Clean Cooking Fuels: What’s the Big Deal?

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The Environmental Health Pathway

SOURCE → EMISSIONS → CONCENTRATION → EXPOSURE → DOSE → HEALTH EFFECTS
The three major solid fuels
The Environmental Health Pathway

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Toxic Pollutants in Biomass Fuel 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: 400 cigarettes an hour worth of PM₂.₅

The Environmental Health Pathway

SOURCE ➔ EMISSIONS ➔ CONCENTRATION ➔ EXPOSURE ➔ DOSE ➔ HEALTH EFFECTS
Health-Damaging Air Pollutants From Typical Wood-fired Cookstove.

Typical Health-based Standards

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

Typical Indoor Concentrations

Best single indicator
The Environmental Health Pathway

SOURCE ➔ EMISSIONS ➔ CONCENTRATION ➔ EXPOSURE ➔ DOSE ➔ HEALTH EFFECTS
First person in human history to have her exposure measured doing the oldest task in human history

~5000 ug/m3 PM during cooking
>500 ug/m3 24-hour

Emissions and concentrations, yes, but what about exposures?

Kheda District, Gujarat, India 1981
The Environmental Health Pathway

SOURCE ➔ EMISSIONS ➔ CONCENTRATION ➔ EXPOSURE ➔ DOSE ➔ HEALTH EFFECTS
How much PM$_{2.5}$ is unhealthy?

- **WHO Air Quality Guidelines**
  - 10 ug/m$^3$ annual average
  - No public microenvironment, indoor or outdoor, should be more than 35 ug/m$^3$

- **USEPA**
  - Was 15 ug/m$^3$ until 2012: annual outdoors
  - Now 12 ug/m$^3$
  - Same as California since ~2000

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 compares deaths against best life expectancy in world – 86 years
Diseases for which we have many epidemiological studies

- ALRI/Pneumonia
- COPD
- Lung cancer
- Blindness (cataracts, opacity)
- Heart disease
  - Blood pressure
  - ST-segment

These diseases are included in the 2010 Comparative Risk Assessment (released in 2012)
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

Million Premature Deaths

Blood Pressure - 9.3
Alcohol – 7.7
Tobacco – 5.7
SHS-T – 0.6
House Air Pol – 3.5
SHS-C – 0.5
Overweight – 3.4
Inactivity – 3.2
Outdoor Air Pol – 3.3
High Sodium – 3.1
### DALYS: South Asia by Risk Factor

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<thead>
<tr>
<th>Risk Factor</th>
<th>1990</th>
<th>2010</th>
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<tbody>
<tr>
<td>1 Childhood underweight</td>
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<td>1 Household air pollution</td>
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<td>2 Household air pollution</td>
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DALYS. South Asia by Risk Factor

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
Global DALYs 2010: Top 20 Risk Factors

1. High blood pressure
2. Tobacco smoking, including second-hand smoke
3. Alcohol use
4. Household air pollution from solid fuels
5. Diet low in fruits
6. High body-mass index
7. High fasting plasma glucose
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15. High total cholesterol
16. Diet low in whole grains
17. Diet low in vegetables
18. Diet low in seafood omega-3 fatty acids
19. Drug use
20. Occupational risk factors for injuries

Heart Disease
The framing

- Household air pollution from use of solid fuels for cooking
- Much less confusion with space heating than before, but not perfectly separated
Population Cooking with Solid Fuels in 2010 (%)

41% globally
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.
Percent Household Sources of all PM$_{2.5}$ Emissions

25-30% of primary particle pollution in India is from household fuels

Urban Beijing – Winter 2013
24-hr PM$_{2.5}$ (Jan 18-19): 334 µg/m$^3$

Source: PM data from US Embassy monitors in Beijing - https://twitter.com/BeijingAir
Photo from AP Images: http://seattletimes.com/html/nationworld/2020288471_chinapollutionxml.html
Rural Site outside Beijing
24-hr PM$_{2.5}$ (Jan 18-19): 695 µg/m$^3$

Source: Mean PM concentration from 2 gravimetrically calibrated DustTrak monitors on rooftops in ErHeZhuang Village, 40 km SW from central Beijing. Photos & measurements in village from Anna Zimmermann (Smith research group).
Important Message #1!

• Implied full health benefit from HAP reduction only potentially achieved by shifting to truly clean cooking – gas & electricity
Integrated Exposure-Response: Outdoor Air, SHS, and HAP

Pneumonia from combustion particles
Annual average PM2.5 in ug/m³
Important Message #2!

- Just because we know it is a risk does not mean that we know how to fix it.
- Think of poor water/sanitation and mosquitoes – 100 years knowing they are risks – still not fixed
- Poor people – no money to be made; no high-tech technologies; unhealthy alternatives are free; behavioral change required
Newborn Stove (NBS) Project

SOMAARTH Surveillance Site – Haryana ~200,000 people

Berkeley, Columbia INCLEN, SRU
NBS Project
Introducing advanced combustion stoves to pregnant women through the official ante-natal care system in India

Monitoring air pollution, usage, and birth outcomes
For behavioral changes like other aspects of HAP studies, you don’t get what you expect, but what you inspect.
What is to be done?

A fresh look
World cooking in Pictograms –

One billion people each

With apologies to Hans Rosling at Gapminder*
*”Magic Washing Machine”

And thanks to Ajay Pillarisetti
What do the richest one billion people cook with?

Gas or electric stoves

Plus
~4 billion worldwide cook with liquified petroleum gas, natural gas, and electricity
What about the other 3 billion?
NON-SMOKING

LPG
Natural Gas
Electricity
MARKET BASED OPTIONS
NON-SMOKING
UNPURCHASED
Wood
Dung
Crop Residues

Not willing or able to join market

Willing & able to join market

PURCHASED
Coal
Kerosene
Charcoal
Wood
Electricity

Consumer & Market Participant

Around half have some access to electricity
SMOKING

UNPURCHASED
NO MARKET ACCESS

UNPURCHASED BUT WILLING TO USE THE MARKET

PURCHASED MARKET USER

NON-SMOKING
Incentives to move to new cooking technologies? Subsidized fuel / capital cost? Access to infrastructure and improved markets?

Market-ready advanced stoves + fuels
Many thanks

Funders for HAP CRA
USEPA
Shell Foundation
For NBS Project
World Bank
CDC/GACC
World Lung Foundation