GBD 2017 State-Level Burden of Disease from Air Pollution in India: Findings and Future Research Needs

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On Behalf of the India State-Level Disease Burden Initiative

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India State-Level Disease Burden Initiative Air Pollution Collaborators

76 collaborators

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India State-Level Disease Burden Initiative

- Launched in October 2015 as joint effort of the Indian Council of Medical Research (ICMR), the Public Health Foundation of India (PHFI) and the Institute for Health Metrics and Evaluation (IHME), in collaboration with the Ministry of Health and Family Welfare
- Extensive engagement with about 300 experts from over 100 institutions across India and with policy makers for this work
- Produce disaggregated disease burden trends by age groups, sexes, rural-urban populations for each state
- Identify major data gaps that could be addressed over time
- Build systems and capacity for producing robust sub-national disease burden estimates on a regular basis
- Estimations in collaboration with and as part of the Global Burden of Disease (GBD) Study
Methods: GBD Data and Model Flow Chart

DEATHS by age, sex, year, and country

DALYs for diseases and injuries

YLLs for each disease and injury

YLDs for each disease and injury

DALYs attributable to each risk

YLDs attributable to each risk

Estimated Causes of Death

Causes of death database

Rescaling deaths to equal all-cause mortality

Data correction, mapping, redistribution, and noise reduction

Disease sequelae epidemiology data

Nature and external cause of injury analysis

Estimating disease sequelae prevalence, incidence, duration (DISMOD – MR)

Severity distribution

Disability weights

Cross-validation of impairment levels

Methods developed and refined over 25 years

PAF = population attributable fraction
DALY = disability-adjusted life years
YLL = years of life lost due to premature mortality
YLD = years lived with disability
Initial Published Materials

Report:
http://www.healthdata.org/policy-report/india-health-nation%E2%80%99s-states

Lancet Paper:
www.thelancet.com/journals/lancet/article/PIIS0140-6736(17)32804-0/fulltext

Findings Released by Vice-President and Health Minister of India in Nov 2017
Epidemiological Transition Across the States of India

Infectious and related diseases cause less than half of the disease burden in every state now.

This transition occurred in some states 30 years ago and in others only in the past few years

Lancet 2017; 390: 2437–2460
Leading Individual Causes of DALYs in India

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Neonatal disorders [14.4%]</td>
<td>Neonatal disorders [9.2%]</td>
</tr>
<tr>
<td>2</td>
<td>Diarrheal diseases [10.8%]</td>
<td>Ischemic heart disease [7.7%]</td>
</tr>
<tr>
<td>3</td>
<td>Lower respiratory infections [10.4%]</td>
<td>Chronic obstructive pulmonary disease [5.1%]</td>
</tr>
<tr>
<td>4</td>
<td>Tuberculosis [4.6%]</td>
<td>Diarrheal diseases [5.1%]</td>
</tr>
<tr>
<td>5</td>
<td>Ischemic heart disease [3.5%]</td>
<td>Lower respiratory infections [4.9%]</td>
</tr>
<tr>
<td>6</td>
<td>Chronic obstructive pulmonary disease [3.0%]</td>
<td>Stroke [3.7%]</td>
</tr>
<tr>
<td>7</td>
<td>Congenital birth defects [2.4%]</td>
<td>Tuberculosis [3.3%]</td>
</tr>
<tr>
<td>8</td>
<td>Measles [2.3%]</td>
<td>Dietary iron deficiency [2.5%]</td>
</tr>
<tr>
<td>9</td>
<td>Dietary iron deficiency [2.2%]</td>
<td>Diabetes mellitus [2.3%]</td>
</tr>
<tr>
<td>10</td>
<td>Tetanus [2.0%]</td>
<td>Road injuries [2.3%]</td>
</tr>
</tbody>
</table>

DALYs = disability-adjusted life years

https://vizhub.healthdata.org/gbd-compare/
### DALYs Attributable to Risk Factors in India

<table>
<thead>
<tr>
<th>Year</th>
<th>Risk Factor</th>
<th>DALYs %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1990</strong></td>
<td>Child and maternal malnutrition</td>
<td>36.4%</td>
</tr>
<tr>
<td></td>
<td>Unsafe water and sanitation</td>
<td>11.5%</td>
</tr>
<tr>
<td></td>
<td>Air pollution</td>
<td>9.0%</td>
</tr>
<tr>
<td></td>
<td>Tobacco use</td>
<td>5.2%</td>
</tr>
<tr>
<td></td>
<td>Dietary risks</td>
<td>4.5%</td>
</tr>
<tr>
<td></td>
<td>High systolic blood pressure</td>
<td>3.6%</td>
</tr>
<tr>
<td></td>
<td>Alcohol use</td>
<td>2.2%</td>
</tr>
<tr>
<td></td>
<td>High fasting plasma glucose</td>
<td>2.2%</td>
</tr>
<tr>
<td></td>
<td>Occupational risks</td>
<td>1.9%</td>
</tr>
<tr>
<td></td>
<td>High LDL cholesterol</td>
<td>1.7%</td>
</tr>
<tr>
<td><strong>2017</strong></td>
<td>Child and maternal malnutrition</td>
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<tr>
<td></td>
<td>Alcohol use</td>
<td>4.5%</td>
</tr>
<tr>
<td></td>
<td>High body-mass index</td>
<td>3.9%</td>
</tr>
<tr>
<td></td>
<td>High LDL cholesterol</td>
<td>3.9%</td>
</tr>
</tbody>
</table>

DALYs = disability-adjusted life years

[https://vizhub.healthdata.org/gbd-compare/](https://vizhub.healthdata.org/gbd-compare/)
Estimation of Air Pollution Exposure in GBD 2017

- **Outdoor air pollution**
  - Annual average PM$_{2.5}$ concentration
  - Satellite-based aerosol optical depth data calibrated with ground-level PM$_{2.5}$ data
  - Data from 369 ground monitoring sites in India

- **Household air pollution**
  - Proportion of population using solid cooking fuels converted into PM$_{2.5}$ exposure
  - Major data sources included national surveys such as NFHS, DLHS and NSSO,
    Census of India, and other epidemiological studies

- **Ambient ozone pollution**
  - Mean of daily maximum 8-hour average concentration
  - GBD 2017 used new database of global surface ozone observations

*Lancet Planetary Health* 2019; 3: e26-e39 – Epub 6 Dec 2018

GBD = Global Burden of Disease
PM$_{2.5}$ = fine particulate matter
NFHS = National Family Health Survey
DLHS = District Level Household Survey
NSSO = National Sample Survey Office
Disease Burden and Deaths Attributable to Air Pollution

- Assessed risk-outcome pairs that had strong evidence for a biologically plausible association between exposure and disease outcomes
- Estimated relative risk of lower respiratory infections, chronic obstructive pulmonary disease, ischaemic heart disease, stroke, lung cancer, and diabetes for PM$_{2.5}$ exposure (60 studies)
- Estimated relative risk of cataract for household air pollution exposure
- Based on above, deaths and DALYs attributable to air pollution estimated
- GBD 2017 estimated mutually exclusive disease burden for outdoor particulate matter pollution and household air pollution
Air Pollution Exposure in the States of India: 2017

Population-weighted particulate matter PM$_{2.5}$

- India mean: 90 µg/m$^3$

Proportion of population using solid fuels

- India mean: 55.5%

**Lancet Planetary Health** 2019; 3: e26-e39 – Epub 6 Dec 2018

PM$_{2.5}$ = fine particulate matter
Deaths and DALYs Attributable to Air Pollution in India: 2017

12.5% of all deaths attributable to air pollution in India

Total deaths attributable to air pollution:
1.24 million (95% uncertainty interval 1.09 to 1.39 million)

673,000 from outdoor particulate air pollution
482,000 from household air pollution

India had 18% of the global population in 2017
India suffered 26% of the global DALYs attributable to air pollution

*Lancet Planetary Health* 2019; 3: e26-e39 – Epub 6 Dec 2018

DALYs = disability-adjusted life years
Air Pollution Death Rate in India: 1990-2017

Ambient versus Household

Crude death rate

- Ambient particulate matter: 50% increase
- Household air pollution: 56% decrease

Age-standardized death rate

- Ambient particulate matter: 22% increase
- Household air pollution: 64% decrease

https://vizhub.healthdata.org/gbd-compare/
Ambient Particulate Matter Death Rate Comparison: 1990-2017

India, China, Global

Age-standardized rates

https://vizhub.healthdata.org/gbd-compare/
DALYs Attributable to Air Pollution by Cause in India: 2017

- Lower respiratory infections: 29.3%
- Chronic obstructive pulmonary disease: 29.2%
- Ischemic heart disease: 7.5%
- Stroke: 6.9%
- Diabetes mellitus: 1.8%
- Lung cancer: 1.5%
- Cataract: 1.5%

DALY rates attributable to air pollution and tobacco use in India, 2017

Error bars represent 95% uncertainty intervals. DALY = disability-adjusted life-year.
Impact of Air Pollution on Life Expectancy in India

Increase in life expectancy in years if air pollution levels had been below minimum risk levels

Impact of outdoor air pollution on life expectancy

Impact of household air pollution on life expectancy

The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: the Global Burden of Disease Study 2017

**Background** Air pollution is a major planetary health risk, with India estimated to have some of the worst levels globally. To learn more at substantial levels in India, we estimated the exposure to air pollution and its impact on deaths, disease burden, and life expectancy in every state of India in 2017.

**Methods** We estimated exposure to air pollution, including ambient particulate matter pollution, defined as the annual average ground-level concentration of PM₂.₅, and household air pollution, defined as percentage of households using solid cooking fuels and the corresponding exposure to PM₁₀, across the states of India using accessible data from multiple sources as part of the Global Burden of Disease, Injuries, and Risk Factors Study (GBD) 2017. The states were grouped into three socioeconomic strata (high, middle, and low) as estimated by the GBD 2017 on the basis of logistic regression models using mean education in years aged 15 years or older and total fertility rate in people younger than 25 years. We estimated the health and economic burden (DALYs attributable to air pollution exposure), under the basis of exposure-response relationships from the published literature, as assessed in the GBD 2017: the proportion of total global air pollution DALYs in India, and what the life expectancy would have been in each state of India if air pollution levels had been less than the minimum level causing health loss.

**Findings** The annual population-weighted mean exposure to ambient particulate matter PM₂.₅, in India was 89.9 μg/m³ (95% uncertainty interval [86.0–93.9]) in 2017. Mean states, and 76.4% of the population of India, were exposed to annual population-weighted mean PM₂.₅, greater than 40 μg/m³, which is the limit recommended by the National Ambient Air Quality Standard in Delhi. Delhi had the highest annual population-weighted mean PM₂.₅, in 2017, followed by Uttar Pradesh, Tamil Nadu, and Haryana, with mean values greater than 100 μg/m³. The proportion of population using solid fuels in India was 55.7% (94.8–66.2%) in 2017, which exceeded 75% in the low DALY states of Uttar Pradesh, Tamil Nadu, and Haryana, where 1.26 million (0.04–1.98) million deaths in India in 2017, which were 11.5% of the total deaths, were attributable to air pollution, including 0.67 million (0.03–0.79) million from ambient particulate matter pollution and 0.59 million (0.02–0.76) million from household air pollution. Of these deaths attributable to air pollution, 31.4% were in people younger than 70 years. India contributed 39.9% of the global pollution burden and 26% of the global air pollution DALYs in 2017. The ambient particulate matter pollution DALYS rate was highest in the northern Indian states of Uttar Pradesh, Haryana, Delhi, Punjab, and Rajasthan, spread across the three states groups, and the household air pollution DALYS rate was highest in the low DALY states of Orissa, Bihar, and Madhya Pradesh, and lowest in south and northeastern India. We estimated that if air pollution levels in India were less than the minimum level causing health loss, the average life expectancy in 2017 would have been higher by 1.7 years (1.6–1.8), with this increase exceeding 2.0 years in the northern Indian states of Rajasthan, Uttar Pradesh, and Haryana.

**Interpretation** India has disproportionately high mortality and disease burden due to air pollution. This burden is generally higher in the low DALY states of northern India. Reducing the substantial avoidable deaths and disease burden from the major environmental risk is dependent on rapid deployment of effective multifactorial policies throughout India that are consistent with the guidelines of air pollution exposure across India.

**Funding** IHME, Melinda Gates Foundation, and Indian Council of Medical Research, Department of Health Research, Ministry of Health and Family Welfare, Government of India.

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**Introduction** Air pollution contributes substantially to premature mortality and disease burden globally, with a greater impact in low-income and middle-income countries than in high-income countries. India has one of the highest exposure levels to air pollution globally. The major components of air pollution are ambient particulate matter pollution, household air pollution, and a smaller extent since in the tropopause, the lowest level of atmosphere. In India, the major sources of ambient particulate matter pollution are road burning for thermal power production, industry emissions, construction activity, and solid waste disposal.
Bad air kills more than a million Indians a year, study says

By Joanna Slater December 7
NEW DELHI – At least 1 in 8 deaths in India can be attributed to air pollution, according to a new nationwide study that serves as the latest grim addition to research on the long-term health effects of the country’s bad air.

More people died last year in India because of air pollution than from tobacco use, according to the study published Thursday in the journal Lancet Planetary Health.

The fact that pollution is behind 1 in 8 deaths is “remarkable,” said Lalit Dandona, director of the India State Level Disease Burden Initiative, which conducted the study. “We’ve always thought of it as high, but to see it like that is quite a massive impact on health.”

About 50 news reports including front page and editorials
What Causes Air Pollution in India?
Particulate Matter Emission Sources in Delhi

Results shown for six different studies.
Policy and Action for Air Pollution Control

- National Air Quality Index launched by the Prime Minister of India in 2015
- National scheme launched in 2016 to increase clean cooking fuel use with the aim to reach 80 million households
- India pledged in 2016 to increase electricity generation from renewable sources as part of the Paris Agreement
- National Clean Air Programme launched in 2018
- Target set by the National Clean Air Programme in early 2019 for 20-30% reduction in air pollution in 102 cities across India

Visibly higher attention to air pollution in public and policy discussions over the past year
Evidence for the Impact of Air Pollution on Disease Burden in India

- Short-term exposure effects of outdoor particulate matter on acute diseases and on all-cause mortality are similar in India and other countries.

- Recent cohort study in China, which included exposure at levels comparable to those observed in India, shows similar cause-specific mortality as in the more developed countries.

- Some cohort studies have been initiated in India, select early findings from which are consistent with meta-analyses estimates from elsewhere.

- Reasonable for now to use disease attribution data from worldwide long-term exposure cohort studies to estimate disease burden attributable to air pollution in India.
Air Pollution Evidence Gaps in India

- Limited ground monitoring of air pollution, especially in less developed states and rural areas
  - National Pollution Control Board has announced plans to increase ground monitoring sites
- No comprehensive long-term cohort studies to assess the health impact of air pollution
  - Tamil Nadu Study (TAPHE) – low birth weight, respiratory diseases
  - Hyderabad Study (CHAI) – cardiovascular arterial thickening
  - Delhi-Chennai Study (CARRS) – cardio-respiratory diseases
- Divergent estimates of contributors to ambient air pollution
- No significant policy or intervention research related to air pollution
Air Pollution Research in India

- Few air pollution research groups
  - Chennai – Sri Ramachandra University
  - Delhi – Public Health Foundation of India (PHFI), Indian Institute of Technology – Delhi (IITD)
  - Mumbai – Indian Institute of Technology - Mumbai (IITM)
  - Kanpur – Indian Institute of Technology - Kanpur (IITK)
  - Chandigarh – Post Graduate Institute of Medical Education & Research, Chandigarh (PGIMER)
  - Pune – Chest Research Foundation (CRF), System of Air Quality and Weather Forecasting And Research (SAFAR)

- Limited resources for air pollution research
  - India – Indian Council of Medical Research (ICMR), Department of Biotechnology (DBT), Department of Science & Technology (DST), Ministry of External Affairs (MoE)
  - International – National Institutes of Health (NIH), World Health Organization (WHO), Medical Research Council (MRC), Health Effects Institute (HEI)

Various sporadic research outputs but few established programs of air pollution research
Strengthening Evidence for Air Pollution Control in India

- Establish comprehensive long-term cohort studies to assess the health impact of air pollution
  - Ideally nationwide representation, or at least cover diverse parts of the country
  - Tag with existing large scale data collection efforts – pros and cons
  - Challenges with starting fresh cohorts
  - Include all-cause mortality, cause-specific mortality, morbidity, possibly biomarkers

- Establish collaborative efforts to standardize estimation of the contribution of various sources to ambient air pollution
  - Emission inventory assessment methods
  - Simulation modelling methods

- Plan strategic policy and intervention research
  - Assess through research how policy engagement can be enhanced
  - Efficient impact assessment of recent and new air pollution control programs
  - Develop research to assess the impact of specific interventions