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

Dan Greenbaum
President, Health Effects Institute
ECT - 2016
New Delhi
9th November 2016

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
    - Health Effects in India and Globally
    - GBD 2015: The Latest Results!
- Looking Ahead:
  - GBD MAPS: Understanding Source-Specific Health Impacts in China, India and Eastern Europe
- The Special Case of Traffic
- Concluding Thoughts
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)

• Additional Support and 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 studies, reviews, and reanalysis conducted around the world, including increasingly in Asia

  Understanding local impacts in a global context to inform policy
Growing number of Indian air pollution and health studies...

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

Source: CSE
Also a Growing Number of Ambient Air Pollution Adult Mortality Studies

Find Links between Long term PM and Premature Mortality

(including studies from Asia, Europe, North America)

<table>
<thead>
<tr>
<th>Study</th>
<th>PM$_{2.5}$ Mean ($\mu g/m^3$)</th>
<th>PM$_{2.5}$ Min ($\mu g/m^3$)</th>
<th>PM$_{2.5}$ 5th/95th ($\mu g/m^3$)</th>
<th>IHD HR /10 $\mu g/m^3$ (95% CI)</th>
<th>CEV HR /10 $\mu g/m^3$ (95% CI)</th>
<th>COPD HR /10 $\mu g/m^3$ (95% CI)</th>
<th>LC HR /10 $\mu g/m^3$ (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>
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<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>
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<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>
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<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>
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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>1.06 (0.82-1.38) n=1,670</td>
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<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>
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<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>
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<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 (1.15-1.45) n=43400</td>
<td>1.04 (0.93-1.16) n=13300</td>
<td>1.29 (0.95-1.76) n=2154</td>
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<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>
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<tr>
<td>English Cohort* (ENDOC)</td>
<td>12.9</td>
<td>8.5</td>
<td>10.6/15.2</td>
<td>1.05 (0.81-1.29) 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=5264</td>
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<tr>
<td>Japanese Cohort (JAPAN)</td>
<td>Mean Not Reported N=635,607</td>
<td>8.5</td>
<td>10.6/15.2</td>
<td>1.05 (0.81-1.29) n=8168</td>
<td>1.00 (0.81-1.29) n=5458</td>
<td>1.43 (1.00-1.79) n=4105</td>
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<tr>
<td>Agricultural Health Study**</td>
<td>5.7</td>
<td>7.3</td>
<td>12.6</td>
<td>2.68 (1.04-6.87)</td>
<td>1.78 (0.72-4.42)</td>
<td>0.75 (0.34-1.65)</td>
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</tbody>
</table>
The Global Burden of Disease (GBD)

- A systematic scientific effort to quantify the magnitude of health loss from disease and injuries in 195 countries around the world from 1990 to 2015
  - E.g. cardiovascular disease, respiratory disease, HIV-AIDS, cancer, road traffic injuries, others
- Risks factors associated with those diseases
  - E.g. smoking, diet, high blood pressure, air pollution, overweight
- Organized by the Institute for Health Metrics and Evaluation (IHME), U Washington
- HEI leadership for outdoor air pollution

“The latest estimates and analyses from the Global Burden of Disease Study 2015 (GBD 2015) provide a vital link...”
- Dr. Srinath Reddy, PHFI, Lancet October 2016
A global study with a global network of investigators: 1,656 investigators, 119 countries
Changes in Life-Expectancy at Birth 1970-2015

Good news: Longer lives worldwide
But, more people dying from diseases of aging
First Step: Estimating 2015 Global Average PM$_{2.5}$
Enhanced ground monitoring and other data leading to higher quality estimates
GBD 2015: Growing Number of Measurements in East and South Asia

<table>
<thead>
<tr>
<th>Country</th>
<th>PM2.5</th>
<th>PM10</th>
<th>PM2.5</th>
<th>PM10</th>
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<tr>
<td>China</td>
<td>96</td>
<td>312</td>
<td>1035</td>
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<tr>
<td>India</td>
<td>14</td>
<td>186</td>
<td>14 (+8)</td>
<td>357</td>
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<tr>
<td>Bangladesh</td>
<td>4</td>
<td>3</td>
<td>11</td>
<td>1</td>
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<td>Pakistan</td>
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<td>Nepal</td>
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<td>Bhutan</td>
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<td>Afghanistan</td>
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</table>
Second Step: 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
  - Chronic obstructive lung disease (COPD)
  - Lung cancer
  - Lower respiratory infection (Age 0 – 5)

- Four of Five are Diseases of Aging...
The Growing Number of Ambient Air Pollution Adult Mortality Studies - from Asia, Europe, North America - provide key links between PM and Premature Mortality

<table>
<thead>
<tr>
<th>Study</th>
<th>PM$_{2.5}$ Mean 14.2</th>
<th>PM$_{2.5}$ Min 5.8</th>
<th>PM$_{2.5}$ 95% 8.8/20.0</th>
<th>IHD HR 1.26 (1.16-1.38)</th>
<th>CEV HR 1.12 (1.01-1.24)</th>
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<td>2.1</td>
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<td>1.05 (1.05-1.43)</td>
<td>1.04 (0.93-1.16)</td>
<td>1.24 (1.01-1.79)</td>
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<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)</td>
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<td>Agricultural Health Study*</td>
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<td>0.75 (0.34-1.65)</td>
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</table>
GBD 2015 Integrated Exposure Response Functions
Linking PM Exposure to Health

Heart Disease
Lung Disease
Stroke
Lower Respiratory Infections
Percent of total deaths in 2015 attributable to ambient PM$_{2.5}$
India and China: Greater than 9% of all deaths

http://vizhub.healthdata.org/gbd-compare/
Third Step: Comparing Air Pollution to All Other Risks

GBD 2015 Premature Deaths:
Air Pollution among top-ranked *global* risk factors

Outdoor PM contributed to 4.2 million premature deaths

Air pollution combined - *ambient plus household* - contributed to 10% of global mortality in 2015 – the 4\textsuperscript{rd} ranked global risk factor
India GBD 2015:
Premature Deaths attributable to combined risk factors

In India: Indoor and outdoor combined are now the 2nd highest risk factor
India: Deaths attributable to all Risk Factors 2015
Ambient PM Ranks 3\textsuperscript{rd} overall, contributing to 1.1 million premature deaths each year

Both Ambient PM (3\textsuperscript{rd}) and Household Air Pollution (4\textsuperscript{th}) are significant contributors to health burden

GBD 2015 The Lancet 7 October 2016
A Fourth Step: Understanding Health Burdens from Different Sources to Achieve Cleaner Air
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. transport, biomass, coal)
  - China, India, Eastern Europe, in a global context
  - Using GBD methods, data
  - At national, provincial levels
- In partnership with leading Chinese, Indian partners (Tsinghua, IIT-B, others)

Underway now; China results published August 2016; India in Spring 2017

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GBD MAPS International Steering Committee

Dan Greenbaum / Bob O’Keefe  
Health Effects Institute  

Terry Keating  
US EPA  

Hao Jiming  
Tsinghua University  

Yang Gonghuan  
Peking Union Medical College  

Christopher Murray  
IHME  

Majid Ezzati  
Imperial College, London  

K Srinath Reddy  
Public Health Foundation of India, Delhi  

Michal Krzyzanowski  
Kings College, London  

Greg Carmichael  
WMO/U Iowa
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

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**GBD-MAPS general methodology**

- Estimate major source contribution to ambient PM$_{2.5}$
- Calculate emissions from all major sources

- $f_{\text{source}} \times$ ambient PM$_{2.5} =$ ambient PM$_{2.5}$ attributable to each source

- Use integrated exposure response functions and cause-specific mortality estimates in combination with PM$_{2.5}$ source = source contribution to disease burden
GBD MAPS:
Estimate of India source primary emission contributions to ambient PM$_{2.5}$ using latest available information on current emissions (2013)

![Bar chart showing emissions for PM$_{2.5}$, SO$_2$, NO$_x$, and NMVOC categories with various sources and activities represented by different colors and labels.](chart.png)
Spatial Extent of Source Emission Estimates

Power, Industry

Transport, Brick Kilns
2015 Annual Average PM$_{2.5}$

Emission factors will then be applied to estimate Indian source-specific population exposure.
GBD 2015 Integrated Exposure Response Functions
Linking PM Exposure to Health

1.0
1.5
2.0
2.5
3.0

0 25 50 75 100 125
PM2.5
RR
age
25
50
80
Cardiovascular...Diseases
1.2
1.6
2.0
0 25 50 75 125
PM2.5
RR
cause
ALRI
Lower Respiratory Disease

Heart Disease
Lung Disease
Stroke
Lower Respiratory Infections

Submitted
Looking Forward:
GBD MAPS will project Business as Usual and Modest and Advance Control scenarios for all sources through 2050

Peer-Reviewed Final GBD MAPS India results in April 2017
The Special Case of Traffic Sources
Traffic Related Air Pollution & Health: An Expert HEI Review 2010

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 2017 (10 more years of data)
  • Initiating new Studies of traffic and health
The Traffic Impact Area in Delhi:

HEI Analysis: 55% of the Population within 500 meters of a Freeway; 50 meters of a Major Road
A Key Challenge: Old Diesel

• Primary health concern: effects on the heart from exposure to **Particulate Matter (PM)** from older diesel
  • Significant effects on mortality, life expectancy
  • Strong evidence of respiratory effects: reduced lung function, respiratory irritation, asthma exacerbation

• IARC (WHO) Review of diesel carcinogenicity (2012)
  • Diesel a “Known Human Carcinogen”
  • Based on Two Major Occupational Studies (reviewed in HEI 2015 Special Report):
    • US Diesel Exposed Miners Study (DEMS)
    • US Truckers Study

• Exposure to older diesel pervasive in much of the world

Epidemiologic Studies

US 2007, 2010 engines
And Now:

Evidence that Traffic Actions Can Improve Health!

Los Angeles Then and Now

Source: New York Times
With major vehicle fuel and emissions rules, Air Quality Improved
Cleaner Air and Improved Lung Health

- Tracked growth in Lung Function in 3 “cohorts” (2,100 children total) in Southern California 1994 – 2011
- Saw notable improvement in lung function in the most recent cohort (who grew up 2007 – 2011 in cleaner air)
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 2015 includes new approaches to exposure and exposure-response

• Actions beginning in India:
  • AQI, BS VI Leapfrog, thermal power plants standards

• Source-specific impacts are likely to best inform and drive future control measures
  • GBD MAPS Report for India in Spring 2017
  • New Traffic Review and Studies

Trusted Science • Cleaner Air • Better Health
Thank You!

Dan Greenbaum
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