Household Air Pollution and Health: An Introduction for the HAPIT

Household Energy, Climate, and Health Research Group
University of California, Berkeley
The three major solid fuels
Population Cooking with Solid Fuels in 2010 (%)
Total Population Cooking with Solid Fuels

Bonjour et al., CRA-2010
1990:
85%: 700 million people using solid fuels

2010:
60%: 700 million people

~1980
700 million people in entire country
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%
Energy flows in a well-operating traditional wood-fired cookstove

A Toxic Waste Factory!!

Typical biomass cookstoves convert 6-20% of the fuel carbon to toxic substances

- Into Pot: 2.8 MJ (18%)
- In PIC: 1.2 MJ (8%)
- Waste Heat: 11.3 MJ (74%)

PIC = products of incomplete combustion = CO, HC, C, etc.

Source: Smith, et al., 2000
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(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

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

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

Emissions and concentrations, yes, but what about exposures?

Kheda District, Gujarat, 1981
How much PM2.5 is unhealthy?

- **WHO Air Quality Guidelines**
  - 10 ug/m³ annual average
  - No public microenvironment, indoor or outdoor, should be more than 35 ug/m³

- **National standards – annual outdoors**
  - USA: 12 ug/m³
  - China: 35 ug/m³
  - India: 40 ug/m³

Millions Dead: How Do We Know and What Does It Mean? Methods Used in the Comparative Risk Assessment of Household Air Pollution

Kirk R. Smith,¹,* Nigel Bruce,²,* Kalpana Balakrishnan,³ Heather Adair-Rohani,¹ John Balmes,¹,⁴ Zöe Chafe,¹,⁵ Mukesh Dherani,² H. Dean Hosgood,⁶ Sumi Mehta,⁷ Daniel Pope,² Eva Rehfuess,⁸ and others in the HAP CRA Risk Expert Group¹

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
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
<table>
<thead>
<tr>
<th>Rank and disorder 1990</th>
<th>Rank and disorder 2010</th>
<th>(% of total)</th>
</tr>
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<tbody>
<tr>
<td>1 Lower respiratory infections</td>
<td>1 Lower respiratory infections</td>
<td>223 (11.9%)</td>
</tr>
<tr>
<td>2 Diarrheal diseases</td>
<td>2 Ischemic heart disease</td>
<td>108 (5.8%)</td>
</tr>
<tr>
<td>3 Congenital anomalies</td>
<td>3 Diarrheal diseases</td>
<td>114 (6.0%)</td>
</tr>
<tr>
<td>4 Preterm birth complications</td>
<td>4 Congenital anomalies</td>
<td>102 (5.4%)</td>
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<tr>
<td>5 Tetanus</td>
<td>5 Stroke</td>
<td>97 (5.2%)</td>
</tr>
<tr>
<td>6 Tuberculosis</td>
<td>6 Preterm birth complications</td>
<td>93 (4.9%)</td>
</tr>
<tr>
<td>7 Measles</td>
<td>7 Tuberculosis</td>
<td>72 (3.8%)</td>
</tr>
<tr>
<td>8 Malaria</td>
<td>8 Road injury</td>
<td>56 (3.0%)</td>
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<tr>
<td>9 Protein-energy malnutrition</td>
<td>9 Neonatal encephalopathy</td>
<td>51 (2.7%)</td>
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<tr>
<td>10 Ischemic heart disease</td>
<td>10 Meningitis</td>
<td>30 (1.6%)</td>
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<tr>
<td>11 Stroke</td>
<td>11 Asthma</td>
<td>31 (1.6%)</td>
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<tr>
<td>12 Meningitis</td>
<td>12 Self-harm</td>
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<tr>
<td>13 Neonatal encephalopathy</td>
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<tr>
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<td>14 Cirrhosis</td>
<td>26 (1.4%)</td>
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<tr>
<td>15 Asthma</td>
<td>15 Drowning</td>
<td>26 (1.4%)</td>
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<tr>
<td>16 Mechanical forces</td>
<td>16 COPD</td>
<td>25 (1.3%)</td>
</tr>
<tr>
<td>17 COPD</td>
<td>17 Protein-energy malnutrition</td>
<td>26 (1.4%)</td>
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<tr>
<td>18 Rabies</td>
<td>18 Diabetes</td>
<td>24 (1.3%)</td>
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<tr>
<td>19 Drowning</td>
<td>19 Maternal disorders</td>
<td>23 (1.2%)</td>
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<tr>
<td>20 Road injury</td>
<td>20 Dengue</td>
<td>81 (4.0%)</td>
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</tbody>
</table>
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
State-wise estimates of 24-h kitchen concentrations of PM2.5 in India

Solid-fuel using households

Balakrishnan et al. 2013 (SRU group)
Diseases for which we have epidemiological studies

ALRI/Pneumonia

COPD
Lung cancer (coal)
Lung cancer (biomass)
Cataracts
Ischemic heart disease
Stroke

These diseases are included in the 2010 Comparative Risk Assessment (released in 2012)
Global DALYs 2010: Top 20 Risk Factors

Premature Deaths
- HBP -9.3 million
- Alcohol – 7.7
- Tobacco – 5.7
- SHS-T – 0.6
- SHS-C – 0.5
- High BMI – 3.4
- Phys Inactive – 3.2
- Outdoor AP – 3.3
- High Sodium – 3.1
Top 15 causes of ill-health in India (GBD/CRA 2010)
HAP Total: ~1,000,000 premature deaths annually

Women and Girls
- Household air pollution
- Dietary risks
- Iron deficiency
- Childhood underweight
- High blood pressure
- Ambient PM pollution
- Fasting plasma glucose
- Smoking
- Suboptimal breastfeeding
- Intimate partner violence
- Physical inactivity
- Alcohol use
- Sanitation
- High body-mass index
- Occupational risks

Men and Boys:
- Dietary risks
- Smoking
- Household air pollution
- Occupational risks
- High blood pressure
- Alcohol use
- Ambient PM pollution
- Fasting plasma glucose
- Childhood underweight
- Physical inactivity
- Iron deficiency
- Suboptimal breastfeeding
- High total cholesterol
- Sanitation
Framing, cont.

• Not called “indoor” because stove smoke enters atmosphere to become part of general outdoor air pollution (OAP)
• HAP contributes about 12% to OAP globally, but much more in some countries
• ~25% in India
• Thus, part of the burden of disease due to OAP is attributable to cooking fuels in households ~150,000 premature deaths in India.
%PM$_{2.5}$ from “Residential” Emissions from INTEX_B

18% of primary particle pollution in SE Asia is from household fuels

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
IERs: Integrated Exposure-Response Functions

An Integrated Risk Function for Estimating the Global Burden of Disease Attributable to Ambient Fine Particulate Matter Exposure


Burnett et al., *Environmental Health Perspectives* • volume 122 | number 4 | April 2014

Combine multiple studies across four categories of exposure to combustion particles: ambient air pollution; secondhand tobacco smoke; household air pollution, and active smoking
Integrated Exposure-Response: Ischemic Heart Disease

- Outdoor Air Pollution
- Secondhand Tobacco Smoke
- HAP Zone

Smokers
Stroke
Ischemic Heart Disease
ALRI
2.5 ug/m³ annual average PM
COPD
Lung Cancer
ug/m³ annual average PM
Ischemic Heart Disease
Summary

- One of the top risk factors in the world for ill-health.
- 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 globally or in Laos
Bottom line #1

• We know now that to achieve the major health benefits required, stove/fuel emissions need to be very low.
• Biomass stoves are getting much cleaner.
• To achieve actual exposure reductions, they need to match people’s needs and be widely used/adopted.
• How much ill-health can they reduce and how much do they leave untouched?
• HAPIT can give us estimates.
**Exposure-response relationship**

- **Risk**
  - WHO air quality annual guideline: 10 µg/m³
  - IT1: 35 µg/m³

- **PM2.5 Exposure**
  - LPG: 25
  - Fan: 125
  - Rocket: 200
  - ‘Chimney’: 300 µg/m³

- **Child pneumonia**
  - If you start here
  - Even if you get here
  - It leaves ~80% of burden untouched
Bottom Line #2

• Clean cooking now only achievable with gas and/or electric cooking
• High priority needs to be given to expanding gas and electricity to all households
• In spite of cost barriers
• Usage/adoptions still issues, but not emissions
Energy Ladder

How do we help people move into this realm?

- Very Low Income 200 million
- Low Income 400 million
- Middle Income 400 million
- High Income 200 million

- Wood
- Charcoal
- Biogas, ethanol, etc
- Liquefied Petroleum Gas
- Electricity
- Natural Gas
- Non-solid fuels

Smith/Pillarisetti, 2014
Bottom lines, restated
– In addition to continuing to try to make the available clean
– Shouldn’t we also try to make the clean available?
Either can be evaluated using the HAPIT
Many thanks

Publications and presentations on website – easiest to just “google” Kirk R. Smith
HAPIT
Household Air Pollution Intervention Tool

made possible by Global Alliance for Clean Cookstoves

Ajay Pillarisetti and Kirk R. Smith

14 August 2014
Overview

- Background + Motivation
- HAPIT Demos
- Next Steps
HAPIT Overview

An easy-to-use, web-based tool to estimate the health benefits of household energy interventions

Allow users to modify parameters to create potential intervention “scenarios”

Benefits by default are estimated at the country level
- Based on the best available health effects evidence from the Global Burden of Disease
- HAPIT estimates the approximate morbidity and premature mortality reductions due for each scenario.
- As the evidence improves, these estimates of deaths and DALYs averted will change

Generates a time-stamped report with tables and graphs based
Avoided deaths are an important metric, but do not take into account age or years of illness.

Disability-adjusted life years do account for both age and illness. They have two main components:
- Years of Lost Life (YLLs)
- Years Lost to Disability (YLDs)

DALYs allow comparison between interventions, causes of disease, and risk factors.

Background & Motivations

HAPIT contains background information for 15 countries
Bangladesh, China, Ghana, Guatemala, India, Kenya, Laos, Mali, Mexico, Nepal, Nigeria, Peru, Rwanda, Uganda, Zambia

It requires specific inputs
– average PM$_{2.5}$ exposures before intervention
– average PM$_{2.5}$ exposures after intervention
– expected usage fraction of intervention
– number of households receiving intervention
– cost details
Cost-effectiveness is estimated using WHO CHOICE criteria in international dollars per DALY

- Very Cost Effective: less than GDP per capita / DALY
- Cost Effective: more than one but less than 3 x GDP per capita / DALY
- Not Cost Effective: more than 3 x GDP per capita / DALY

CEA accounts for national program costs and health benefits.

It does not

- consider costs or savings at the household level (payment for fuel or intervention)
- consider costs or savings at the societal scale (saved health costs, CAP reductions)
- discount or consider the time value of funds

Program costs can be altered to incorporate household scale benefits
**Audience**

HAPIT is catered towards policy makers, donors, and investors seeking to evaluate a range of household energy intervention scenarios at the country level.

HAPIT users are encouraged to conduct feasibility studies in advance of investments to obtain local field evidence on

- usage patterns of the proposed intervention
- pre- and post-intervention exposures to PM2.5
- UC Berkeley and collaborators are developing standard methods for gathering input data required for HAPIT (stay tuned)

Users could replace included background disease values from the GBD with their own, locally measured/obtained estimates, though at this stage we do not advise such undertakings

- reliable, valid data can be hard to find
- if using GBD country totals as a reference, manipulations of and assumptions about background data required.
HAPIT

Estimates are based on an attributable burden calculation parallel to that used in the GBD-2010

– PM$_{2.5}$ annual avg. exposures used as the indicator of risk
– Integrated Exposure-Response relationships distilled from the world epidemiology literature by disease
– Population attributable fraction (PAF) metrics by disease
– Background national or regional disease conditions
– EPA cessation lag for chronic diseases; 80% of benefits by year 5
**Background Data**

- **2010 Background Disease Data – Deaths & DALYs**
  GBD Compare 2013
- **2010 Population Data**
  US Census Int’l Bureau
- **2010 Solid Fuel Use**
  Bonjour et al 2013 via WHO
- **GDP per capita (Int’l $)**
  IHME 2013
- **Average HH Size**
  GACC 2013 • UNPD

**User Inputs**

- Pre-Intervention & Post-Intervention PM Exposures
- # of Target HH & Fraction Using
- Intervention & Maintenance Costs
- Evaluation period

**Relative Risks + PAFS**

- Calculate relative risks for each disease at each user-input exposure level using mathematical functions fit to exposure-response data.
- Calculate population attributable fractions for each disease at each exposure level.

**Attributable Burden**

- Calculate attributable burdens for each exposure scenario.

**Averted Burden**

- Subtract post-intervention deaths and DALYs from pre-intervention values to determine the health benefits of the intervention.
Relative Risks + PAFS

Calculate relative risks for each disease at each user-input exposure level using mathematical functions fit to exposure-response data.

Calculate population attributable fractions for each disease at each exposure level.

Attributable Burden

Calculate attributable burdens for each exposure scenario.

Averted Burden

Subtract post-intervention deaths and DALYs from pre-intervention values to determine the health benefits of the intervention.

Relative risks are derived from equations fit to the Integrated exposure response curves.

\[ AF = \frac{\text{Fraction Exposed} \times (\text{RR}-1)}{\text{Fraction Exposed} \times (\text{RR}-1) + 1} \]

\[ \text{Fraction Exposed} = \% \text{ Solid Fuel Users} \]

Attributable burden = AF \times (DALYs or Deaths)

Repeat for both post-intervention and pre-intervention PM levels. Subtract post-intervention burden from pre-intervention burden to determine averted burden.
HAPIT

HAPIT built using
  – R, the open-source, free stats programming environment
  – Shiny, an R package and web framework allowing creation of interactive data processors and visualizers
  – jQuery, a javascript library

Allows comparison of multiple user-defined interventions
  – Contains a number of default intervention scenarios (for LPG, rocket stoves, chimney stoves, etc)
  – Users can customize additional scenarios as needed

Any analysis or function that can be implemented in R can be presented and manipulated in a web browser

Available at the end of August at hapit.shinyapps.io/HAPIT
The table below is modifiable. Click on any cell and change values as needed. It is currently not possible to rename interventions. Click the "Redraw Graphs" button to update graphs. Tables refresh automatically when you alter any dropdown menu or the Intervention Scenarios table below. * denotes exposures based on values reported in scientific literature. These values are unmeasured in the selected country.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Num</th>
<th>Pre-Intvn Exposure</th>
<th>Post-Intvn Exposure</th>
<th>Targeted Households</th>
<th>Fraction Using Intvn</th>
<th>Useful Intvn Life</th>
<th>Cost per Intvn (USD)</th>
<th>Maintenance / Fuel Cost (USD/yr)</th>
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</thead>
<tbody>
<tr>
<td>LPG*</td>
<td>1</td>
<td>285</td>
<td>40</td>
<td>100000</td>
<td>1</td>
<td>3</td>
<td>85</td>
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<td>Chimney*</td>
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<td>285</td>
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**HAPIT**

*Household Air Pollution Intervention Tool v2.0.2*

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### Evaluation Period

<table>
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</tbody>
</table>

### Counterfactual

### Country Selection

### User defined scenarios
Table directly editable

### Download Report

*Health Impacts* | WHO CHOICE Cost Effectiveness | Tables | Documentation & Background
Deaths and DALYs avoided over 3 year evaluation period

HAPIT reports values for chronic diseases adjusted using the EPA 30 year Cessation lag. ALRI deaths and DALYs are unadjusted and are assumed to accrue quickly after intervention deployment. For more information, see the 'Documentation' tab.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Num</th>
<th>ALRI DALYs &lt;5</th>
<th>ALRI Deaths &lt;5</th>
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<th>COPD Deaths</th>
<th>IHD DALYs</th>
<th>IHD Deaths</th>
<th>Lung Cancer DALYs</th>
<th>Lung Cancer Deaths</th>
<th>Stroke DALYs</th>
<th>Stroke Deaths</th>
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<td>3180</td>
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</table>
For each scenario, the DALYs that could be avoided if all recipients used the intervention & the intervention got down to the counterfactual exposure level.
### WHO CHOICE Cost Effectiveness

<table>
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<tr>
<th>Scenario</th>
<th>Num</th>
<th>First Year Cost</th>
<th>Yearly Cost</th>
<th>Total Annual Cost</th>
<th>ALRI Deaths &lt;5</th>
<th>Total DALYs</th>
<th>Total Deaths</th>
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<th>USD/DALY</th>
<th>CHOICE Criterion</th>
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## Population Attributable Fractions at the Counterfactual and Before and After the Intervention

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<td>1.63</td>
<td>2.66</td>
<td>2.03</td>
<td>1.94</td>
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</table>
Background Health information for Bangladesh

The outputs reported by HAPIT are national estimates. For countries with wide income or demographic heterogeneity -- such as India, China, and Mexico -- estimates generated by HAPIT must be used with caution.

<table>
<thead>
<tr>
<th>COPD DALYs</th>
<th>COPD Deaths</th>
<th>IHD DALYs</th>
<th>IHD Deaths</th>
<th>ALRI DALYs &lt;5</th>
<th>ALRI Deaths &lt;5</th>
<th>Lung Cancer DALYs</th>
<th>Lung Cancer Deaths</th>
<th>Stroke DALYs</th>
<th>Stroke Deaths</th>
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Overview

The burden of disease attributable to household PM2.5 pollution is estimated for five diseases: Lung Cancer; Ischemic Heart Disease (IHD); Stroke; Acute Lower Respiratory Infection (ALRI) in those aged 0-4; and Chronic Obstructive Pulmonary Disease (COPD). This version of HAPIT does not account for the additional disease burden attributable to household air pollution’s contribution to ambient air pollution.

The risk of each disease at a given pollution exposure is estimated using an integrated exposure response (IER) function. More details on the IER modeling process can be found at IHME’s website. A functional form was fit to data provided by IER authors using Eureqa Formulize.

The relative risk is used to find the population attributable fraction for each disease, which is the fraction of the background disease rate that is attributable to PM2.5 pollution (rather than, say, high cholesterol intake). The difference between the disease attributable to PM2.5 at the pre- and post-pollution levels is the benefit of the intervention.

Burden of disease estimates and health benefits estimated by HAPIT require definition of an 'ideal' counterfactual exposure, below which there is no risk to health. In the 2010 Burden of Disease, this value was set at 7.3 µg/m³ for annual average PM_{2.5} exposure. In HAPIT, the default value is 10 µg/m³, which is the official Air Quality Guideline of WHO. HAPIT offers a third choice as well -- 35 µg/m³, which is the Interim Target -1 in the WHO AQG document.

Data Sources

All DALYs at the country and subregional level are from the 2010 Global Burden of Disease. All were extracted using IHME’s GBD Compare tool and custom scripts to download raw data from the IHME website. Scripts were designed at UC Berkeley and are available at github.

The deaths and DALYs from lung cancer includes the Global Burden of Disease estimates of trachea, bronchus, and lung cancers. Cardiovascular diseases are broken down into two categories -- Ischemic Heart Disease and Ischemic & Other Hemorrhagic Strokes. The integrated exposure response equation for acute lower respiratory infection relative risk is specific only to those children ages 0 to 4. HAPIT calculates deaths and DALYs due to ALRI only among the population of 0-4.
HAPIT Results: Health Benefits of Stove Interventions in Bangladesh

Generated by HAPIT 2.0.2 on 2014-08-12

This document contains output from HAPIT, the Household Air Pollution Intervention Tool. Based on user inputs of information in their own setting, HAPIT calculates the potential health benefits of stove interventions to reduce health impacts related to household air pollution (HAP) from use of solid cookstoves in traditional stoves.

This report focuses on Bangladesh. 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 GBD (Global Burden of Disease) project (2010-2016). It includes exposure-response information for each of the major disease categories that have been accepted as valid by WHO as well as background health, demographic, economic, and environmental conditions for an additional 13 countries. An * indicates that pre and post intervention PM exposures used default values estimated from the literature and not empirical, country-specific measurements, which are recommended in actual use.

For countries with large demographic, geographic, or economic heterogeneity, estimates generated by HAPIT must be used with caution. In these areas, scenarios and sub-national input data are strongly recommended.

Overview

This document is split into two sections. The first contains a text-based overview of HAPIT and output from the model. The second contains a number of relevant tables and graphs for the user-selected scenarios, intervention lifetimes, and counterfactual exposure.

Scenario Modeled

HAPIT requires definition of an ‘ideal’ counterfactual exposure, below which there is no risk to health. In the 2010 Burden of Disease, this value was set at 7.5 μg/m3 for annual average PM2.5 exposure. In HAPIT, the default value is 10 μg/m3, which is the official Air Quality Guidelines of WHO. HAPIT offers a third choice as well: 25 μg/m3, which is the Interim Target 1 in the WHO AQG document. The other parameters of each scenario modeled are below. Note, here we use default values from the literature, but HAPIT is designed to accept information derived from each user's own setting for case, pre- and post-intervention exposures, etc.

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<th>Scenario</th>
<th>Pre-Interv PM2.5</th>
<th>Post-Interv PM2.5</th>
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<th>Fix Using</th>
<th>Useful Life</th>
<th>Cost per Interv</th>
<th>Yearly Cost</th>
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<td>0.5</td>
<td>3</td>
<td>80</td>
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Deaths and DALYs avoided over 3-year evaluation period

HAPIT reports values for chronic diseases adjusted using the EPA 20 year Cessation lag. Deaths and DALYs in children (due mainly to acute lower respiratory infections, ALRI) are not discounted and are assumed to occur quickly after intervention deployment. Avoided deaths and DALYs are reported in Table 2. DALYs avoided by the interventions, summed across all disease categories, are presented in dark grey in Figure 1. Red indicates avoidable DALYs still remaining in the target population. Table 5 contains avoided Deaths and DALYs by disease category for each scenario.

WHO Choice Cost-Effectiveness Analysis

Cost-effectiveness is determined by comparing the expected annual cost of the intervention per DALY to the GDP/Per Capita (PPP) in international dollars. The World Health Organization’s CHOosing Interventions that are Cost-Effective (WHO CHOICE) effort advises that interventions costing less than the GDP/capita are very cost-effective, those costing one to three times the GDP/capita are cost-effective, and those costing more than three times the GDP/capita are not cost-effective.
Demo
HAPIT Sample Scenarios

Scenario 1
Nepal
Evaluating Multiple Interventions

Pre-intervention exposure: 266 $\mu$g/m³  
Counterfactual: 10 $\mu$g/m³  
Targeted households: 25,000  
People per household: 5  
Annual Maintenance Costs: 10% of first year cost  
100% of targeted households receive intervention

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Num</th>
<th>Pre-Intvn Exposure</th>
<th>Post-Intvn Exposure</th>
<th>Targeted Households</th>
<th>Fraction Using Intvn</th>
<th>Useful Intvn Life</th>
<th>Cost per Intvn (USD)</th>
<th>Maintenance / Fuel Cost (USD/yr)</th>
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Avoided and Unavoided DALYs by Scenario

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### WHO Choice Cost Effectiveness

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<th>Total Annual Cost</th>
<th>USD/Averted Child Death</th>
<th>USD/DALY</th>
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HAPIT Sample Scenarios

Scenario 2
Rwanda
Evaluating Multiple Interventions

Pre-intervention exposure: 450 µg/m³
Counterfactual: 10 µg/m³
Targeted households: 25,000
People per household: 5
Annual Maintenance Costs: 10% of first year cost
100% of targeted households receive intervention

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Num</th>
<th>Pre-Intvn Exposure</th>
<th>Post-Intvn Exposure</th>
<th>Targeted Households</th>
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Tables and Figures

Avoided and Unavoided DALYs by Scenario

![Avoided and Unavoided DALYs by Scenario](image)

Total Averted Deaths and DALYs

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WHO CHOICE Cost-Effectiveness by Scenario

![Graph showing cost-effectiveness by scenario.]

### WHO Choice Cost Effectiveness

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<th>Scenario</th>
<th>First Year Cost</th>
<th>Yearly Cost</th>
<th>Total Annual Cost</th>
<th>USD/Averted Child</th>
<th>USD/DALY</th>
<th>CHOICE Criterion</th>
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</table>
Report Demo
Next Steps

Consider additional, specialized versions
– sub-national regions (geographic, state boundaries, etc)
– by poverty/income quintiles
– single scenario with sensitivity analyses

Differentiate potential benefits by sex

Explore ways to include disease categories not currently included in GBD assessment – including cataract, tuberculosis, low birth weight, and others

Build in more sophisticated lag models to better and more accurately describe ‘achieved’ health benefits

Evaluate inclusion of GBD 2013 updates recently released by IHME

Additional countries (coming in Fall 2014)
Next Steps

Setting up a mailing list for occasional updates
– background data changes
– additional features, countries, etc

Publically available at the end of August
Thank you

hapit.shinyapps.io/HAPIT

Contact hapitweb@gmail.com for more information

Ajay Pillarisetti
ajaypillarissetti@gmail.com

Kirk R. Smith
krksmith@berkeley.edu