:

Global high resolution (100m) NO$_2$ model

0 2 4 6 8 12 16 20 25 30 35 40 (ppb)
Exposure: Matching exposure to population data

\[ \text{Burden} = Inc_{c,a} \times \sum_{i,j} \text{Pop}_{i,j,a} \times \left(1 - e^{-\beta X_{i,j}}\right) \]

250m x 250m population (GHS-POP) available for 1975, 1990, 2000, 2015

2010-2012 ground-level NO$_2$ at 100m x 100m (Larkin et al., 2017)

Regridded and reprojected to match the GHS-POP raster
### Literature review: multi-national meta-analyses of traffic-related air pollution (TRAP) exposure and pediatric asthma incidence

<table>
<thead>
<tr>
<th>Meta-analysis</th>
<th>Relative risk per 10 ppb NO₂</th>
<th>Relative risk per 10 μg m⁻³ PM₂.₅</th>
<th># of epi studies and locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khreis et al. (2017)</td>
<td>1.26 (1.10-1.37)</td>
<td>1.34 (1.11-1.63)</td>
<td>41 studies in North America, Latin America, Europe, East Asia</td>
</tr>
<tr>
<td>Bowatte et al. (2015)</td>
<td>1.18 (0.93-1.48)</td>
<td>1.93 (1.00-3.71)</td>
<td>10 studies in Europe, Canada</td>
</tr>
<tr>
<td>Anderson et al. (2013)</td>
<td>1.24 (1.06-1.45)</td>
<td>Not given</td>
<td>14 studies in Europe, North America, Japan</td>
</tr>
<tr>
<td>Gasana et al. (2012)</td>
<td>1.28 (1.12-1.50)</td>
<td>1.40 (0.77-2.56)</td>
<td>9 studies in Europe, North America, Latin America, East Asia</td>
</tr>
</tbody>
</table>

Khreis et al. reviewed the largest number of studies that include all but one of those considered in the other meta-analyses. No apparent regional heterogeneity in reported relative risks.

“The overall evidence indicates that there is **likely a causal** relationship between long-term NO₂ exposure and pediatric asthma development.” -- EPA, 2016; Health Canada, 2016.
Methods: Estimating asthma burden attributable to NO$_2$

\[ \text{Burden} = I_{nc,c,a} \times \sum_{i,j} P_{op_{i,j,a}} \times (1 - e^{-\beta X_{i,j}}) \]

2015 national incidence rates from IHME (for 1-4, 5-9, 10-14, 15-18 year age groups)

2015 gridded population at 250 m x 250 m from the European Commission Joint Research Center GHS-POP + gridded age-group fractions from 2010 NASA CIESIN GPWv4

2010-2012 gridded surface NO$_2$ (100 m x 100 m) from Land Use Regression modeling by Larkin et al. (2017) \( \rightarrow \) aggregated to 250 m x 250 m

Relative risk from Khreis et al. (2017)

Applied in each 250 m x 250 m grid cell globally, and aggregated over 21 regions, 194 countries, and 125 major cities*

Counterfactual concentrations of 0, 2, and 5 ppb.

*GHS-SMOD city extents (contiguous cells with \( \geq 50,000 \) people & population density of \( \geq 1,500 \) inhabitants/km$^2$ or built-up density \( > 50\% \)).
4 million (95% UI 1.8-5.2) children developed asthma due to NO$_2$ pollution in 2015

• Top 5 national burdens (cases/year): China (760,000), India (350,000), USA (240,000), Indonesia (160,000), and Brazil (140,000).

Achakulwisut et al., 2019, *Lancet Planetary Health*
13% (6-16) of global pediatric asthma burden

Top 5 national rates (case/year per 100,000): Kuwait (550), United Arab Emirates (460), Canada (450), Taiwan (420), and Qatar (410).

~97% of children lived, and ~92% of NO₂-attributable pediatric asthma incidence occurred, in areas below the current WHO guideline (21 ppb annual average NO₂).

Achakulwisut et al., 2019, Lancet Planetary Health
NO$_2$-attributable pediatric asthma incidence impacts are largest in middle and high-income countries

- Globally, 64% of NO$_2$-attributable pediatric asthma incidence occurred in urban centers
- ....and exceeded 50% in 106 countries, reflecting the distribution of children living in urban areas and the high NO$_2$ concentrations in urban centers.

Achakulwisut et al., 2019, *Lancet Planetary Health*
In both developed and developing cities, NO$_2$ pollution is an important risk factor for pediatric asthma incidence. In 125 major cities, the percentages of new pediatric asthma cases attributable to NO$_2$:

- Ranged from 6% (Orlu, Nigeria) to 48% (Shanghai, China).
- Exceeded 20% in 92 cities, located in both developed and developing countries.
- Highest in 8 cities in China, in Moscow, and Seoul.
Concluding thoughts

• Traffic-related air pollution is responsible for a sizeable proportion (13% globally, > 20% in many cities) of pediatric asthma. 730,000 DALYs in 2015

• While only 3% of children were exposed above the WHO guideline, 4.0 (1.8-5.2, 95% UI) million new pediatric asthma cases attributable to NO₂ pollution in 2015

• Reductions in traffic emissions and/or TRAP exposure could prevent a large portion of pediatric asthma in urban areas.
Extra figures
(a) Number of new asthma cases due to NO$_2$ exposure

(b) Number of new asthma cases due to NO$_2$ exposure (per 100k)

(c) Percent of new asthma cases due to NO$_2$ exposure

Results: National estimates

Top 5 national burdens: China (760,000 cases/year), India (340,000), USA (230,000), Indonesia (150,000), and Brazil (140,000)

Top 5 national burdens per 100k children: Kuwait (540 cases/year), followed by Canada, United Arab Emirates, Singapore, and Jordan (410-450) due to relatively high asthma incidence rates and/or population-weighted urban NO$_2$ concentrations.

The percentage of NO$_2$-attributable pediatric asthma incidence exceeds 15% for 51 countries. The highest contributions of around 30% are estimated for South Korea, Qatar, United Arab Emirates, and Kuwait.
Globally, 64% of NO₂-attributable pediatric asthma incidence occurred in urban centers

(a) Percent of NO₂–attributable incidence in urban centers

- This percentage increases to 90% if surrounding suburban areas are also considered.
- On a national level, this percentage exceeded 50% in 106 countries, reflecting both the distribution of children living in urban areas and the prevalence of high NO₂ concentrations found in urban centers.

Achakulwisut et al., 2019, Lancet Planetary Health (in press)
Asthma incidence rates have the least influence, given that their uncertainties are relatively small. Uncertainty resulting from those in the RR and NO$_2$ concentrations are generally comparable.
Traffic pollution, Asthma Genetics (TAG)

NO$_2$ - Asthma, by GSTP1 rs1138272

Adjusted for study, city, intervention, gender, maternal age at birth, maternal smoking during pregnancy, environmental tobacco smoke in the home, birth weight and parental atopy

GSTP1 and TNF Gene variants and associations between air pollution and incident childhood asthma: the traffic, asthma and genetics (TAG) study.
