Household Air Pollution and Public Health

Sumi Mehta, MPH, PhD
smeha@cleancookstoves.org
Overview

• What is the Burden of Disease from Household Air Pollution?
  • How is this Calculated?
• How Can We Estimate the Public Health Benefits of Adopting Clean Cooking?
  • Overview of the HAPIT Tool
What Do We Mean By Household Air Pollution (HAP)?

• Incomplete Combustion → complex mix of health damaging pollutants:
  – respirable particles, carbon monoxide, oxides of nitrogen and sulfur, benzene, formaldehyde, 1,3-butadiene, and polyaromatic compounds, such as benzo(a)pyrene (Smith 1987)

Note: not just ‘indoor’ air pollution!
HAP solid fuel emissions are a major source of ambient (outdoor) air pollution, particularly in India and China

- Global: household emissions contribute ~12% (4 µg/m³) of PM
- Substantially greater contribution in some regions, especially those with highest population-weighted PM
  - In 3 regions (with ~4 billion people) the contribution ranges from 7-10 µg/m³
  - Contributes 27% of OAP in India
  - Contributes 15% of OAP in China
- Household emissions must be addressed along with other sources in order to meet ambient air quality standards
Global Burden of Disease

- >1000 global experts coordinated by Institute for Health Metrics and Evaluation
- Systematic quantification of health loss due to diseases, injuries and risk factors
- Disease, injury, & risk burden estimates using comparable methods for 1990 – 2013
  - 188 countries (+ sub-national analyses)
  - Incidence and Prevalence by age and sex for 301 diseases and injuries, 2,337 relevant disabling sequelae
  - Comparative risk assessment: 79 modifiable risk factors

- Burden measured as “Disability Adjusted Life Years” (DALYs)

\[ \text{DALY} = \text{YLL} + \text{YLD} \]

  YLL: Years of Life Lost (Premature Death)
  YLD: Years Lived with Disability (Lost Years of Healthy Life)

- Annual updates beginning in 2016
Household Solid Fuel Use Estimates

- Definition: proportion of households using solid cooking fuels (coal, wood, charcoal, dung, and agricultural residues) - data from national/multi-national surveys, WHO data base and literature review

WHO, 2012
National estimates for 1990-2013 modelled with 3-stage regression approach using data on mean years of education of women of reproductive age, proportion of population living in urban areas, and allowing for additional spatio-temporal variation in exposure prevalence.
Health Impacts Are Driven By Exposure, not Emissions!

User Behavior: Time Activity Patterns and Proximity to Sources

Emissions from All Stoves and Fuels

Household Air Pollution

Competing Sources of Pollution (Smoking, ETS, Incense, Generators, Occupational and Neighborhood Exposures)

Ambient Air Pollution
Quantitative Exposure Estimates (PM$_{2.5}$)

GBD 2010:
- State-wise estimates of 24-hr kitchen concentrations of PM$_{2.5}$ in India

GBD 2013:
- Database of household PM2.5 levels from indoor burning of solid fuels from 67 studies in 16 countries
- Estimate country-specific PM2.5 concentrations in the kitchen area

Balakrishnan, 2013
Exposure-Response Relationships

Criteria for Inclusion in GBD/CRA for HAP:
• Sufficient evidence of causal pathway (comparable to other risk factors)
• Sufficient data on background burden of disease

Outcomes included:
• Child pneumonia
• COPD
• Lung cancer
• Cardiovascular disease

Not included:
• Cooking-related burns and injury (Global Burns Registry to inform etiology under development)
• Adverse Pregnancy Outcomes (low birth weight, preterm births
• Tuberculosis?
Integrated Exposure Response Curve: ALRI

![Graph showing the relationship between exposure to PM$_{2.5}$ and incidence of ALRI with data from different studies.]
Integrated Exposure Response Curves: Adult Outcomes

Ischaemic Heart Disease

Stroke

COPD

Lung Cancer

Burnett et al, 2014
“Counterfactual” Exposure Levels

Current Exposures vs. What?

- Ambient air pollution:
  - ~2% cleanest city in the world $\rightarrow$ ~7 ug/m$^3$ PM$_{2.5}$
- Household air pollution
  - cooking with gas $\rightarrow$ ~7 ug/m$^3$ PM$_{2.5}$

Credit: Project Gaia

Credit: World LPG Association
Disease Rates: GBD 2013 from IHME
Main causes of death:
- Child pneumonia
- COPD
- Lung cancer
- Cardiovascular disease

~ 4 M deaths per year
> 6% of global deaths

IHME, 2013
10% of All Deaths in 2013 Are Attributable to Air Pollution

Deaths from air pollution in 2013

85% of the world’s population lives in areas where WHO air quality guidelines are exceeded.

In China and India, less than 1% of the population lives in areas meeting WHO guidelines.

Air pollution was responsible for 5.5 million deaths in 2013

10% of all deaths were from air pollution in 2013

Source:
Attributable Risk?

• The amount of ill-health that would not exist today if the exposure to the risk factor had not occurred in the past.
• Counter-factual level important, i.e., what lower exposure level would have been possible?
• Assumesthe all other risk factors remain constant

\[
\text{AB}_{\text{int}} = \left( \frac{\text{PAF}_{\text{pre-intervention}} - \text{PAF}_{\text{post-intervention}}}{\text{B}_{\text{endpoint}} \times \text{Use}_{\text{fraction}} \times \text{SFU}_{\text{fraction}}} \right)
\]

➔ All attributable risks for a disease can add up to more than 100%
➔ Size of attributable risk depends on the order that different factors are examined

Examples for Discussion:
• Road Traffic Injury
• Child Pneumonia
FIGURE 2.2 Worldwide Years of Life Lost Due to Household Air Pollution from Cooking with Solid Fuels, 2013


Source: GBD 2013 Collaborators 2016c.
Note: COPD – chronic obstructive pulmonary disease.
HAP and Non-Communicable Disease

- HAP is the leading risk factor for NCDs among the poor in developing countries
  - the one major modifiable risk factor for NCDs shared by virtually 100% in the bottom 3 billion (vast majority are nonsmoking, do not abuse alcohol, are physically active, and not ‘over’ nourished)
  - While cigarettes are the leading cause of chronic lung disease in developed countries, HAP is the leading risk cause of chronic lung disease among nonsmoking women in developing countries.

- HAP increases the risk of having low birth weight babies, who are then at increased risk of developing NCDs.

- The link between HAP and two major NCDs, chronic lung disease and lung cancer has been well established.

- Needed: direct evidence for cardiovascular disease

Challenge: what are the right biomarkers and ‘indicators’ to evaluate over a relatively short time frame?

- Analogous to smoking cessation
- 4 studies in Ghana, India, Peru, Nepal recently launched by Alliance and Public Health Institute

For More Detailed Technical Information:

Global Burden of Disease Methodology
- http://ehp.niehs.nih.gov/1307049/

2010 Estimates – IHME (includes national burden estimates)
- http://download.thelancet.com/pdfs/journals/lancet/PIIS0140673612617668.pdf?id=eaa8GQJpba7QgcGjj_6tu
- http://www.healthmetricsandevaluation.org/gbd/visualizations/country

WHO 2012 Estimates (only deaths, only air pollution)
- http://www.who.int/phe/en/

2013 Estimates – IHME
- http://www.healthmetricsandevaluation.org/gbd/visualizations/country
- Detailed methodology in WB 2016 report
Estimating the public health benefits of scaling up clean cooking

Household Air Pollution Intervention Tool (HAPIT):
A web-based tool to estimate the health benefits of household air pollution interventions
Why do we need risk assessment tools vs directly measuring health impacts?

- Large-scale evaluations are expensive, time consuming, difficult, burdensome for participants

- Decision tools are not a substitute for these types of studies, but are an attempt to integrate the comprehensive body of scientific evidence currently available to credibly estimate public health benefits attributable to different intervention scenarios

- Note: HAPIT is one decision tool specific to clean cooking – also important to integrate with other public health decision tools – discussions with the Lives Saved (LiST) tool for child survival also underway!
Household Air Pollution Intervention Tool (HAPIT)
A web-based tool to estimate the health benefits of household air pollution interventions

www.cleancookstoves.org/HAPIT

Intended Audience:

• NGOs and advocacy groups seeking to raise awareness of HAP interventions by presenting policy-makers with a suite of potential interventions across a range of exposure reduction and cost
• Policy-makers, implementers, and NGOs seeking to evaluate the potential implications of an intervention
• Stove designers interested in estimating the potential impacts of their intervention or who are trying to determine whether they are “clean enough” to provide intended health benefits

Created by Dr. Ajay Pillarisetti

HOUSEHOLD ENERGY, CLIMATE, & HEALTH RESEARCH GROUP
UNIVERSITY OF CALIFORNIA, BERKELEY
HAPIT: Household Air Pollution Intervention Tool (Version 2)
(www.cleancookstoves.org/HAPIT)

Benefits by default are estimated at the country level
- Tool contains background disease information for 50+ countries
- Based on the best available health effects evidence from the Global Burden of Disease
- HAPIT estimates the approximate morbidity and the premature mortality reductions for user-created scenarios
- As the evidence improves, the estimates of death and DALYs averted will change

HAPIT can also estimate cost-effectiveness
- Based on WHO-CHOICE criteria
- Requires per-unit costs and annual program maintenance costs
What interventions can / should be evaluated?

‘Green’ for the Environment ≠ ‘Clean’ for Health

Benefits for health, climate
Public Health Impacts Driven by Exposure, Not Emissions
Credible International Standards Development Bodies Inform Definition of ‘Clean’

Tier 4 for ‘indoor emissions’ will likely achieve the greatest health benefits
### Current State of Cookstove Technology

<table>
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<th>Performance</th>
<th>Subtier 0</th>
<th>Subtier 1</th>
<th>Subtier 2</th>
<th>Subtier 3</th>
<th>Subtier 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM2.5 (mg/min)</td>
<td>&gt;40</td>
<td>17-40</td>
<td>8-17</td>
<td>2-8</td>
<td>0-2</td>
</tr>
<tr>
<td>PM2.5 (μg/m³)</td>
<td>&gt;600</td>
<td>6-300</td>
<td>300-100</td>
<td>100-35</td>
<td>&lt;35</td>
</tr>
</tbody>
</table>

#### Stoves
- TSF
- Traditional
- Rocket
- Charcoal
- Solar
- Gasifiers/TLUDs
- Forced Draft
- Ethanol
- LPG/Biogas
- Electric/Induction
- Oorja
- ACE
- Mimi Moto
- LPG
- TTK

#### Models
- Chulhas Prestige
- Chulika
- AgniStar
- Biolite

#### Fuels
- Greenway
- Unprocessed Biomass
- Processed Biomass
- Clean Fuels

- Performance by tech can vary widely within type
- Forced draft stoves are generally cleaner than natural draft stoves
- Processed fuel needed to maximize performance
- User factors (ease-of-use, familiarity, etc.) impact adoption and thus benefits
Applied Example: Child Pneumonia in India

2010: 185,000 deaths
2013: 155,000 deaths

Despite major progress in diagnostics and treatment, substantial number of child pneumonia deaths occur each year

→ How much further progress can be achieved by scaling up clean cooking?

(Source: IHME, 2016)
Beyond India: HAP is a Major Risk Factor for Pneumonia in all UNICEF / WHO Diarrhea Pneumonia Working Group (DPWG) Countries

(Source: IHME, 2010)
Child Pneumonia Deaths Averted Over 5 Years By Scaling Coverage At District Level

www.cleancookstoves.org/HAPIT
Child Pneumonia Deaths Averted Over 5 Years By Scaling Coverage At State Level

www.cleancookstoves.org/HAPIT
HAPIT Version 2 → HAPIT Version 3

HAPIT Version 2:
- GBD 2010 data and functional forms fit to IERs
- Population data from US Census Bureau’s international databases
- Single point estimates of exposure to evaluate potential ill-health averted by adoption of an intervention
- Default scenarios and household demographics
- No sensitivity analysis

HAPIT Version 3:
- 2013 GBD data
- IHME population data for consistency, verified against US Census bureau estimates
- Requires users to input pre- and post-intervention exposures, standard deviations, addresses measurement uncertainty
- More flexibility on scenarios and demographics
- Performs HAPIT math for between 10 and 1000 draws from the distributions
- Calculates burdens separately for children and primary cook and scales findings for non-cook adults in the house
- More user-friendly overall
Exposure-related parameters

Exposure distributions

HAPIT 3 Input Parameters

Exposures (ug/m³)

Pre-Intervention, Adult

Pre-Intervention, Child

Post-Intervention, Adult

Post-Intervention, Child

PM₂.₅ Exposures

Adult Pre-Intervention Exposure

285

SD

200

Adult Post-Intervention Exposure

140

SD

100

Mother to Child Exposure Ratio

0.45

Number of Iterations

100

Population Details

Number of Targeted HH

25,000

People Per HH

1

Children Per HH

6

Adults Per HH

4

Intervention Details

% using Intervention

50

Intervention Useful Life

3

Per-unit cost (USD)

100

Per-unit yearly cost (USD)

10
Applied Example: Deaths Averted Over 5 Years By Scaling Intervention Coverage for 500,000 Households in Ghana

www.cleancookstoves.org/HAPIT
Health Benefits of a Household Air Pollution Intervention in Malawi

Created using HAPIT 3 on 05 May 2016 00:34

Introduction

Thanks for using HAPIT! This report contains output from your most recent HAPIT run. Based on your inputs of information, HAPIT estimates health benefits attributable to stove and/or fuel programs that reduce exposure to household air pollution (HAP) resulting from solid fuel use in traditional stoves in developing countries. As each country’s health and HAP situation is different, HAPIT currently contains the background data necessary to conduct the analysis in 47 countries. HAPIT also estimates program cost-effectiveness in US dollars per averted DALY (disability-adjusted life year) based on the World Health Organization’s CHOICE methodology.

This report focuses on Malawi. It is tailored to the national average conditions (household size, background disease rates, GDP per capita, etc.). Estimates derived from HAPIT are based on methods and databases developed during the Comparative Risk Assessment, a component of the IHME Global Burden of Disease project. Data in HAPIT is derived from GBD-2013. It includes exposure-response information for each of the major disease categories that have been accepted as being due to HAP as well as background health, demographic, energy, and economic conditions for an additional 46 countries. For countries with large demographic, geographic, or economic heterogeneity, estimates generated by HAPIT must be used with caution. In these areas, sub-national scenarios and input data...
Reducing Exposures to Achieve Health Benefits is Complex!

User Behavior: Time Activity Patterns and Proximity to Sources

Emissions from All Stoves and Fuels

Household Air Pollution

Ambient Air Pollution

Competing Sources of Pollution (Smoking, ETS, Incense, Generators, Occupational and Neighborhood Exposures)
Ensuring Public Health Benefits Requires Focus on:

- Competing risk factors
- Behavior change communication
- Increasing coverage
- Innovation to ensure product performance and user acceptability
- Ensuring diversity of products to meet different customer segments
- Increasing access and affordability

‘Household sanitation could provide other benefits, including convenience, dignity, privacy, and safety... Our results show that the health benefits ... cannot be assumed simply by construction of latrines. As efforts to expand sanitation coverage are undertaken worldwide, approaches need to not only meet coverage-driven targets, but also achieve levels of uptake that could reduce levels of exposure, thereby offering the potential for genuine and enduring gains.’