The Global Burden of Disease Attributable To Air Pollution: Latest Results and Future Directions for Source-Specific Burdens

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ECT - 2015
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Trusted Science ● Cleaner Air ● Better Health
Air Pollution and the Global Burden of Disease

• Air Quality and Health
  • Estimating the Global Burden of Disease GBD
    • GBD 2010 Review
    • GBD 2013: What’s New?
      • 2013 Preliminary Results

• Looking Ahead:
  • GBD MAPS: Understanding Source-Specific Health Impacts in China, India and Eastern Europe
  • The Special Case of Traffic

• Concluding Thoughts

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The Health Effects Institute

Trusted Science ➔ Cleaner Air ➔ Better Health

• An independent non-profit institute providing trusted science on the health effects of air pollution for 35 years
• Balanced Core Support
  • US EPA and Industry (Worldwide Motor Vehicle)
• Partnerships
  • Also WHO, ADB, Clean Air Asia, TERI, Sri Ramachandra Medical School, EU, US DOE, industries, foundations, others
• Independent Board and Expert Science Committees
  • Oversee and intensively peer review all science
  • International experts from India, China, many others
• Over 350 scientific reviews, reanalysis conducted around the world, including increasingly in Asia

Understanding local impacts in a global context to inform policy
India’s National Air Quality Challenge:

PM10:
• Number of critically polluted cities has increased from 57 in 2009 to 85 in 2012;
• Nearly half have critical pollution levels

Source: Based on National Ambient Air Quality Status 2009 and 2012
Indian Results:
PM10 Evidence from HEI Chennai study
Approximately 0.3% - 0.6% increase in mortality per 10 µg/m³ PM10
Similar Results in Delhi as Well...

Fig. 23: A comparison of the estimated RR’s for PM10 obtained from the core zonal model, alternative models and sensitivity analysis.

Dr. Kalpana Balakrishnan and colleagues HEI 2011
Recent Indian studies look at diverse health end points....

Respiratory health symptoms dominate....
Broadening to include cardiovascular, eye disorders, cellular changes, cancer, premature deaths....

Source: CSE
Asia in a Global Context

(\textit{PM}_{10} \textit{and Daily Mortality})

The effects of pollution are more similar than different ...

... and global science can be broadly relevant

Figure 1

Estimates from Meta-analyses

<table>
<thead>
<tr>
<th>Increase in Mortality (%)</th>
<th>29 cities (PM\textsubscript{10}) (Levy et al. 2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GAM-Optim-ized studies (PM\textsubscript{10})</td>
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<td>Non-GAM-Optim-ized studies (PM\textsubscript{10})</td>
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<td>Publication bias adjusted (PM\textsubscript{10})</td>
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<td></td>
<td>(Anderson et al. 2005)</td>
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<td>PHO  \textsubscript{10} (Anderson et al. 2005)</td>
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</table>

Estimates from Multicity Studies

<table>
<thead>
<tr>
<th>Increase in Mortality (%)</th>
<th>6 U.S. cities (PM\textsubscript{2.5}) (Kemrn and Mazon 2003)</th>
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<tbody>
<tr>
<td></td>
<td>9 Californian cities (PM\textsubscript{2.5}) (Caton et al. 2006)</td>
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<td>10 U.S. cities (PM\textsubscript{2.5}) (Schwartz and Coul 2003)</td>
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<td>14 U.S. cities: case-crossover (PM\textsubscript{2.5}) (Schwartz 2004)</td>
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<td>APHEA 22 European cities (PM\textsubscript{10}) (Katsayanni et al. 2006)</td>
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<td>APHEA combined analysis, 4 Asian cities (PM\textsubscript{10})</td>
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<tr>
<td></td>
<td>ESCAL (Preliminary Results), 9 Latin American cities (PM\textsubscript{10}) (Romieu et al. 2010)</td>
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Per 10 -\mu g/m\textsuperscript{3} Increase in PM
The Global Burden of Disease (GBD)

• A systematic scientific effort to quantify the magnitude of health loss from disease and injuries in 187 countries around the world from 1990 to 2010
  • E.g. cardiovascular disease, respiratory disease, HIV-AIDS, cancer, road traffic injuries and
• Risks factors associated with those diseases
  • E.g. smoking, diet, high blood pressure, air pollution, overweight
  • GBD 2010, published in The Lancet December 2012
• Organized by the Institute for Health Metrics and Evaluation (IHME), U Wash.
• HEI leadership for outdoor air pollution
2010: Ambient PM$_{2.5}$ among the leading global risks for mortality and lost years of healthy life

(Lim et al 2012, and http://viz.healthmetricsandevaluation.org/gbd-compare/)

Contributes to ~3 million premature deaths worldwide (2/3 occurred in developing Asia)
Top 20 Mortality Risk Factors in India for 2010
Ambient PM$_{2.5}$ is 5$^{th}$ leading mortality risk factor

Leading Risk Factors for Deaths in 2010 in India

- High blood pressure
- Household air pollution from solid fuels
- Tobacco smoking, including second-hand smoke
- Diet low in fruits
- Ambient particulate matter pollution
- High fasting plasma glucose
- Alcohol use
- Physical inactivity and low physical activity
- Diet low in nuts and seeds
- Diet high in sodium
- Diet low in vegetables
- Diet low in whole grains
- Diet low in seafood omega-3 fatty acids
- Occupational risk factors for injuries
- Childhood underweight
- High total cholesterol
- Lead exposure
- High body-mass index
- Suboptimal breastfeeding
- Diet high in processed meat

Ambient PM$_{2.5}$ caused an estimated 627,000 deaths ~6% of all deaths in 2010
Extensive Press on Global Burden of Disease

Including detailed coverage in China/India/Western media

- ‘Airpocalypse’ in China: Air Pollution Kills Over a Million

Risk factors for disease in 2010 (In Asia/mainly India):

1. Household air pollution from solid fuels
2. Smoking/second hand smoke
3. High blood pressure
4. Childhood underweight
5. Low fruit intake
6. Pollution
7. High plasma glucose
8. Alcohol use
9. Iron deficiency
10. Sub optimal breastfeeding

Top killers across the world:

- High blood pressure
- Household air pollution from solid fuels
- High body mass index
- High fasting plasma glucose
- Air pollution
- High cholesterol
- Low bone mineral density

Death due to dietary risk factors:

- Disease attributable to tobacco smoking: 6.3
- Alcohol and drug use: 5
- Low diet of fruits: 4.9
- High sodium diet: 4
- Low nuts, seeds diet: 2.5
- Low vegetable food: 1.8
- Occupational risk factors accounted: 0.9
NEW: The Global Burden of Disease (GBD) 2013

More Comprehensive
• Health loss from over 291 diseases and injuries in 188 countries.
  • New estimates for all 76 risk factors including ambient and household air pollution
  • Provincial level estimates for China, UK, Mexico

Advanced Science
• Expands upon the methodology, datasets and tools in GBD 2010 including for air pollution – PM$_{2.5}$, ozone, household
  • New improved PM$_{2.5}$ exposure data from ground level monitors, satellites, transport models

• PM health risk estimates now include 13 epidemiologic cohort mortality studies including new, large studies published since 2010
  • New data on pneumonia in children and adults
1990 – 2013 Change in Annual Average PM$_{2.5}$

Enhanced ground monitoring and other data
Leading to higher quality estimates
Changes in Life-Expectancy at Birth 1970-2013

Longer lives worldwide

More people dying from heart disease
Estimating Mortality Risk for the Global Burden of Ambient PM$_{2.5}$

- Five Major Diseases related to PM$_{2.5}$
  - Ischemic heart disease (IHD)
  - Stroke
  - Lower respiratory infection (Age 0 – 5)
  - Chronic obstructive lung disease (COPD)
  - Lung cancer
### Ambient Air Pollution Cohort Adult Mortality Studies Used to Estimate Burden of Disease (including additional studies from Europe, Canada, Japan)

<table>
<thead>
<tr>
<th>Study</th>
<th>PM$_{2.5}$ Mean (µg/m$^3$)</th>
<th>PM$_{2.5}$ Min (µg/m$^3$)</th>
<th>5th/99th (µg/m$^3$)</th>
<th>IHD HR /10 µg/m$^3$ (95% CI)</th>
<th>CEV HR /10 µg/m$^3$ (95% CI)</th>
<th>COPD HR /10 µg/m$^3$ (95% CI)</th>
<th>LC HR /10 µg/m$^3$ (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Cancer Society* (ACS)</td>
<td>14.2</td>
<td>5.8</td>
<td>8.8/20.0</td>
<td>1.26 (1.16-1.38) n=29875</td>
<td>1.12 (1.01-1.24) n=9116</td>
<td>1.05 (0.95-1.17) n=9006</td>
<td>1.14 (1.06-1.23) n=9,557</td>
</tr>
<tr>
<td>Six City* (SCS)</td>
<td>17.8</td>
<td>8.7</td>
<td>10.2/23.6</td>
<td>1.33 (1.16-1.52) n=1065</td>
<td>0.89 (0.67-1.18) n=317</td>
<td>1.17 (0.85-1.62) n=247</td>
<td>1.37 (1.07-1.75) n=351</td>
</tr>
<tr>
<td>California Teachers* (CTS)</td>
<td>15.6</td>
<td>3.1</td>
<td>8.3/23.0</td>
<td>1.20 (1.02-1.41) n=773</td>
<td>1.16 (0.92-1.46) N=382</td>
<td>1.21 (0.88-1.68) n=196</td>
<td>0.95 (0.70-1.28) n=234</td>
</tr>
<tr>
<td>Adventist Study of Health and Smog* (ASHSmog)</td>
<td>29.0</td>
<td>12.9</td>
<td>15.0/45.1</td>
<td>1.00 (0.87-1.15) n=145</td>
<td></td>
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<tr>
<td>Dutch Study of Diet and Cancer* (DSDC)</td>
<td>28.3</td>
<td>23.0</td>
<td>24.8/31.8</td>
<td>0.96 (0.75-1.22) n=3,521</td>
<td>1.62 (1.07-2.44) n=1,175</td>
<td></td>
<td>1.06 (0.82-1.38) n=1,670</td>
</tr>
<tr>
<td>Male Health Professionals* (MHP)</td>
<td>17.9</td>
<td>5.8</td>
<td>12.3/23.4</td>
<td>0.98 (0.71-1.36) n=746</td>
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<tr>
<td>Nurses Health* (NHS)</td>
<td>13.9</td>
<td>5.8</td>
<td>10.0/17.8</td>
<td>2.02 (1.07-3.78) n=379</td>
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<tr>
<td>Women’s Health Initiative* (WHI)</td>
<td>13.5</td>
<td>3.4</td>
<td>7.4/19.6</td>
<td>2.21 (1.17-4.16) n=80</td>
<td>1.83 (1.11-3.00) n=122</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canadian Census Health &amp; Environment Cohort* (CanCHEC)</td>
<td>8.7</td>
<td>2.1</td>
<td>3.6/13.8</td>
<td>1.30 (1.15-1.43) n=43400</td>
<td>1.04 (0.93-1.16) n=13300</td>
<td></td>
<td>1.29 (0.95-1.76) n=2154</td>
</tr>
<tr>
<td>Canadian National Enhanced Cancer Surveillance System Cohort (NECSS)*</td>
<td>11.9</td>
<td>3.8</td>
<td>6.7/16.8</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>English Cohort* (ENDOC)</td>
<td>12.9</td>
<td>8.5</td>
<td>10.6/15.2</td>
<td>1.05 (0.81-1.32) n=8168</td>
<td>1.00 (0.81-1.29) n=5458</td>
<td>1.43 (1.00-1.79) n=4105</td>
<td>1.11 (0.88-1.43) n=5244</td>
</tr>
<tr>
<td>Japanese Cohort* (JAPAN)</td>
<td>16.8</td>
<td>16.8</td>
<td>16.8/41.9</td>
<td>0.89 (0.70-1.12) n=64</td>
<td></td>
<td>0.89 (0.70-1.12) n=518</td>
<td>1.24 (1.12-1.37) n=518</td>
</tr>
<tr>
<td>Agricultural Health Study*</td>
<td>5.7</td>
<td>7.3</td>
<td>7.3/12.6</td>
<td>2.68 (1.04-6.87) n=1206</td>
<td>1.78 (0.72-4.42) n=20</td>
<td></td>
<td>0.75 (0.34-1.65) n=233</td>
</tr>
</tbody>
</table>

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New Studies added for GBD 2013
GBD 2013 Premature Deaths:
Air Pollution among top-ranked global risk factors

Air pollution combined — ambient plus household — contributed to 10% of global mortality in 2013 – the 4\textsuperscript{rd} ranked global risk factor.

GBD 2013 Risk Factor Collaborators ***PRELIMINARY ESTIMATES***
Household air pollution in India remains as the 2\textsuperscript{nd} highest risk factor, ambient all source air pollution also a top risk factor in India.
India: Deaths attributable to combined risk factors

Indoor and outdoor combined are now the 3rd highest risk factor

GBD 2013 Risk Factor Collaborators ***PRELIMINARY ESTIMATES***
A Key Need for Cleaner Air: Health Burden from Different Sources

Vehicles ~20% - 30% of total PM2.5 (depending on city and season)

- Fossil fuel and biomass combustion dominates:
  - Fossil Fuel
    - Del: 25-33%
    - Kol: 37-53%
    - Mum: 21-35%
  - Biomass
    - Del: 7-19%
    - Kol: 13-18%
    - Mum: 7-20%

- Dust dominates during Spring and Summer
  - Long range transport and dust from local construction

- Biomass and coal are high in winter
  - Heating
  - Poor mixing and atmospheric inversion

Road Dust an additional 10% - 30%

Source: Adapted from Chowdhury et al. (2007).
Many Sources of PM in India
GBD MAPS: Understanding Source Specific Impacts

- Source-specific impacts best inform, drive climate and air pollution control measures
- GBD MAPS: Global Burden of Disease from Major Air Pollution Sources
- New HEI-IHME initiative to understand source-specific impacts (e.g. coal, transport)
  - China, India, Eastern Europe, in a global context
  - Using GBD 2013 methods, data
  - At national, provincial levels
- In partnership initially with leading Chinese, Indian partners (Tsinghua, IIT-B, others)

Underway now; China results expected in 2015; India in 2016
GBD MAPS Working Group

Michael Brauer (co-chair)  University of British Columbia
Aaron Cohen (co-chair)  Health Effects Institute
Wang Shuxiao  Tsinghua University
Zhang Qiang  Tsinghua University
Ma Qiao  Tsinghua University
Zhou Maigeng  China CDC
Yin Peng  China CDC
Chandra Venkataraman  IIT Bombay
Pankaj Sadavarte  IIT Bombay
Wang Yuxuan  University of Texas, Galveston
Kan Haidong  Fudan University
Randall Martin  Dalhousie University
Aaron van Donkelaar  Dalhousie University
Richard Burnett  Health Canada
Mohammad Forouzanfar  IHME
Joseph Frostad  IHME
GBD MAPS: All the Major Sources

- Transportation (on-road, non-road)
- Household Biomass
- Brick Kilns
- Coal:
  - Power, Industry, Domestic
- Non-coal Industrial
- Agriculture
- Open Burning
- Solvent Use

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**GBD MAPS Approach**

1. Estimate fractions of PM$_{2.5}$ from transport, industry, coal-combustion and other sources

2. Multiply source fractions with ambient PM$_{2.5}$ to estimate source-specific ambient PM$_{2.5}$

3. Combine source-specific ambient PM$_{2.5}$ and GBD PM$_{2.5}$ health estimates to provide source contributions to disease burden

***PRELIMINARY ESTIMATES***
GBD MAPS: Estimate of source emission contributions to ambient PM$_{2.5}$ using latest available information on current and projected emissions (India 2013)

- **PM$_{2.5}$:**
  - Total: 7400 Gg/yr
  - Industry: 3400 Gg/yr
  - Transport: 2600 Gg/yr
  - Residential: 1400 Gg/yr

- **SO$_2$:**
  - Total: 8500 Gg/yr
  - Industry: 3200 Gg/yr
  - Transport: 2200 Gg/yr
  - Residential: 1300 Gg/yr

- **NO$_x$:**
  - Total: 9700 Gg/yr
  - Industry: 3700 Gg/yr
  - Transport: 2800 Gg/yr
  - Residential: 1500 Gg/yr

- **NMVOC:**
  - Total: 13200 Gg/yr
  - Industry: 5000 Gg/yr
  - Transport: 4000 Gg/yr
  - Residential: 2900 Gg/yr
  - Others: 1300 Gg/yr
Source Emission Estimates

**India 2013 PRELIMINARY ESTIMATES**

Expect initial GBD MAPS results for India 2016
1990 – 2013 Change in Annual Average PM$_{2.5}$

Emission factors will then be applied to estimate Indian source-specific population exposure.
The Special Case of Traffic Sources
Summarized & synthesized over 700 studies on health effects of traffic
• However, not all of equal quality

Found:
• Highest exposures 300-500 meters from major roads
• Growing evidence of effects, especially asthma exacerbation in children

New:
• HEI Traffic Exposure, Tunnel Studies underway
• Updated traffic expert review to get underway in 2016 (10 more years of data)
The Traffic Impact Area in Delhi:
HEI Analysis: 55% of the Population within 500 meters of a Freeway; 50 meters of a Major Road
An Important Traffic Concern: Older Diesel Health Effects

• Primary concern is exposure to particulate matter and NO\textsubscript{x} from older diesel

• Also, evidence of respiratory effects:
  • reduced lung function, respiratory irritation, asthma exacerbation

• Diesel and cancer: IARC 2012
  • Older diesel a known human carcinogen
  • But highlights the changes with New Technology Diesel Engines (NTDE)
    • HEI ACES Results
Key IARC Evidence: Diesel Exhaust in Miners Study
(NCI/NIOSH Attfield et al. 2012; Silverman et al. 2012)

• Major occupational study in “non-coal and non-metal” mines
  • Risk of Lung Cancer increased 300% to 700% in exposed workers
  • Key input into IARC decision

• Some continuing questions about study
  • HEI Systematically reviewing and analyzing the data
  • HEI Expert Diesel Epidemiology Report on strength of study - Fall 2015
Concluding Thoughts

• We know much more today about the Health Effects of Air Pollution in Asia
  • Growing science base
  • New Short and Long Term Studies

• GBD is increasing understanding of the population health burdens
  • GBD 2010, and now GBD 2013 including new approaches to exposure and exposure-response

• Important clean air progress underway in China

• Actions beginning in India:
  • AQI, BS V/VI, thermal power plants

• Source-specific impacts are likely to best inform and drive future control measures
  • GBD MAPS
  • New Traffic Review and Studies

*Trusted Science • Cleaner Air • Better Health*
Thank You!

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