Ambient air quality and human health in India

Luke Conibear

Dominick V. Spracklen, Stephen R. Arnold, Christoph Knote, Alan Williams
How bad is air quality in India?

Small particles (PM$_{2.5}$).

Guarnieri & Balmes (2014)

Ozone (O$_3$).

American Lung Association (2019)

WORLD’S MOST POLLUTED CITIES ARE IN INDIA

<table>
<thead>
<tr>
<th>Rank</th>
<th>City</th>
<th>PM$_{2.5}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Kanpur</td>
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<td>5.</td>
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<td>7.</td>
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<td>8.</td>
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<td>9.</td>
<td>Muzaffarpur</td>
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<td>10.</td>
<td>Srinagar</td>
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<tr>
<td>11.</td>
<td>Gurgaon</td>
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<td>12.</td>
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<tr>
<td>13.</td>
<td>Patiala</td>
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<tr>
<td>14.</td>
<td>Jodhpur</td>
<td>98</td>
</tr>
<tr>
<td>15.</td>
<td>Ali Subah Al-Salem (Kuwait)</td>
<td>94</td>
</tr>
</tbody>
</table>

* Annual average in 2016
Source: WHO

Number of Indian cities among 15 most polluted

Times of India (2019)
How does this poor air quality damage human health?

Detection
Mortality and morbidity trends (hospital records, etc.).

Attribution
Air pollution (epidemiology).

- **PM$_{2.5}$** (*indicator pollutant, mass, mixture*).
  - Respiratory:
    - Chronic obstructive pulmonary disease (COPD).
    - Lower respiratory infections (LRI).
  - Cardiovascular:
    - Ischaemic heart disease (IHD).
    - Cerebrovascular disease (CEV).
  - Lung cancer (LC).
- **O$_3$**
  - COPD.
What are the mechanisms?

Detection
Mortality and morbidity trends (*hospital records, etc.*).

Mechanisms
Biologically plausible (*toxicology*).

Attribution
Air pollution (*epidemiology*).

**Respiratory disease mortality**
- Respiratory disease morbidity
- Lung cancer
- Pneumonia
  - Upper and lower respiratory symptoms
  - Airway inflammation
  - Decreased lung function
  - Decreased lung growth

**Insulin resistance**
- Type 2 diabetes
- Type 1 diabetes
- Bone metabolism

**High blood pressure**
- Endothelial dysfunction
- Increased blood coagulation
- Systemic inflammation
- Deep venous thrombosis

**Stroke**
- Neurological development
- Mental health
- Neurodegenerative diseases
  - Cardiovascular disease mortality
  - Cardiovascular disease morbidity
  - Myocardial infarction
  - Arrhythmia
  - Congestive heart failure
  - Changes in heart rate variability
  - ST-segment depression
  - Skin ageing

**Premature birth**
- Decreased birthweight
  - Decreased fetal growth
  - Intrauterine growth retardation
  - Decreased sperm quality
  - Pre-eclampsia

Thurston et al. (2017)
What are the mechanisms?

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Neurological development
Mental health
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Changes in heart rate variability
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Skin ageing

Premature birth
Decreased birthweight
Decreased fetal growth
Intrauterine growth retardation
Decreased sperm quality
Pre-eclampsia

Thurston et al. (2017)
How does the risk change with pollution levels?

- Non-linear exposure–response relationships.
- Health impacts saturate at higher concentrations.
How does the risk of air pollution exposure compare to other risks?

### DALYs per 100,000

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>SE &amp; E Asia &amp; Oceania</th>
<th>C &amp; E Europe &amp; C Asia</th>
<th>HI</th>
<th>Latin Am &amp; Caribbean</th>
<th>MENA</th>
<th>S Asia</th>
<th>Sub-Saharan Africa</th>
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<tbody>
<tr>
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### Deaths per 100,000

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<td>8</td>
<td>6</td>
<td>1</td>
<td>8</td>
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</table>
Can we simulate Indian air quality well?

- **Annual mean concentration performance:**
  - PM$_{2.5}$: NMB = $-0.1$
  - O$_3$: NMB = 0.35

- Model skill adequate for this research question of long–term chronic impacts.
Current disease burden from ambient PM$_{2.5}$

- 990,000 (95UI: 624,000–1,389,000) premature mortalities per year.
- 71% within the Indo–Gangetic Plain.
- Mortality rate (independent of population) of 60 per 100,000, reaching 100 per 100,000 in Delhi.
Current disease burden from ambient $O_3$

**a** O$_3$ concentrations

94.5 ppbv

**d**

77.2 ppbv

Control 3mDMA1 ambient surface (ppbv)

Latitude

Longitude

Control 3mDMA1 ambient surface (ppbv)
What are the sources of poor air quality in India?
Source contributions to the current disease burden from ambient PM$_{2.5}$

- Attributable burden > (x2) subtraction burden.
- Flatter part of non-linear exposure-response relationship and low threshold.
- Large reductions in emissions will be required to reduce the health burden.
Source contributions to the current disease burden from ambient $O_3$

- Attributable burden $< (-20\%)$ subtraction burden.
- Steeper part of non-linear exposure-response and high threshold.
Future Indian population
Future background mortality rates
Future air pollutant emissions

Sectoral emission scenarios for India from IEA 2016 (Mt year$^{-1}$)

- **2015 SO$_2$**
  - Industry
  - Power
  - Residential
  - Transport
  - Other

- **2015 NO$_x$**
  - Industry
  - Power
  - Residential
  - Transport
  - Other

- **2015 PM$_{2.5}$**
  - Industry
  - Power
  - Residential
  - Transport
  - Other
Future disease burden from ambient PM$_{2.5}$

- If no emissions growth to 2050, mortality +75% and mortality rate +40%.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>PM$_{2.5}$ conc.</th>
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<tbody>
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<td>NPS</td>
<td>-9%</td>
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<tr>
<td>CAS</td>
<td>-68%</td>
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</table>
Future disease burden from ambient $O_3$

- If no emissions growth to 2050, mortality +200% and mortality rate +140%.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>$O_3$ conc.</th>
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<td>NPS</td>
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<tr>
<td>CAS</td>
<td>-24%</td>
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</table>
Is ozone the air toxic of the future?

- Present disease burden is dominated by PM$_{2.5}$.
  - PM$_{2.5} \approx 1.0$ million with rate of 60 per 100,000.
  - O$_3 \approx 0.4$ million with rate of 30 per 100,000.
- Future disease burdens may be of similar magnitude (e.g. 2050 CAS).
  - PM$_{2.5} \approx 1.1$ million with rate of 50 per 100,000.
  - O$_3 \approx 0.8$ million with rate of 50 per 100,000.

O$_3$, from this study, using Turner et al., (2016) risks and LCCmin
PM$_{2.5}$, from Conibear et al., (2018b), using GBD2016 IER risks
Ambient air quality and human health in India

1. How bad is it?
   a) \( \approx 1 \) million premature mortalities from ambient \( \text{PM}_{2.5} \) exposure.
   b) 0.37 million premature mortalities from ambient \( \text{O}_3 \) exposure (3x previous estimate).
   c) Non-linear exposure–response relationships means large emission reductions required to improve public health.

2. What are the sources?
   a) \( \text{PM}_{2.5} = \) solid fuels \( \rightarrow \) residential (52%), power and industry.
   b) \( \text{O}_3 = \) land transport, power, and residential.

3. How might it change in the future?
   a) Population ageing and growth increases susceptibility and the disease burden.
   b) Ozone may be the air toxic of the future:
      i. Currently \( \text{PM}_{2.5} \) dominates the disease burden, though future disease burden from \( \text{O}_3 \) may be of similar size to that from \( \text{PM}_{2.5} \), as \( \text{O}_3 \) concentrations more difficult to reduce.
   c) Strong emission reductions focusing on solid fuel use can provide important public health benefits in a challenging environment.
Thank you

Papers
1. Current PM$_{2.5}$ and its sources.

2. Future PM$_{2.5}$ scenarios.

References


