Examining health effects of air pollution in India

*Summary of recent progress from research studies*

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Expanding our thinking on exposure environments
Dimensions of progress in research studies linking air quality and health in India

- Inputs for global/regional efforts
  - WHO IARC : (HAP 2006); (Diesel 2009); (AAP 2013)
  - WHO-SEAR Action Plan on NCDs

- Inputs for national actions (AQI, MOHFW Report)
  - Sources, emissions, concentrations, exposures and intake fractions
  - Exposure-response relationships
  - Biomarkers

- Inputs for ongoing/future efforts
  - Implementation of WHO-AQGs, WHA 2015 Resolution
  - GBD 2015, GBDMAPS
  - National and State Level Environmental Burden of Disease Efforts
  - Revisions to WHO AQGs
Inputs for recent global efforts
79 risk factors (top 58 shown)

Ambient air pollution
587,000 deaths
8th ranking

Household air pollution
924,000 deaths
2nd ranking


http://vizhub.healthdata.org/gbd-compare
<table>
<thead>
<tr>
<th></th>
<th>CHINA OUTDOOR PM</th>
<th>CHINA HOUSEHOLD</th>
<th>INDIA OUTDOOR PM</th>
<th>INDIA HOUSEHOLD</th>
<th>USA OUTDOOR PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>IHD</td>
<td>236,926</td>
<td>151,722</td>
<td>296,489</td>
<td>315,039</td>
<td>43,160</td>
</tr>
<tr>
<td></td>
<td>17%</td>
<td>11%</td>
<td>19%</td>
<td>20%</td>
<td>7.9%</td>
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<tr>
<td>Stroke</td>
<td>363,494</td>
<td>256,674</td>
<td>139,941</td>
<td>166,871</td>
<td>10,881</td>
</tr>
<tr>
<td></td>
<td>19%</td>
<td>13%</td>
<td>20%</td>
<td>23%</td>
<td>6.6%</td>
</tr>
<tr>
<td>COPD</td>
<td>75,761</td>
<td>295,786</td>
<td>56,665</td>
<td>338,491</td>
<td>1,710</td>
</tr>
<tr>
<td></td>
<td>8%</td>
<td>32%</td>
<td>7%</td>
<td>45%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Lung Cancer</td>
<td>201,864</td>
<td>75,050</td>
<td>21,432</td>
<td>12,882</td>
<td>17,363</td>
</tr>
<tr>
<td></td>
<td>37%</td>
<td>14%</td>
<td>35%</td>
<td>21%</td>
<td>9.8%</td>
</tr>
<tr>
<td>ALRI</td>
<td>38,064</td>
<td>28,041</td>
<td>72,041</td>
<td>90,878</td>
<td>5,718</td>
</tr>
<tr>
<td></td>
<td>18%</td>
<td>13%</td>
<td>18%</td>
<td>22%</td>
<td>6.7%</td>
</tr>
<tr>
<td></td>
<td>916,102</td>
<td>807,238</td>
<td>586,788</td>
<td>924,550</td>
<td>78,814</td>
</tr>
</tbody>
</table>
Air Pollution Attributable Burdens in India (1990-2013)

<table>
<thead>
<tr>
<th></th>
<th>AAP (PM$_{2.5}$)</th>
<th>HAP (PM$_{2.5}$)</th>
<th>AAP (Ozone)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DALYs</td>
<td>15 million</td>
<td>16.6 million</td>
<td>28 million</td>
</tr>
</tbody>
</table>

http://vizhub.healthdata.org/gbd-compare
AAP (PM$_{2.5}$) exposure estimates for India (GBD 2010, 2013)

Brauer et al. 2012
AAP( PM$_{2.5}$) exposure estimates for India (GBD 2010, 2013)

<table>
<thead>
<tr>
<th>Country</th>
<th>1990 PM$_{2.5}$</th>
<th>2013 PM$_{2.5}$</th>
<th>% Change</th>
<th>1990 Ozone</th>
<th>2013 Ozone</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td>26.4</td>
<td>31.8</td>
<td>20.4</td>
<td>57.3</td>
<td>62.4</td>
<td>8.9</td>
</tr>
<tr>
<td>China</td>
<td>39.3</td>
<td>54.3</td>
<td>38.0</td>
<td>57.0</td>
<td>64.5</td>
<td>13.2</td>
</tr>
<tr>
<td>India</td>
<td>30.2</td>
<td>46.7</td>
<td>54.3</td>
<td>61.5</td>
<td>74.0</td>
<td>20.2</td>
</tr>
<tr>
<td>United States</td>
<td>16.4</td>
<td>10.7</td>
<td>-34.5</td>
<td>70.3</td>
<td>67.0</td>
<td>-4.7</td>
</tr>
<tr>
<td>Indonesia</td>
<td>21.0</td>
<td>14.8</td>
<td>-29.7</td>
<td>47.3</td>
<td>39.6</td>
<td>-16.1</td>
</tr>
<tr>
<td>Brazil</td>
<td>9.7</td>
<td>16.5</td>
<td>70.4</td>
<td>43.4</td>
<td>51.0</td>
<td>17.3</td>
</tr>
<tr>
<td>Pakistan</td>
<td>36.5</td>
<td>46.2</td>
<td>26.3</td>
<td>59.0</td>
<td>68.8</td>
<td>16.5</td>
</tr>
<tr>
<td>Nigeria</td>
<td>31.0</td>
<td>29.5</td>
<td>-4.7</td>
<td>66.3</td>
<td>67.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>29.9</td>
<td>48.3</td>
<td>61.6</td>
<td>59.4</td>
<td>72.0</td>
<td>21.3</td>
</tr>
<tr>
<td>Russia</td>
<td>19.7</td>
<td>14.2</td>
<td>-27.6</td>
<td>48.6</td>
<td>48.3</td>
<td>-0.6</td>
</tr>
<tr>
<td>Sri</td>
<td>19.4</td>
<td>16.0</td>
<td>-17.5</td>
<td>56.8</td>
<td>60.5</td>
<td>6.7</td>
</tr>
<tr>
<td>Japan</td>
<td>19.4</td>
<td>16.0</td>
<td>-17.5</td>
<td>56.8</td>
<td>60.5</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Brauer et al. 2016
HAP (PM$_{2.5}$) estimates for India (GBD 2010, 2013)

**HH Concentrations**
- Kitchen: 450µg/m$^3$ (95% CI: 318,640)
- Living: 113µg/m$^3$ (95% CI: 102,127)

**Exposures**
- Children: 285µg/m$^3$ (95% CI: 201,405)
- Women: 337µg/m$^3$ (95% CI: 238,479)
- Men: 204µg/m$^3$ (95% CI: 144, 290)

Balakrishnan et al. 2013

Forouzanfar, Balakrishnan et al. 2016 (In preparation)

24 HRS Kitchen Concentration (µg/m$^3$)

- 0 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350
- 350 - 400
- 400 - 450
- 450 - 500
- 500 - 550
- 550 - 600

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### Representation of air pollution related health effects studies from India in GBD related meta-analyses, IERs

<table>
<thead>
<tr>
<th>Health Outcome</th>
<th>India studies</th>
<th>Reported ORs</th>
<th>Meta-analysis estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COPD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAP</td>
<td>Behera et al (1991)</td>
<td>3.04 (2.15-4.31)</td>
<td>Kurmi et al 2.80 (1.85–4.0)</td>
</tr>
<tr>
<td></td>
<td>Qureshi et al (1994)</td>
<td>2.10 (1.50 to 2.94)</td>
<td>Hu et al 2.44(1.9-3.33)</td>
</tr>
<tr>
<td></td>
<td>Dutt et al (1996)</td>
<td>2.80 (0.61-12.85)</td>
<td>PO et al 2.4(1.47-3.93)</td>
</tr>
<tr>
<td></td>
<td>Malik et al(1985)</td>
<td>2.95(1.6-5.44)</td>
<td>Smith et al 1.93(1.61-2.92)</td>
</tr>
<tr>
<td></td>
<td>Pandey et al(1984)</td>
<td>4.05(3.23- 4.16)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jindal et al(2006)</td>
<td>1(0.79-1.27)</td>
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<tr>
<td><strong>Child ALRI</strong></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Mishra et al (2004)</td>
<td>2.2(1.16-4.18)</td>
<td>Smith et al(2014) 1.18(1.03-1.35)</td>
</tr>
<tr>
<td></td>
<td>Kumar et al (2004)</td>
<td>3.67(1.42-10.57)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mishra et al (2005)</td>
<td>1.58 (1.28–1.95)</td>
<td></td>
</tr>
<tr>
<td><strong>Lung Cancer (Biomass)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAP</td>
<td>Gupta et al (2000)</td>
<td>1.52 (0.33–6.98)</td>
<td>Smith et al (2014) 1.18(1.03-1.35)</td>
</tr>
<tr>
<td></td>
<td>Sapkota et (2008)</td>
<td>3.76 (1.64-8.63)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Behera et al (2005)</td>
<td>3.59 (1.08-11.67)</td>
<td></td>
</tr>
<tr>
<td><strong>Cataracts</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAP</td>
<td>Mohan et al (1989)</td>
<td>1.61 (1.02–2.50)</td>
<td>Smith et al (2014) 2.46(1.74-3.5)</td>
</tr>
<tr>
<td></td>
<td>Badrinath(1996)</td>
<td>4.91 (2.82-8.55)</td>
<td></td>
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<tr>
<td></td>
<td>Sreenivas(1999)</td>
<td>1.82 (1.13-2.93)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Saha(2005)</td>
<td>2.40 (0.9-6.38)</td>
<td></td>
</tr>
<tr>
<td><strong>Lung Cancer(Coal)</strong></td>
<td></td>
<td>Not available</td>
<td></td>
</tr>
<tr>
<td>HAP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ALRI, IHD, Stroke, Lung Cancer, COPD</strong></td>
<td>Not Available</td>
<td></td>
<td>Burnett et al (2014) 1.12 (1.03, 1.30)</td>
</tr>
<tr>
<td><strong>Asthma</strong></td>
<td></td>
<td>Not Available</td>
<td></td>
</tr>
<tr>
<td><strong>Low Birth Weight</strong></td>
<td>Not Available</td>
<td></td>
<td>Anderson et al (2009) (PM2.5) 1.16 (0.98 to 1.37)</td>
</tr>
</tbody>
</table>
IERS used in GBD 2010
Percent Risk Factor Attributions for Air Pollution (India GBD 2010 Results)

A. Male IHD: 17,100,000 DALYs

B. Female IHD 9,090,000 DALYs

C. Child ALRI 17,100,000 DALYs

Smith-Bruce, Balakrishnan 2014
Inputs for recent national efforts/actions
Exposure Inputs for National AQI (AAP)

- Builds on earlier AQI related efforts in Pune and Delhi (Beig et al 2010)
- Uses expanded continuous (real to near–real time) air quality monitoring data from CPCB on eight pollutants
- Uses breakpoints based on review/synthesis across available Global AQIs

Sharma et al; CPCB, 2014
http://aqicn.org/map/india/
Exposure Inputs for National AQI (AAP)

http://aqicn.org/map/india/
Tuesday May 23, 2016
Sri Ramachandra University

PM 2.5

SO2

CO

PM 10

O3

SO2

CO

NO2

AQI:312 Hazardous

AQI:103 Unhealthy for sensitive groups
Exposure Inputs for the MOHFW Report (AAP)

Ghosh et al 2014

Dey et al 2012
Exposure Inputs for the MOHFW Report (HAP)

Mukhopadhyay et al 2012
Sambandam et al 2011
Pillariseti et al 2014
Balakrishnan et al 2015
Interfacing National Policy with WHO Air Quality Guidelines

Our aim is to achieve the quality of energy services from cook stoves comparable to that from other clean energy sources such as LPG: MNRE, 2009

TC-Traditional cook stove; FRC-Free convection cook stove; FC-Forced convection; FOFC: Fuel optimized forced convection

Note: The chosen guideline is arbitrary on this scale as are the relative positions of the stoves. It is shown to merely illustrate the need to integrate multiple inputs for choosing a technology to confer a required degree of exposure reduction.
Exposure Inputs for MOHFW Report

Guttikunda 2014
Sri Ramachandra University
Health Inputs for AQI and MOHFW Report

- Relies primarily on global pool of exposure-response studies with limited representation from India, but an increasing representation from countries with overlapping exposure configurations.
- Included end points beyond what was considered in GBD efforts.
- Informed by multiple health impact assessment studies.
New/On-going Efforts
The TAPHE Cohort Study in Southern India

ADULT COHORT

Indoor

Respiratory symptoms

PFT

Outdoor

EXPOSURE ASSESSMENT

EXPOSURE MODELING

EXPOSURE MODELING

Bio-repository + SNPs

Birth Weight

ARI

Primarily Rural & HH fuel use related

MOTHER-CHILD COHORT

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Primarily Urban & Fossil fuel use related
TAPHE Study Outputs

- Provides some of the first quantitative exposure-response functions centered on more proximal (household) measures of PM 2.5 exposure for birthweight, ARI, respiratory symptoms and lung function.
- Provides some of the first integrated rural urban E-R estimates
- Large emphasis on reducing exposure misclassification and confounding
- Uses well validated study instruments/protocols while developing a parsimonious and yet reliable framework of data collection
GBDMAPS

% contribution of household fuels to Ambient PM 2.5 Concentrations

District wise reports @
http://www.urbanemissions.info
regional WRF-CAMx simulations to support health and air quality alerts

District: South (Delhi)

Modelled hourly source contributions in forecast mode
The Challenge

- The burden is not decreasing and the evidence is unequivocal!
- The burden is seamless across rural–urban boundaries
- Interventions to tackle OAP and HAP would have to be in sync (at least in some measure)
- WHO-AQGs are universally applicable for defining counterfactuals but NAAQM focused only on the urban
- Density of intervention efforts would need to be substantively increased to achieve and demonstrate health benefits
- Range of health effects are broader and magnitudes bigger than previously estimated (more chronic outcomes included in the ambit)
- Multitude of competing risk factors
Critical Gaps

- Limited focus on exposure-response, exposure modeling (New opportunities provided by on-going cohorts)
- Limited exposure assessment capacities (New capacity building efforts to be launched under GEO-HUB efforts)
- Limited multi-sectoral efforts for interfacing with policy (Facilitated by MOHFW/MOES efforts)
Grateful Thanks

- ICMR
- Offices of the DG and NCD, ICMR
- Departments of Health and Environment, Govt. of Tamil Nadu
- National Collaborators from Calcutta University, IITM, IIT-D, IIT-K, INCLLEN, PHFI, NIOH, NIOH-ROHC, NEERI
- International Collaborators from UC Berkeley, GACC, Berkeley Air, Columbia University, CREAL, Tufts University and HEI.
Thank you & Namaste!