Household Air Pollution and Health

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**Framing #1**

- Household air pollution from burning solid fuels for cooking -- counterfactual is usually gaseous fuel
- Also spaceheating and lighting, but not as well documented and not in the burden of disease estimates
- Not called “indoor” because, while cookstove smoke may start in the kitchen, it goes outdoors to expose people in other household locations. Total impact is greater
- Even cooking outdoors causes exposure.
- Problem is creating smoke near people
- After tobacco smoking, household cookfuel sources cause the most global exposure of any one source category
- Also has solutions within single agencies and technology groups
The three major solid fuels
Low- and Middle-Income Countries

More than any time in human history
Use of solid fuels for cooking:

Countries by percent of population living below $3.10 in 2011 PPP dollars. Based on World Bank API data.
Woodsmoke is natural – how can it hurt you?

Or, since wood is mainly just carbon, hydrogen, and oxygen, doesn’t it just change to $\text{CO}_2$ and $\text{H}_2\text{O}$ when it is combined with oxygen (burned)?

Reason: the combustion efficiency is far less than 100%
Toxic Pollutants in Wood Smoke from Simple (poor) Combustion

- Small particles, CO, NO₂
- Hydrocarbons
  - 25+ saturated hydrocarbons such as n-hexane
  - 40+ unsaturated hydrocarbons such as 1,3 butadiene
  - 28+ mono-aromatics such as benzene & styrene
  - 20+ polycyclic aromatics such as benzo(α)pyrene
- Oxygenated organics
  - 20+ aldehydes including formaldehyde & acrolein
  - 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

Typical wood cookfire releases 300 cigarettes per hour worth of smoke

Source: Naehler et al, J Inhal Tox, 2007
Health-Damaging Air Pollutants From Typical Wood-fired Cookstove.

Typical Health-based Standards

Typical Indoor Concentrations

- Carbon Monoxide: 150 mg/m³
  - 10 mg/m³

- Particles: 3.3 mg/m³
  - 0.1 mg/m³

- Benzene: 0.8 mg/m³
  - 0.002 mg/m³

- 1,3-Butadiene: 0.15 mg/m³
  - 0.0003 mg/m³

- Formaldehyde: 0.7 mg/m³
  - 0.1 mg/m³

Wood: 1.0 kg Per Hour in 15 ACH 40 m³ kitchen

Best single indicator
First person in human history to have her exposure measured doing the oldest task in human history

India, 1981

Emissions and concentrations, yes, but what about exposures?

~3000 ug/m³ during cooking
>300 ug/m³ 24-hour
-typical around the world

India, 1981
How much PM$_{2.5}$ is unhealthy?

- **WHO Air Quality Guidelines**
  - 10 µg/m$^3$ annual average - AQG
  - No public microenvironment, indoor or outdoor, should be more than 35 µg/m$^3$ - Interim Target I
  - Health effects exist down to the AQG, however.

- **Important Standards**
  - USA: 12 µg/m$^3$
  - EU: 20 µg/m$^3$
  - China: 35 µg/m$^3$
  - India: 40 µg/m$^3$
Four types of evidence

• Hundreds of epidemiological studies comparing health effects in households using cleaner cooking versus less clean cooking (fuels or stoves)
• For child ALRI – Randomized controlled trials – “improved” stoves
  – Intention to treat (several)
  – Exposure-response study (only one)
• Integrated Exposure-Response Curves for 5 diseases – link across 4 air pollution types using PM$_{2.5}$ exposure
• Biomarkers of disease
<table>
<thead>
<tr>
<th>Study design</th>
<th>N*</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention</td>
<td>2</td>
<td>1.28</td>
<td>1.06, 1.54</td>
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<tr>
<td>Cohort</td>
<td>7</td>
<td>2.12</td>
<td>1.06, 4.25</td>
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<tr>
<td>Case-control</td>
<td>15</td>
<td>1.97</td>
<td>1.47, 2.64</td>
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<tr>
<td>Cross-sectional</td>
<td>3</td>
<td>1.49</td>
<td>1.21, 1.85</td>
</tr>
<tr>
<td>All</td>
<td>26</td>
<td>1.78</td>
<td>1.45, 2.18</td>
</tr>
</tbody>
</table>

# Physician-assessed outcomes (ITT)
(blind to intervention status)

<table>
<thead>
<tr>
<th>Case finding</th>
<th>Outcome</th>
<th>adj RR (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physician diagnosed pneumonia</td>
<td>All</td>
<td>0.78 (0.59, 1.06)</td>
<td>0.095</td>
</tr>
<tr>
<td></td>
<td>Severe (low oxygen)</td>
<td><strong>0.67 (0.45, 0.98)</strong></td>
<td><strong>0.042</strong></td>
</tr>
<tr>
<td>Investigations:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Pulse oximetry</td>
<td><strong>RS Virus</strong></td>
<td>0.76 (0.42, 1.16)</td>
<td>0.275</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>0.87 (0.46, 1.51)</td>
<td>0.633</td>
</tr>
<tr>
<td></td>
<td><strong>No RSV</strong></td>
<td><strong>0.79 (0.53, 1.07)</strong></td>
<td><strong>0.192</strong></td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td><strong>0.54 (0.31, 0.91)</strong></td>
<td><strong>0.026</strong></td>
</tr>
</tbody>
</table>

*Likely bacterial pneumonia
Diseases from HAP with Strong Evidence

ALRI/Pneumonia

Cataracts

Lung cancer

COPD

Heart disease and stroke

These diseases are included in the Comparative Risk Assessment of the Global Burden of Disease
Framing, IER

• Much effort made to make estimates consistent across the four combustion particle groups in the Integrated Exposure-Response Functions
• Active tobacco smoking, household air pollution, secondhand tobacco smoking, and outdoor air pollution
• PM$_{2.5}$ exposure used as link
• HAP risks are determined in comparisons with a vented gas stove or electric cooking
What data feeds the IERs?

- 300 epidemiological studies
  - 78 Outdoor air pollution
  - 49 Household air pollution
  - 68 Second-hand smoke
  - 99 Active smoking

- 62 for Ischaemic Heart Disease
- 44 for Stroke
- 77 for Acute Lower Respiratory Infections
- 27 for Chronic Obstructive Pulmonary Disease
Integrated Exposure-Response: Outdoor Air, SHS, and Smoking and Heart Disease

CRA, 2012
GBD- PM$_{2.5}$ Integrated Exposure-Response Functions

Burnett et al. 2014; Forouzanfar et al. 2015; Cohen et al. 2017
RESPIRE

Outdoor Air Pollution

Secondhand Tobacco Smoke

Burnett et al., EHP. 2014, Integrated Exposure-Response Functions
Growing indirect evidence

- Biomarkers of effect
  - Blood pressure – two dozen studies
  - Heart function – one dozen studies
  - Lung function – two dozen studies - mixed
  - Urinary toxin levels - several
  - Etc.
Summary of CRA results

• One of the top risk factors in the world for ill-health.
• Most important environmental risk factor among all examined, when contribution to ambient air pollution is included
• Impact in adults is a growing fraction
• Still important for children, but pneumonia rates are declining nearly everywhere
• Not currently counted – several diseases, but adverse pregnancy outcomes most important
• Important source of outdoor air pollution
• Much research ongoing, including major multinational RCTs using LPG
Not all diseases yet included

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

• 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
Exposure to HAP associated with 86 g (95%CI: 55.0, 117) reduction in birthweight and a 35% increased odds of low birthweight (OR: 1.35, 95%CI: 1.15, 1.5) (Amegah et al 2014)

Results from the TAPHE cohort in India estimate a \(~80\) gm change associated with longterm biomass use when compared to LPG (Balakrishnan et al 2018)
Satellite-based ambient PM$_{2.5}$

About 30% from households in India and in China based on ~10 independent estimates
Needed

• New full Comparative Risk Assessment with systematic reviews of all diseases, old and new
• Reframing of ambient and household air pollution categories to make them separate and consistent
  – Now, ambient contains substantial contribution from households
  – Misleading as it misses full health benefit for household interventions
• Systematic assessment of major non-disease benefits of clean fuels – particularly time savings.
• Better studies of charismatic outcomes – particularly cognitive effects, e.g. IQ
Many thanks
Publications and presentations on website – easiest to just “google” Kirk R. Smith

Annual Review of Public Health, 2014