Household Air Pollution and Chronic Disease in Developing Countries

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What NCD risk factor is shared by all everyone in the bottom two billion?

- Diet (fat, etc.)?
- Physical inactivity (obesity, etc.)?
- Smoking?
- Appropriate infectious agents?

- No, but there is one
- So ubiquitous, in fact, that it is one of the best quick indicators of poverty?
Households using biomass or coal to cook today

Comparative Risk Assessment (CRA) 2011- preliminary,

% of HH Exposed to HAP
- Green: <5
- Orange: 51 - 75
- Yellow: 6 - 20
- Red: 76 - 94
- Light Yellow: 21 - 50
- White: No Data
Distribution of Household Cooking Fuel by Income in India

160 million households

NFHS, 2006
World Population Using Solid Fuels

Million People

World Pop
Solid Fuel Users

0 1000 2000 3000 4000 5000 6000 7000 8000
Biomass Cooking in History

• Today, ~40% use solid fuels, about 2.7 billion people

• Although the percentage is dropping, the absolute number is still rising.

• Perhaps 10-15 million people a year are added to the total each year.

• Indeed, there are more people using solid fuels today for cooking than the total world population in 1950

• Or any year previously
Road Map

• Intro – what’s wrong with biomass smoke?
• COPD – several new meta-analyses
• Lung cancer – new meta-analyses for both biomass and coal smoke [not further discussed].
• Cataracts/opacity – a major burden
• Cardiovascular disease – interpolation backed up by physiological evidence
• “Epidemiologic” transition – do NCD risks rise with development?
Toxic Pollutants in Biomass Fuel Smoke from Simple (poor) Combustion

Organics known to be mutagens, immune system suppressants, severe irritants, inflammation agents, central nervous system depressants, cilia toxins, endocrine disrupters, or neurotoxins.

Several chemicals firmly established as human carcinogens.

Other toxic inorganic chemicals.

- 25+ alcohols and acids such as methanol
- 33+ phenols such as catechol & cresol
- Many quinones such as hydroquinone
- Semi-quinone-type and other radicals
  - Chlorinated organics such as methylene chloride and dioxin

Source: Naeher et al., J Inhal Tox, 2007
First person in human history to have her exposure measured doing the oldest task in human history

Exposures seem to be high in a large vulnerable population. But what are the health effects?

Kheda District, Gujarat, India

1981
Household Air Pollution Comparative Risk Assessment, 2011
Preliminary Estimates for India

Estimated 24-h PM$_{2.5}$ for solid-fuel-using households

~400 ug/m$^3$ mean
EPA standard = 15ug/m$^3$
WHO AQG = 10 ug/3

Balakrishnan et al. forthcoming
Diseases for which we have epidemiological studies - 2011

ALRI/Pneumonia (meningitis)
Low birth weight
Stillbirth
Cognitive Impairment?
Asthma?
Birth defects?

Chronic obstructive lung disease
Cancer (lung, NP, cervical, aero-digestive)
Blindness (cataracts, opacity)
Tuberculosis?
Heart disease*
Blood pressure ST-segment

*Interpolated
Biomass Smoke and COPD: Meta-analysis

- Summary RR estimates calculated using both fixed effects and random effects models
- Heterogeneity among studies assessed using general variance-based methods
- Publication bias assessed using funnel plot, Eggers and Begg’s tests

### Exposure Assessment

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th># of Final Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Only</td>
<td>7</td>
</tr>
<tr>
<td>Wood Only</td>
<td>6</td>
</tr>
<tr>
<td>Stove Type</td>
<td>2</td>
</tr>
<tr>
<td>Years Exposed</td>
<td>5</td>
</tr>
<tr>
<td>Urban v. Rural</td>
<td>2</td>
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</tbody>
</table>

### Outcome Assessment

<table>
<thead>
<tr>
<th>Outcome Assessment</th>
<th># of Final Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Bronchitis, clinical definition</td>
<td>20</td>
</tr>
<tr>
<td>COPD, FEV₁/FVC &lt;0.70</td>
<td>4</td>
</tr>
<tr>
<td>Previous Physician Diagnosis</td>
<td>4</td>
</tr>
</tbody>
</table>
Forest Plot for All Studies Included in Meta-analysis

- Random effects model was used to account for significant heterogeneity between studies $X^2=150.33$, $df=29$ ($p=0.000$)
- Overall effect measure for all studies, OR=2.14 (1.78, 2.58)
Risk of COPD: Vented vs. unvented coal stoves

Xuan Wei County, China, retrospective cohort, 1976-1992, 20,453 subjects, 81% added chimneys

Cataracts

- Major burden of disease in developing countries
- In South Asia, 2.8% of total DALYs in 2005
- Half that of ischaemic heart disease
- Roughly same as TB or stroke
- Greater than COPD or maternal conditions
- Women suffer 40% more than men
Summary of 7 (of 9 total) studies

Studies adjusted for smoking (random effects)

<table>
<thead>
<tr>
<th>Study (year)</th>
<th>ES (95% CI)</th>
<th>Weight</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saha (2005)</td>
<td>2.41 (0.906, 42)</td>
<td>10.23</td>
<td></td>
</tr>
<tr>
<td>Pokhrel (2004)</td>
<td>1.90 (0.99, 3.62)</td>
<td>14.93</td>
<td></td>
</tr>
<tr>
<td>Sreenivas (a) (1999)</td>
<td>0.37 (0.02, 6.69)</td>
<td>1.9</td>
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</tr>
<tr>
<td>Sreenivas (b) (1999)</td>
<td>1.82 (1.14, 2.92)</td>
<td>17.91</td>
<td></td>
</tr>
<tr>
<td>Ughade (1998)</td>
<td>4.14 (2.69, 6.37)</td>
<td>18.58</td>
<td></td>
</tr>
<tr>
<td>Badrinath (1996)</td>
<td>4.90 (2.83, 8.49)</td>
<td>16.57</td>
<td></td>
</tr>
<tr>
<td>Mohan (1989)</td>
<td>1.62 (1.14, 2.30)</td>
<td>19.86</td>
<td></td>
</tr>
<tr>
<td>Overall (I-squared = 71.3%, p = 0.002)</td>
<td>2.45 (1.61, 3.73)</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: Weights are from random effects analysis

Adair, et al., forthcoming
Heart Disease and Combustion Particle Doses

Smith/Peel (2010), “Mind the Gap” based on Pope et al. (2009)
Argument from consistency across combustion particle exposures for CVD

- Fine combustion particles are best measure of risk in each setting and seem to have similar effects per unit mass across the four source types.
- Remarkable consistency across 3 orders of magnitude of dose measured in mg/day of PM$_{2.5}$.
- Where household air pollution has no direct epi data, seems reasonable to interpolate for outcomes where there are well established effects at both lower and higher doses.
Indian National Biomass Cookstove Initiative – Dec 2, 2009

• “Our aim is to achieve the quality of energy services from cookstoves [for all Indian households] comparable to that from other clean energy sources such as LPG.”

Analysis of total health benefits of 150 million advanced stoves introduced over 10 years in India

Health Benefits Upon Completion, 2020

- Remaining ALRI, IHD, COPD DALYs in 2020: 83%
- Avoided DALYs: 17%
- Avoided COPD DALYs: 9%
- Avoided IHD DALYs: 5%
- Avoided ALRI DALYs: 3%
The Classic Epidemiological Transition

Mortality Rates

Time

Infectious Diseases

Non-Communicable Diseases
Epidemiological Transition: All Ages

Communicable
Non-communicable
Injuries

Data from WHO
GBD database

Garcia, 2011
Age-Adjusted Death Rates Compared to USA - 2008

CDs include communicable, maternal, and perinatal causes.
Many thanks

Publications and presentations available at my website:
http://ehs.sph.berkeley.edu/krsmith/

Or just Google “Kirk R. Smith”