Global and South Asian Burdens of Disease from Household Air Pollution: the GBD 2010 Study

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Kathmandu, Nepal
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Expert Group

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- With much help from Majid Ezzati, Imperial/GBD; and Aaron Cohen, HEI
Definitions

- Global Burden of Disease (GBD)
  - Envelope of death, illness, and injury by age, sex, and region.
  - Coherent – no overlap – one death has one cause

- Comparative Risk Assessment (CRA)
  - The amount of the GBD due to a particular risk factor, e.g. smoking
  - Not coherent – deaths can be prevented by several means
GBD 2010

• The global burden of diseases, injuries, and risk factors 2010 (GBD) Study examines 3 major disease groups (communicable diseases, non-communicable diseases and injuries), with 1045 specific outcomes/sequelae of 235 causes of death.

• 21 regions
• 1990 and 2010
• 20 age groups.
• Associated CRA addresses more than 60 risk factors, including household air pollution
GBD 2010

- Involves hundreds of experts working on epidemiology and exposures related to specific diseases, injuries, and risk factors.
- Core group brings the pieces together in common analytical frameworks.
- Coordinated by the Institute for Health Metrics and Evaluation at the University of Washington.
- Unlike previous efforts, the WHO was not involved in the core group at the end.
Metrics

• Mortality – important, but can be misleading as it does not take age into account or years of illness/injury
  – Death at 88 years counts same as at 18, which is not appropriate

• Disability-adjusted Life Years (DALYs) lost do account for age and illness.

• GBD 2010 compares deaths against best life expectancy in world – 86 years

• Much improved method for determining severity weights for diseases and injuries
Leading causes of global disease burden, 1990 and 2010

<table>
<thead>
<tr>
<th>Mean rank (95% UI)</th>
<th>Disorder</th>
<th>1990</th>
<th>Disorder</th>
<th>Mean rank (95% UI)</th>
<th>% change (95% UI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-0 (1 to 2)</td>
<td>Lower respiratory infections</td>
<td>1990: 1</td>
<td>Ischaemic heart disease</td>
<td>1-0 (1 to 2)</td>
<td>29 (22 to 34)</td>
</tr>
<tr>
<td>2-0 (1 to 2)</td>
<td>Diarrhoea</td>
<td>1990: 2</td>
<td>Lower respiratory infections</td>
<td>2-0 (1 to 3)</td>
<td>-44 (-48 to -39)</td>
</tr>
<tr>
<td>3-4 (3 to 5)</td>
<td>Preterm birth complications</td>
<td>1990: 3</td>
<td>Stroke</td>
<td>3-2 (2 to 5)</td>
<td>19 (5 to 26)</td>
</tr>
<tr>
<td>3-8 (3 to 5)</td>
<td>Ischaemic heart disease</td>
<td>1990: 4</td>
<td>Diarrhoea</td>
<td>4-9 (4 to 8)</td>
<td>-51 (-57 to -45)</td>
</tr>
<tr>
<td>5-2 (4 to 6)</td>
<td>Stroke</td>
<td>1990: 6</td>
<td>COPD</td>
<td>6-1 (3 to 11)</td>
<td>45 (34 to 53)</td>
</tr>
<tr>
<td>6-3 (5 to 8)</td>
<td>COPD</td>
<td>1990: 7</td>
<td>Low back pain</td>
<td>6-7 (3 to 11)</td>
<td>43 (34 to 53)</td>
</tr>
<tr>
<td>8-0 (6 to 13)</td>
<td>Malaria</td>
<td>1990: 8</td>
<td>Preterm birth complications</td>
<td>8-0 (5 to 11)</td>
<td>27 (-37 to -16)</td>
</tr>
<tr>
<td>9-9 (7 to 13)</td>
<td>Tuberculosis</td>
<td>1990: 10</td>
<td>Ischemic heart disease</td>
<td>10-1 (7 to 15)</td>
<td>-17 (-30 to -1)</td>
</tr>
<tr>
<td>10-2 (7 to 14)</td>
<td>Protein-energy malnutrition</td>
<td>1990: 11</td>
<td>COPD</td>
<td>10-1 (7 to 15)</td>
<td>-17 (-30 to -1)</td>
</tr>
<tr>
<td>10-3 (7 to 15)</td>
<td>Neonatal encephalopathy*</td>
<td>1990: 12</td>
<td>Road injury</td>
<td>12-1 (8 to 16)</td>
<td>-2 (-8 to 5)</td>
</tr>
<tr>
<td>11-3 (7 to 17)</td>
<td>Low back pain</td>
<td>1990: 13</td>
<td>Major depressive disorder</td>
<td>12-1 (8 to 16)</td>
<td>-17 (-30 to -1)</td>
</tr>
<tr>
<td>11-8 (8 to 15)</td>
<td>Road injury</td>
<td>1990: 14</td>
<td>Neonatal encephalopathy*</td>
<td>12-1 (8 to 16)</td>
<td>-17 (-30 to -1)</td>
</tr>
<tr>
<td>12-9 (8 to 16)</td>
<td>Congenital anomalies</td>
<td>1990: 15</td>
<td>Tuberculosis</td>
<td>12-1 (8 to 16)</td>
<td>-17 (-30 to -1)</td>
</tr>
<tr>
<td>15-0 (8 to 18)</td>
<td>Iron-deficiency anaemia</td>
<td>1990: 16</td>
<td>Diabetes</td>
<td>15-0 (8 to 18)</td>
<td>69 (58 to 77)</td>
</tr>
<tr>
<td>15-2 (11 to 18)</td>
<td>Major depressive disorder</td>
<td>1990: 17</td>
<td>Iron-deficiency anaemia</td>
<td>15-2 (11 to 18)</td>
<td>-3 (-6 to -1)</td>
</tr>
<tr>
<td>15-3 (3 to 36)</td>
<td>Measles</td>
<td>1990: 18</td>
<td>Neuronal deficiency anaemia</td>
<td>15-3 (3 to 36)</td>
<td>-3 (-6 to -1)</td>
</tr>
<tr>
<td>15-4 (8 to 24)</td>
<td>Neonatal sepsis</td>
<td>1990: 19</td>
<td>Congenital anomalies</td>
<td>15-4 (8 to 24)</td>
<td>-28 (-43 to -9)</td>
</tr>
<tr>
<td>17-3 (15 to 19)</td>
<td>Meningitis</td>
<td>1990: 20</td>
<td>Meningitis</td>
<td>17-3 (15 to 19)</td>
<td>-28 (-43 to -9)</td>
</tr>
<tr>
<td>20-0 (17 to 26)</td>
<td>Self-harm</td>
<td>1990: 21</td>
<td>Self-harm</td>
<td>20-0 (17 to 26)</td>
<td>-42 (-51 to -33)</td>
</tr>
<tr>
<td>20-1 (8 to 26)</td>
<td>Drowning</td>
<td>1990: 22</td>
<td>Neck pain</td>
<td>20-1 (8 to 26)</td>
<td>42 (28 to 55)</td>
</tr>
<tr>
<td>21-1 (8 to 25)</td>
<td>Diabetes</td>
<td>1990: 23</td>
<td>Lung cancer</td>
<td>21-1 (8 to 25)</td>
<td>36 (18 to 47)</td>
</tr>
<tr>
<td>24-1 (19 to 30)</td>
<td>Cirrhosis</td>
<td>1990: 24</td>
<td>Cirrhosis</td>
<td>24-1 (19 to 30)</td>
<td>28 (19 to 36)</td>
</tr>
<tr>
<td>24-3 (19 to 32)</td>
<td>Lung cancer</td>
<td>1990: 25</td>
<td>Others musculoskeletal disorders</td>
<td>24-3 (19 to 32)</td>
<td>50 (43 to 57)</td>
</tr>
<tr>
<td>25-1 (18 to 34)</td>
<td>Neck pain</td>
<td>1990: 26</td>
<td>Meningitis</td>
<td>25-1 (18 to 34)</td>
<td>-22 (-32 to -12)</td>
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<td>25-3 (18 to 34)</td>
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<td>1990: 27</td>
<td>Meningitis</td>
<td>25-3 (18 to 34)</td>
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</tr>
</tbody>
</table>

Note: * denotes conditions with a substantial increase in burden. ** denotes conditions with a substantial decrease in burden.
### DALYs, South Asia, by Disease

<table>
<thead>
<tr>
<th>1990</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Diarrheal diseases</td>
<td>1 Lower respiratory infections</td>
</tr>
<tr>
<td>2 Lower respiratory infections</td>
<td>2 Preterm birth complications</td>
</tr>
<tr>
<td>3 Preterm birth complications</td>
<td>3 Diarrheal diseases</td>
</tr>
<tr>
<td>4 Tuberculosis</td>
<td>4 Ischemic heart disease</td>
</tr>
<tr>
<td>5 COPD</td>
<td>5 COPD</td>
</tr>
<tr>
<td>6 Protein-energy malnutrition</td>
<td>6 Neonatal encephalopathy</td>
</tr>
<tr>
<td>7 Neonatal sepsis</td>
<td>7 Tuberculosis</td>
</tr>
<tr>
<td>8 Neonatal encephalopathy</td>
<td>8 Neonatal sepsis</td>
</tr>
<tr>
<td>9 Iron-deficiency anemia</td>
<td>9 Low back pain</td>
</tr>
<tr>
<td>10 Ischemic heart disease</td>
<td>10 Iron-deficiency anemia</td>
</tr>
<tr>
<td>15 Low back pain</td>
<td>18 Protein-energy malnutrition</td>
</tr>
</tbody>
</table>
Over 5 Deaths by Cause (Nepal, 2010)

- Ischemic heart disease
- COPD
- Cerebrovascular disease
- Tuberculosis
- Acute Lower Respiratory Infections
- Self-harm
- HIV/AIDS
- Diarrheal diseases
- Diabetes mellitus
- Cirrhosis of the liver

# of Deaths


CRA published along with the other GBD papers on Dec 14, 2012 in The Lancet
CRA of the GBD 2010 – risks quantified

Unimproved water and sanitation
  Unimproved water
  Unimproved sanitation

Air pollution
  Ambient particulate matter pollution
  Household air pollution from solid fuels
  Second-hand cooksmoke
  Ambient ozone pollution

Other environmental risks
  Residential radon
  Lead exposure

Child and maternal undernutrition
  Suboptimal breastfeeding
    Non-exclusive breastfeeding
    Discontinued breastfeeding
  Childhood underweight
  Iron deficiency
  Vitamin A deficiency
  Zinc deficiency

Tobacco smoking and secondhand smoke
  Tobacco smoking
  Second-hand smoke

Alcohol and other drugs
  Alcohol use
  Drug use (opioids, cannabis, amphetamines)

Physiological risks for chronic diseases
  High fasting plasma glucose
  High total cholesterol
  High systolic blood pressure
  High body mass index
  Low bone mineral density

Sexual abuse and violence
  Childhood sexual abuse
  Intimate partner violence
### CRA of the GBD 2010 – (cont)

<table>
<thead>
<tr>
<th><strong>Dietary risk factors and physical inactivity</strong></th>
<th><strong>Occupational exposures</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diet low in fruits</td>
<td>Occupational exposure to asbestos</td>
</tr>
<tr>
<td>Diet low in vegetables</td>
<td>Occupational exposure to arsenic</td>
</tr>
<tr>
<td>Diet low in whole grains</td>
<td>Occupational exposure to benzene</td>
</tr>
<tr>
<td>Diet low in nuts/seeds</td>
<td>Occupational exposure to beryllium</td>
</tr>
<tr>
<td>Diet low in milk</td>
<td>Occupational exposure to cadmium</td>
</tr>
<tr>
<td>Diet high in unprocessed red meat</td>
<td>Occupational exposure to chromium</td>
</tr>
<tr>
<td>Diet high in processed meat</td>
<td>Occupational exposure to diesel</td>
</tr>
<tr>
<td>Sugar-sweetened beverages</td>
<td>Occupational exposure to formaldehyde</td>
</tr>
<tr>
<td>Diet low in fibre</td>
<td>Occupational exposure to nickel</td>
</tr>
<tr>
<td>Diet low in calcium</td>
<td>Occupational exposure to PAHs</td>
</tr>
<tr>
<td>Diet low in seafood omega-3</td>
<td>Occupational exposure to secondhand smoke</td>
</tr>
<tr>
<td>Diet low in polyunsaturated fatty acid (PUFA)</td>
<td>Occupational exposure to silica</td>
</tr>
<tr>
<td>Diet high in trans fatty acids</td>
<td>Occupational exposure to sulfuric acid</td>
</tr>
<tr>
<td>Diet high in sodium</td>
<td>Occupational exposure to asthmagens</td>
</tr>
<tr>
<td>Physical inactivity and low physical activity</td>
<td>Occupational exposure to particulates and gases</td>
</tr>
<tr>
<td></td>
<td>Occupational noise</td>
</tr>
<tr>
<td></td>
<td>Occupational risk factors for injury</td>
</tr>
<tr>
<td></td>
<td>Occupational low back pain</td>
</tr>
</tbody>
</table>
Global DALYs 2010: Top 20 Risk Factors

Premature Deaths
HBP - 9.3 million
Alcohol – 7.7
Tobacco – 5.7
SHS-T – 0.6
House AP – 3.5
SHS-C – 0.5
High BMI – 3.4
Phys Inactive – 3.2
Outdoor AP – 3.3
High Sodium – 3.1
DALYS: South Asia by Risk Factor

1990

1. Childhood underweight
2. Household air pollution
3. Suboptimal breastfeeding
4. Smoking
5. Iron deficiency
6. Ambient PM pollution
7. High blood pressure
8. Low fruit
9. Sanitation
10. Alcohol use
11. High fasting plasma glucose

2010

1. Household air pollution
2. Smoking
3. High blood pressure
4. Childhood underweight
5. Low fruit
6. Ambient PM pollution
7. High fasting plasma glucose
8. Iron deficiency
9. Alcohol use
10. Suboptimal breastfeeding
11. Sanitation
HAP in India in 2010
~900 thousand annual premature deaths
About one-quarter of global total

Secondhand cooksmoke
~150 thousand more

About 10% of national mortality
About the same as tobacco

In Nepal, this would be about 30,000
Comparative Risk Assessment Method

Exposure Levels: Past actual and past counterfactual

Exposure-response Relationships (risk)

Disease Burden by age, sex, and region

Attributable Burden by age, sex, and region
The framing

- Household air pollution from use of solid fuels for cooking
- Exposure based on percent of households using biomass or coal as their primary cooking fuel
- Country models informed now by ~600 nationally representative household surveys over 20+ years.
- Much less confusion with space heating, but not perfectly separated
Percent of households cooking with solid fuels by region

Bonjour et al., GBD-2010
Total Population Cooking with Solid Fuels

Bonjour et al., CRA-2010
Nepal’s Biomass Use for Cooking

- 2010: 82%
  - Bangladesh 91%
  - India 58%
  - Pakistan 64%

- Trends since 1980 in Nepal
  - Number of people increasing each year – shift to modern fuels occurring slower than population growth
Framing, cont

• Five major diseases now accepted to be caused by HAP

• Adults
  – Lung cancer
  – Chronic obstructive pulmonary disease
  – Cataracts
  – Cardiovascular disease - CVD

• Pneumonia in children
Framing, cont

- Two – COPD and cataracts -- use studies of health by fuel type for risk estimates
- CVD, lung cancer, and child pneumonia rely on risks determined by exposures derived from national model using 600+ household measurements in India & Bangladesh
- India itself not a small sample as it has more than one-quarter of the world total.
- Assumption is that rest of world, on average, similar.
Framing, cont.

• Not called “indoor” because stove smoke enters atmosphere to become part of general outdoor air pollution (OAP)
• HAP contributes about 16% to OAP globally, but much more in some countries
• Thus, part of the burden of disease due to OAP is attributable to cooking fuels in households ~500,000 premature deaths.
25-30% of primary particle pollution in India is from household fuels.

Framing, cont.

• Much effort made to make estimates consistent across the four combustion particle groups in the new GBD/CRA

• Active tobacco smoking, household air pollution, secondhand tobacco smoking, and outdoor air pollution

• HAP and OAP use the same counterfactual level for nearly all diseases: ~7 ug/m3 annual mean PM2.5 concentration

• Roughly equivalent to cooking with a vented gas stove or electricity
New Category of Evidence for CVD

- No direct studies of CVD and HAP, yet
  - But studies showing effects on blood pressure and ST-segment, important disease signs
- Epidemiologic evidence shows clear, consistent evidence of increasing risk across exposures to combustion particles
  - at higher exposures – Active smoking
  - and lower exposures – Outdoor air pollution and secondhand tobacco smoke
Heart Disease and Combustion Particle Doses

From “Mind the Gap,” Smith/Peel, 2010 and Pope et al., 2009
Chimney Stove Intervention to Reduce Long-term Wood Smoke Exposure Lowers Blood Pressure among Guatemalan Women

John P. McCracken,1,2 Kirk R. Smith,3 Anaité Diaz,4 Murray A. Mittleman,1,5 and Joel Schwartz1,2

Indoor Air Pollution and Blood Pressure in Adult Women Living in Rural China

Jill Baumgartner,1,2,3 James J. Schauer,3,4 Majid Ezzati,5 Lin Lu,6 Chun Cheng,6 Jonathan A. Patz,2,3,7 and Leonelo E. Bautista2

Intervention to Lower Household Wood Smoke Exposure in Guatemala Reduces ST-Segment Depression on Electrocardiograms

John McCracken,1,2 Kirk R. Smith,2 Peter Stone,3 Anaité Diaz,4 Byron Arana,4 and Joel Schwartz1
Integrated Exposure-Response: Outdoor Air, SHS, and Smoking and Heart Disease

CRA, 2011
Integrated Exposure-Response: Outdoor Air, SHS, and HAP

Pneumonia from combustion particles

Annual average PM2.5 in ug/m3

Annual Incidence

Outdoor Air Pollution

Secondhand Tobacco Smoke

HAP Zone

CRA, 2010
Inform decision making by providing information on:

- Exposure levels needed to deliver substantial health benefits
- Performance of intervention options:
  - HAP/exposure
  - Health risk

WHO air quality annual guideline: 10 µg/m³
IT1: 35 µg/m³

Exposure-response relationship

PM2.5 Exposure

LPG 25
Fan
Chimney/Rocket 125
‘Simple’ improved 200
O/Fire 300 µg/m³

Child pneumonia

Risk

1 2 3

Exposure levels:

- LPG: 25 µg/m³
- Fan: 25 µg/m³
- Chimney/Rocket: 125 µg/m³
- ‘Simple’ improved: 200 µg/m³
- O/Fire: 300 µg/m³

Public health and environment

Exposure-response relationship

36

Risk

1 2 3

WHO air quality annual guideline: 10 µg/m³
IT1: 35 µg/m³
Bottom Lines

• One of the top risk factors in the world for ill-health.
• And in South Asia
• Most important environmental risk factor among all examined
• Biggest impact in adults --3 million premature deaths (two-thirds the DALYs)
• Still important for children ~500,000 deaths (one-third the DALYs)
• Important source of outdoor air pollution
• Impact going down slowly because background health conditions improving
• Actual number of people affected is not going down
Not all diseases included

• Many with evidence not included yet
  – Low birth weight
  – TB
  – Other cancers – cervical, upper respiratory, etc
  – Cognitive effects
  – Pneumonia in adults

• Can expect that HAP effects, over time, will be found for nearly all the many dozen diseases found for smoking.

• But at lower risk levels
Caveats

• Not all important risk factors were included in the GBD analysis, e.g.
  – None for malaria, HIV, child vaccinatable diseases, or road traffic accidents
• Portions of HAP CRA still under journal review – will likely be some changes
• Implied health benefit from HAP reduction only potentially achieved by shifting to clean cooking – gas & electricity
Bhaktapur Study of HAP and Child Pneumonia

- 917 children (452 cases and 465 controls) were recruited into the study in 2006.
- Division of primary fuel use for cooking was almost equally divided among biomass, LPG, kerosene, and electricity.
- High-quality pneumonia (ALRI) surveillance conducted by associated randomized trial for zinc supplementation
Bhaktapur study, cont.

• Accepted for publication last Friday, Jan 11 in *Environmental Health Perspectives*


• Berkeley, Norway, Denmark, and Child Health Department, Institute of Medicine, Tribhuvan University
Bhaktapur results

• Compared to use of electricity for cooking, use of biomass-burning primary stoves was associated with a 65% increase in ALRI
• Cooking with kerosene associated with a 73% increase
• Based on this, about 11% of the ALRI in the population is due to biomass cooking
• And 12% due to kerosene used for cooking.
First person in human history to have her exposure measured doing the oldest task in human history

Kheda District
Gujarat, 1981

Many thanks

Publications and presentations at my website – google Kirk R. Smith