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

Kirk R. Smith, MPH, PhD
UC Berkeley
Chair of the HAP Expert Group

Indian Institute of Technology
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Expert Group

- UC Berkeley: Kirk R. Smith, Heather Adair (WHO), Zoe Chafe, Michael Bates, Maureen Lahiff, Seth Shonkoff, Ray Lui, Jimmy Tran
- UC San Francisco: John Balmes
- Stanford: Sara Stern-Nezer
- World Bank: Doug Barnes
- UN Pop Division/DESA: Vinod Mishra
- HEI/GACC: Sumi Mehta
- NCI: Qing Lan, Dean Hosgood
- IARC: Kurt Straif
- UBC: Michael Brauer
- IIASA: Zig Klimont
- JRC: Rita Van Dingenen
- U of Liverpool: Nigel Bruce (WHO), Dan Pope, Mukesh Dherani, Imran Choudhury
- University of Munich: Eva Rehfues
- WHO: Annette Preuss, Sophie Bonjour
- Sri Ramachandra University: Kalpana Balakrishnan, Santu Ghosh, Sankar Sambandam, Guruswamy Thangavel
- Peking University: Jinliang Zhang, Xiaoli Duan
- Universidad Peruana de Ciencias Aplicadas: Claudio Lanata
- 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>Disorder</th>
<th>1990 Rank (95% UI)</th>
<th>2010 Rank (95% UI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Lower respiratory infections</td>
<td>1-0 (1 to 2)</td>
<td>1-0 (1 to 2)</td>
</tr>
<tr>
<td>2 Diarrhoea</td>
<td>2-0 (1 to 2)</td>
<td>2-0 (1 to 3)</td>
</tr>
<tr>
<td>3 Preterm birth complications</td>
<td>3-4 (3 to 5)</td>
<td>3-2 (2 to 5)</td>
</tr>
<tr>
<td>4 Ischaemic heart disease</td>
<td>3-8 (3 to 5)</td>
<td>4-9 (4 to 8)</td>
</tr>
<tr>
<td>5 Stroke</td>
<td>5-2 (4 to 6)</td>
<td>5-1 (-57 to -45)</td>
</tr>
<tr>
<td>6 COPD</td>
<td>6-3 (5 to 8)</td>
<td>6-7 (3 to 11)</td>
</tr>
<tr>
<td>7 Malaria</td>
<td>8-0 (6 to 13)</td>
<td>6-7 (3 to 11)</td>
</tr>
<tr>
<td>8 Tuberculosis</td>
<td>9-9 (7 to 13)</td>
<td>6-7 (3 to 11)</td>
</tr>
<tr>
<td>9 Protein-energy malnutrition</td>
<td>10-2 (7 to 14)</td>
<td>6-7 (3 to 11)</td>
</tr>
<tr>
<td>10 Neonatal encephalopathy*</td>
<td>10-3 (7 to 15)</td>
<td>10-8 (7 to 14)</td>
</tr>
<tr>
<td>11 Low back pain</td>
<td>11-3 (7 to 17)</td>
<td>10-8 (7 to 14)</td>
</tr>
<tr>
<td>12 Road injury</td>
<td>11-8 (8 to 15)</td>
<td>10-8 (7 to 14)</td>
</tr>
<tr>
<td>13 Congenital anomalies</td>
<td>12-9 (8 to 16)</td>
<td>10-8 (7 to 14)</td>
</tr>
<tr>
<td>14 Iron-deficiency anaemia</td>
<td>15-0 (8 to 18)</td>
<td>15-2 (11 to 18)</td>
</tr>
<tr>
<td>15 Major depressive disorder</td>
<td>15-2 (11 to 18)</td>
<td>15-2 (11 to 18)</td>
</tr>
<tr>
<td>16 Measles</td>
<td>15-3 (3 to 36)</td>
<td>15-2 (11 to 18)</td>
</tr>
<tr>
<td>17 Neonatal sepsis</td>
<td>15-4 (8 to 24)</td>
<td>15-2 (11 to 18)</td>
</tr>
<tr>
<td>18 Meningitis</td>
<td>17-3 (15 to 19)</td>
<td>15-2 (11 to 18)</td>
</tr>
<tr>
<td>19 Self-harm</td>
<td>18-3 (19 to 28)</td>
<td>15-2 (11 to 18)</td>
</tr>
<tr>
<td>19 Falls</td>
<td>19-7 (16 to 25)</td>
<td>15-2 (11 to 18)</td>
</tr>
<tr>
<td>19 Protein-energy malnutrition</td>
<td>20-0 (10 to 26)</td>
<td>15-2 (11 to 18)</td>
</tr>
<tr>
<td>19 Other musculoskeletal disorders</td>
<td>20-7 (18 to 26)</td>
<td>15-2 (11 to 18)</td>
</tr>
<tr>
<td>20 Drowning</td>
<td>20-7 (18 to 26)</td>
<td>15-2 (11 to 18)</td>
</tr>
<tr>
<td>20 Diabetes</td>
<td>21-1 (18 to 25)</td>
<td>15-2 (11 to 18)</td>
</tr>
<tr>
<td>21 Falls</td>
<td>21-1 (18 to 25)</td>
<td>15-2 (11 to 18)</td>
</tr>
<tr>
<td>23 Cirrhosis</td>
<td>23-1 (21 to 30)</td>
<td>23-0 (19 to 27)</td>
</tr>
<tr>
<td>24 Lung cancer</td>
<td>24-1 (21 to 30)</td>
<td>23-0 (19 to 27)</td>
</tr>
<tr>
<td>25 Neck pain</td>
<td>25-1 (20 to 32)</td>
<td>23-0 (19 to 27)</td>
</tr>
<tr>
<td>26 Other musculoskeletal disorders</td>
<td>25-3 (18 to 34)</td>
<td>23-0 (19 to 27)</td>
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<tr>
<td>27 Meningitis</td>
<td>25-3 (18 to 34)</td>
<td>23-0 (19 to 27)</td>
</tr>
<tr>
<td>28 Unintentional injuries</td>
<td>27-3 (18 to 34)</td>
<td>23-0 (19 to 27)</td>
</tr>
<tr>
<td>29 Other musculoskeletal disorders</td>
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<td>30 Meningitis</td>
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<td>32 Drowning</td>
<td>25-3 (18 to 34)</td>
<td>23-0 (19 to 27)</td>
</tr>
<tr>
<td>33 HIV/AIDS</td>
<td>25-3 (18 to 34)</td>
<td>23-0 (19 to 27)</td>
</tr>
<tr>
<td>34 Measles</td>
<td>25-3 (18 to 34)</td>
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</tbody>
</table>

Legend:
- Red: Communicable, maternal, neonatal, and nutritional disorders
- Blue: Non-communicable disorders
- Green: Injuries

Ascending order in rank

Descending order in rank

% change (95% UI)
<table>
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</tr>
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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
Dietary risk factors and physical inactivity

- Diet low in fruits
- Diet low in vegetables
- Diet low in whole grains
- Diet low in nuts/seeds
- Diet low in milk
- Diet high in unprocessed red meat
- Diet high in processed meat
- Sugar-sweetened beverages
- Diet low in fibre
- Diet low in calcium
- Diet low in seafood omega-3
- Diet low in polyunsaturated fatty acid (PUFA)
- Diet high in trans fatty acids
- Diet high in sodium
- Physical inactivity and low physical activity

Occupational exposures

- Occupational exposure to asbestos
- Occupational exposure to arsenic
- Occupational exposure to benzene
- Occupational exposure to beryllium
- Occupational exposure to cadmium
- Occupational exposure to chromium
- Occupational exposure to diesel
- Occupational exposure to formaldehyde
- Occupational exposure to nickel
- Occupational exposure to PAHs
- Occupational exposure to secondhand smoke
- Occupational exposure to silica
- Occupational exposure to sulfuric acid
- Occupational exposure to asthmagens
- Occupational exposure to particulates and gases
- Occupational noise
- Occupational risk factors for injury
- Occupational low back pain
Global DALYs 2010: Top 20 Risk Factors

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

Disability-adjusted life-years (%)

-0.5  0  2  4  6  8
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 in South Asia by Risk Factor

<table>
<thead>
<tr>
<th>1990</th>
<th>2010</th>
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<tbody>
<tr>
<td>Childhood underweight</td>
<td>Household air pollution</td>
</tr>
<tr>
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<td>Smoking</td>
</tr>
<tr>
<td>Suboptimal breastfeeding</td>
<td>High blood pressure</td>
</tr>
<tr>
<td>Smoking</td>
<td>Childhood underweight</td>
</tr>
<tr>
<td>Iron deficiency</td>
<td>Low fruit</td>
</tr>
<tr>
<td>Ambient PM pollution</td>
<td>Ambient PM pollution</td>
</tr>
<tr>
<td>High blood pressure</td>
<td>High fasting plasma glucose</td>
</tr>
<tr>
<td>Low fruit</td>
<td>Iron deficiency</td>
</tr>
<tr>
<td>Sanitation</td>
<td>Alcohol use</td>
</tr>
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<td>Sanitation</td>
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</table>
DALYS. South Asia by Risk Factor

1990 - 2010

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
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
Population Cooking with Solid Fuels in 2010 (%)
Percent of households cooking with solid fuels by region

Bonjour et al., GBD-2010
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
Bottom Lines

• One of the top risk factors in the world for ill-health.
• 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
First person in human history to have her exposure measured doing the oldest task in human history

Kheda District
Gujarat, 1981

Many thanks
Funders for HAP CRA
USEPA
Shell Foundation