Household Air Pollution: An Update from Latin America

Kirk R. Smith
Tyler Laureate 2012
Professor of Global Environmental Health
University of California, Berkeley

Pan American Health Organization
Washington DC, July 2, 2012
The three major solid fuels
Population using solid fuels (%), 2010
Total

Percentage
- <5
- 5–50
- 51–80
- 81–95
- >95
- Data not available
- Not applicable

The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Data Source: World Health Organization
Map Production: Public Health Information and Geographic Information Systems (GIS)
World Health Organization
© WHO 2012. All rights reserved.
<table>
<thead>
<tr>
<th>Country</th>
<th>2010 Biomass Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>0 (0, 12)</td>
</tr>
<tr>
<td>Belize</td>
<td>12 (0, 25)</td>
</tr>
<tr>
<td>Bolivia</td>
<td>29 (32, 58)</td>
</tr>
<tr>
<td>Brazil</td>
<td>6 (0, 19)</td>
</tr>
<tr>
<td>Chile</td>
<td>6 (0, 19)</td>
</tr>
<tr>
<td>Colombia</td>
<td>14 (1, 27)</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>6 (0, 19)</td>
</tr>
<tr>
<td>Cuba</td>
<td>0 (0, 22)</td>
</tr>
<tr>
<td>Dominica</td>
<td>1 (0, 14)</td>
</tr>
<tr>
<td>Domin Repub</td>
<td>7 (0, 20)</td>
</tr>
<tr>
<td>Ecuador</td>
<td>2 (0, 15)</td>
</tr>
<tr>
<td>El Salvador</td>
<td>22 (9, 35)</td>
</tr>
<tr>
<td>Grenada</td>
<td>0 (0, 0)</td>
</tr>
<tr>
<td>Guatemala</td>
<td>57 (44, 70)</td>
</tr>
<tr>
<td>Guyana</td>
<td>7 (0, 20)</td>
</tr>
<tr>
<td>Haiti</td>
<td>91 (78, 100)</td>
</tr>
<tr>
<td>Honduras</td>
<td>51 (38, 64)</td>
</tr>
<tr>
<td>Jamaica</td>
<td>11 (0, 24)</td>
</tr>
<tr>
<td>Mexico</td>
<td>14 (1, 27)</td>
</tr>
<tr>
<td>Nicaragua</td>
<td>54 (41, 67)</td>
</tr>
<tr>
<td>Panama</td>
<td>18 (5, 31)</td>
</tr>
<tr>
<td>Paraguay</td>
<td>49 (36, 62)</td>
</tr>
<tr>
<td>Peru</td>
<td>36 (24, 50)</td>
</tr>
<tr>
<td>St Vinc/Grenad</td>
<td>3 (0, 16)</td>
</tr>
<tr>
<td>Suriname</td>
<td>12 (0, 25)</td>
</tr>
<tr>
<td>Uruguay</td>
<td>0 (0, 13)</td>
</tr>
<tr>
<td>Venezuela</td>
<td>0 (0, 8)</td>
</tr>
</tbody>
</table>
World Population Using Solid Fuels

~40% of the world
~2.8 billion people
More than any time in human history
Woodsmoke is natural – how can it hurt you?

Or, since wood is mainly just carbon, hydrogen, and oxygen, doesn’t it just change to CO$_2$ and H$_2$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 \textit{n-hexane}
  – 40+ unsaturated hydrocarbons such as \textit{1,3 butadiene}
  – 28+ mono-aromatics such as \textit{benzene} & \textit{styrene}
  – 20+ polycyclic aromatic hydrocarbons such as \textit{benzo(α)pyrene}
• Oxygenated organics
  – 20+ aldehydes including \textit{formaldehyde} & \textit{acrolein}
  – 25+ alcohols and acids such as \textit{methanol}
  – 33+ phenols such as \textit{catechol} & \textit{cresol}
  – Many quinones such as \textit{hydroquinone}
  – Semi-quinone-type and other radicals
• Chlorinated organics such as \textit{methylene chloride} and \textit{dioxin}

How much Ill-health?
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

Best single indicator

IARC Group 1 Carcinogens
- 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
First person in human history to have her exposure measured doing the oldest task in human history

Emissions, yes, but what about exposures?

Kheda District, Gujarat, 1981
Preliminary results from the Household Air Pollution Comparative Risk Assessment for the year 2010

Estimated PM2.5 for only solid-fuel-using households

~400 ug/m³ mean
WHO guidelines = 10-35 ug/m³
Diseases for which we have epidemiological studies:

- ALRI/Pneumonia
- COPD
- Lung cancer (coal)

These three diseases were included in the 2004 Comparative Risk Assessment Managed and published by WHO.

First ever comprehensive risk assessment with consistent rules of evidence and common databases.
Global Burden of Disease from Top 10 Risk Factors
plus selected other risk factors

Underweight
Unsafe sex
Blood pressure
Tobacco
Alcohol
Unsafe water/sanitation
Child cluster vaccination*
Cholesterol
Lack of Malaria control*
Indoor smoke from solid fuels
Overweight
Occupational hazards (5 kinds)
Road traffic accidents*
Physical inactivity
Lead (Pb) pollution
Urban outdoor air pollution
Climate change

Percent of All DALYs

0.0%  2.0%  4.0%  6.0%  8.0%  10.0%

2004 CRA

~2 million premature deaths/year
1 million premature deaths/year
Global Burden of Disease Database and Comparative Risk Assessment World Health Organization

Being completely updated For 2012 release

For household air pollution:
New exposure assessment modeling
New outcome estimates based on meta-analyses
ALRI, COPD, Lung Cancer cataracts, cardiovascular
Diseases for which we have epidemiological studies:

- ALRI/Pneumonia
- COPD
- Lung cancer (coal)
- Lung cancer (biomass)
- Blindness (cataracts, opacity)
- Stillbirth
- Low birth weight
- Heart disease
- Blood pressure
- ST-segment

These additional diseases will be included in the 2010 Comparative Risk Assessment (to be released in 2012).

In addition, using evidence from other exposure sources, heart will be included.
There is epi evidence for these other diseases, but considered insufficient to include in the 2010 Comparative Risk Assessment.

- Cognitive Impairment
- Birth defects
- Asthma?
- Tuberculosis
- ALRI
- Other cancers (cervical, NP, upper airway)
- Burns and the health/safety impacts of fuel gathering
<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>
</tr>
<tr>
<td>Cohort</td>
<td>7</td>
<td>2.12</td>
<td>1.06, 4.25</td>
</tr>
<tr>
<td>Case-control</td>
<td>15</td>
<td>1.97</td>
<td>1.47, 2.64</td>
</tr>
<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>


Pneumonia – the biggest single cause of child death in the world
Story of Two Conferences

• Air pollution conference
  – High exposures to large vulnerable population
  – We know there are health effects at 20x lower levels
  – No more health effects work needed

• International health conference
  – Extreme scarcity of resources
  – Need to know exact benefit to be expected
  – Still some doubt about causality
  – Where are your randomized controlled trials?
History of an RCT

• ~1980: Case reports of health effects in South Asia
• 1981: First measurements of pollution levels in India
• 1984: International meeting to decide on needed research
  – Chose randomized controlled trial (RCT) of ALRI
• 1986-89: Unfunded proposals to do RCT in Nepal
• 1990: WHO establishes committee to find best sites
• 1990-1992: Criteria established and site visits made
• 1992: Highland Guatemala chosen
• 1991-1999: Pilot studies to establish data needed for proposal – does stove work and do people use it?
• 1996-1999: Unfunded proposals
• 2001: NIEHS funding secured
• 2002-2006: Fieldwork completed
• 2011: Main results published
• 25+ years from deciding to conduct RCT to results!
Criteria for Choosing RCT Site

- High child mortality
- Lots of ALRI
- Lots of smoke
- Locally available intervention that reduces exposure
- Intervention popular in local population
- Good local partners for running field studies
- 3 sites each in Asia, Africa, and Latin America were considered – including site visits
Partners in Guatemala

• For pilot studies 1992-1999, partner was INCAP
• Since 2000, partner has been Centro de Estudios en Salud (CES) of the Universidad del Valle de Guatemala
• Much non-financial support has come from the Ministry of Health, San Marcos Municipality
International Partners

- University of Liverpool
- WHO, Geneva – RSV studies
- University of Bergen, Norway – adult respiratory health studies
- Harvard University – heart studies
First Randomized Trial In Air Pollution History*

After a worldwide search, chose a site in the Guatemalan Highlands.

* In normal populations
Effect of reduction in household air pollution on childhood pneumonia in Guatemala (RESPIRE): a randomised controlled trial

Kirk R Smith, John P McCracken, Martin W Weber, Alan Hubbard, Alisa Jenny, Lisa M Thompson, John Balmes, Anaite Diaz, Byron Arana, Nigel Bruce
Randomized Exposure Study of Pollution Indoors and Respiratory Effects (RESPIRE):

- Objectives: impact of household air pollution reduction on pneumonia incidence in children ≤ 18 months
  - Primary: intention to treat (ITT) analysis
  - Secondary: exposure-response analysis
- Rural, highland Guatemala, alt. 2200 – 3000 m
- Poor indigenous (Mayan) rural population using open woodfires for cooking
- 518 homes (pregnant woman, child <4 months) using open fire
- Randomized (blocks) to (i) keep open fire or (ii) use chimney wood stove
- Children followed to 18 months: 30,000 child-weeks
- Home-based active surveillance for pneumonia cases
- MD-diagnosis in community centers, blind to stove status
- Repeated individual exposure measurement
RESPIRE
Impact on pneumonia up to 18 months of age

Traditional open 3-stone fire: kitchen 48-hour PM$_{2.5}$ levels of 600 - 1000 μg/m$^3$
WHO AQG = 10-35 ug/m$^3$

Chimney woodstove, locally made and popular with households
Overview of RESPIRE study design

- 530 eligible households: open fire, woman pregnant or child less than 4 months
- Baseline survey and exposure assessment

Randomize

- Keep open fire
- **Plancha**

Follow up till aged 18 months
- Surveillance for ALRI, diarrhoea, &c
- Detailed exposure monitoring

Compare incidence and exposure in 2 groups
- Plancha offered to ‘controls’

Year 1
- 5500 Households total

Years
- 1-3
- 3-4
### Randomisation: balance of groups at baseline

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Socio-demographic factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother’s Age (years)</td>
<td>27.0</td>
<td>26.4</td>
</tr>
<tr>
<td>Pregnant at recruitment (%)</td>
<td>48.3</td>
<td>51.3</td>
</tr>
<tr>
<td>Own home (%)</td>
<td>92.8</td>
<td>94.1</td>
</tr>
<tr>
<td>Migrates part of year (%)</td>
<td>17.7</td>
<td>17.1</td>
</tr>
<tr>
<td><strong>House structure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separate enclosed cooking area (%)</td>
<td>76.2</td>
<td>74.3</td>
</tr>
<tr>
<td>Completely open eaves (%)</td>
<td>42.7</td>
<td>40.6</td>
</tr>
<tr>
<td>Walls – adobe (mud) (%)</td>
<td>88.7</td>
<td>90.7</td>
</tr>
<tr>
<td>Roof – metal (%)</td>
<td>77.4</td>
<td>74.3</td>
</tr>
<tr>
<td>Floor – earth (%)</td>
<td>92.5</td>
<td>88.8</td>
</tr>
<tr>
<td>Leaks in roof (water) (%)</td>
<td>24.5</td>
<td>33.3</td>
</tr>
<tr>
<td>Electricity (%)</td>
<td>70.8</td>
<td>69.3</td>
</tr>
<tr>
<td><strong>Other sources of smoke</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other fire near house (%)</td>
<td>14.6</td>
<td>14.4</td>
</tr>
<tr>
<td>Smoking (tobacco) indoors (%)</td>
<td>26.8</td>
<td>20.4</td>
</tr>
<tr>
<td>Use traditional sauna bath (%)</td>
<td>84.5</td>
<td>87.8</td>
</tr>
<tr>
<td><strong>Geographic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean altitude (metres)</td>
<td>2613</td>
<td>2601</td>
</tr>
</tbody>
</table>
Overview of child health outcomes assessment

Follow-up at weekly visit

**Home**
- Weekly visit
  - Well
  - Mild illness
  - Referral to study doctor

**Community centre**
- Study doctor examines
  - Pulse oximetry
  - If pneumonia, RSV* test and refer for CXR
  - Refer if very ill

**Hospital**
- Assessed by duty doctor
  - Study team obtain CXR and inpatient data and diagnosis

Verbal autopsy

Health outcome definitions

* Respiratory syncitial virus
## Overview of weekly visits

<table>
<thead>
<tr>
<th></th>
<th>Plancha</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of children</strong></td>
<td>265</td>
<td>253</td>
</tr>
<tr>
<td><strong>Weekly visits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total possible in</td>
<td>16,446</td>
<td>15,664</td>
</tr>
<tr>
<td>follow up period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completed</td>
<td>14,756</td>
<td>14,369</td>
</tr>
<tr>
<td><strong>% of possible weekly</strong></td>
<td>89.7%</td>
<td>91.7%*</td>
</tr>
<tr>
<td>visits completed</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mean (SD, range) visits per child</strong></td>
<td>55.7 (17.8; 1 to 80)</td>
<td>56.8 (17.3; 2 to 81)</td>
</tr>
<tr>
<td><strong>Number (%) children - no missed visit</strong></td>
<td>17 (6.4%)</td>
<td>19 (7.5%)</td>
</tr>
<tr>
<td><strong>Withdrawals</strong></td>
<td>19 (7.2%)</td>
<td>14 (5.5%)</td>
</tr>
</tbody>
</table>

* P < 0.001
MD-diagnosed Acute Lower Respiratory Infection

- Open fire babies
- Chimney stove babies

Approximate Mean PM2.5 exposure in 100s of ug/m^3

0.78 (0.59, 1.06)
0.095

RESPIRE-Guatemala
Fieldworker assessed outcomes: ITT: 50% mean reduction in child exposure

<table>
<thead>
<tr>
<th>Upper Respiratory</th>
<th>RR</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>1.01</td>
<td>0.87, 1.17</td>
<td>0.88</td>
</tr>
<tr>
<td>Number of weeks</td>
<td>0.99</td>
<td>0.87, 1.12</td>
<td>0.87</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALRI (‘WHO Pneumonia’)</th>
<th>RR</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>New cases: all</td>
<td>0.91</td>
<td>0.74, 1.13</td>
<td>0.39</td>
</tr>
<tr>
<td>New cases: severe**</td>
<td>0.56</td>
<td>0.32, 0.97</td>
<td>0.04</td>
</tr>
</tbody>
</table>

* Excludes evidence of pneumonia based on FW and physician assessment

** Severe: ill with cough or difficulty breathing and chest wall indrawing and/or unable to drink / breast feed
## 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><strong>RS Virus</strong></td>
<td>0.76 (0.42, 1.16)</td>
<td>0.275</td>
</tr>
<tr>
<td>- Pulse oximetry</td>
<td>Severe</td>
<td>0.87 (0.46, 1.51)</td>
<td>0.633</td>
</tr>
<tr>
<td>- RSV direct antigen test</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
Unpublished results from RESPIRE have been removed.

Watch the website below where they will be posted as soon as they are published.

http://ehs.sph.berkeley.edu/krsmit
~50% reduction in exposure of babies

With chimney

With open fire

Chimney stove did not protect all babies

Predicted Log of CO (ppm)

(ug/m3 PM$_{2.5}$)
Guatemala RCT: Kitchen Concentrations

Effect of Chimney Stove On Kitchen CO Levels

Factor of ~10 less

285 48-h measurements

Smith, et al, 2010
Effect of Chimney Stove On Infant Exposures - 2x less

Smith, et al, 2010

1888 48-h measurements
Kitchens down by 10x, but children exposure down by only 2x, because

--Time-activity: the kids do not spend their entire day in the kitchen

--Household (or “neighborhood”) pollution: a chimney does not reduce smoke, but just shifts it outside into the household environment, where the difference between intervention and control households was less

--No significant difference in bedrooms
RESPIRE Summary

• Results - ITT
  – Chimney stove did not reduce all MD pneumonia,
  – But did reduce severe MD pneumonia and
  – RSV-negative (bacterial pneumonia)
  – Even though well operating, chimney was not capable of sufficient exposure reduction by itself

• Results – Exposure-response
  – All major outcome showed significant results (still not RSV pneumonia)
  – Partial exposure reduction brings some benefit, but exposure-response curve highly non-linear
  – Large reductions needed for substantial health benefits
    – levels not possible with chimneys
Bottom lines

- Chimney stove did not protect against MD-diagnosed pneumonia – strict RCT interpretation
- But did protect against severe pneumonia
- Smoke is a major risk factor for child pneumonia, probably mostly for the bacterial form
- Reasons for apparent difference:
  - RSV cases showed no effect, sample size effectively reduced
  - Effect is mostly in severe cases
  - Intervention status left much exposure misclassification
MD-diagnosed Acute Lower Respiratory Infection

Where we Want to Be!

RESPIRE-Guatemala

Approximate Mean PM2.5 exposure in 100s of ug/m3
Combustion Particles

The Generalized Exposure Response (GER)
Heart Disease and Combustion Particle Doses

From “Mind the Gap,”
Smith/Peel, 2010 and Pope et al., 2009
Chimney Stove Intervention to Reduce Long-term Wood Smoke Exposure Lowers Blood Pressure among Guatemalan Women

John P. McCracken,1,2 Kirk R. Smith,3 Anaïte Diaz,4 Murray A. Mittleman,1,5 and Joel Schwartz1,2

Table 3. Crude and adjusted between-group differences in SBP and DBP (mm Hg) associated with plancha compared with open fire use during the trial period.

<table>
<thead>
<tr>
<th>No. of subjects (measures)</th>
<th>Control group</th>
<th>Intervention group</th>
<th>Crude mean difference</th>
<th>Adjusted mean differencea</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Estimate</td>
<td>95% CI</td>
</tr>
<tr>
<td>SBP</td>
<td>71 (111)</td>
<td>49 (115)</td>
<td>−2.3</td>
<td>−6.6 to 2.0</td>
</tr>
<tr>
<td>DBP</td>
<td>71 (111)</td>
<td>49 (115)</td>
<td>−2.2</td>
<td>−4.7 to 0.3</td>
</tr>
</tbody>
</table>

Table 4. Crude and adjusted within-subject differences in SBP and DBP (mm Hg) after the plancha echo-intervention compared with before.

<table>
<thead>
<tr>
<th>No. of subjects (measures)</th>
<th>Trial period</th>
<th>Echo-intervention</th>
<th>Crude mean difference</th>
<th>Adjusted mean differencea</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Estimate</td>
<td>95% CI</td>
</tr>
<tr>
<td>SBP</td>
<td>55 (88)</td>
<td>55 (65)</td>
<td>−3.7</td>
<td>−6.0 to −1.4</td>
</tr>
<tr>
<td>DBP</td>
<td>55 (88)</td>
<td>55 (65)</td>
<td>−2.3</td>
<td>−3.8 to 0.9</td>
</tr>
</tbody>
</table>
Intervention to Lower Household Wood Smoke Exposure in Guatemala Reduces ST-Segment Depression on Electrocardiograms

John McCracken,¹ ² Kirk R. Smith,² Peter Stone,³ Anaité Díaz,⁴ Byron Arana,⁴ and Joel Schwartz¹

¹Department of Environmental Health, Harvard School of Public Health, Boston, Massachusetts, USA; ²Environmental Sciences Division, University of California, Berkeley, California, USA; ³Brigham and Women’s Hospital, Boston, Massachusetts, USA; ⁴Center for Health Studies, Universidad del Valle, Guatemala City, Guatemala

Table 3. Odds ratios (ORs) for nonspecific ST-segment depression (30-min average $\leq -1$ mm, regardless of slope) associated with chimney-stove intervention compared with open fire from two study designs: between-groups and before-and-after analyses.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Crude</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>p-Value</td>
</tr>
<tr>
<td>Between-groups</td>
<td>0.34 (0.15, 0.81)</td>
<td>0.015</td>
</tr>
<tr>
<td>Before-and-after (only control group)</td>
<td>0.41 (0.24, 0.70)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

*Adjusted for age (quadratic), BMI (quadratic), asset index category, ever smoking, SHS, owning a wood-fired sauna, recent use of wood-fired sauna, and time of day (natural spline with 5 degrees of freedom). * Adjusted for age (quadratic), day of week, season (wet/dry), daily average temperature and relative humidity, daily rainfall, interactions of weather variables with season, recent use of wood-fired sauna, and time of day (natural spline with 5 degrees of freedom).
Table 2. Adjusted relative risk estimates for various increments of exposure from cigarette smoking (versus non-smokers), second hand cigarette smoke, and ambient air pollution from the present analysis and selected comparison studies.

<table>
<thead>
<tr>
<th>Source of risk estimate</th>
<th>Increments of Exposure</th>
<th>Adjusted RR (95% CI)</th>
<th>Estimated Daily Dose PM$_{2.5}$ (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS-present analysis</td>
<td>≤3 (1.5) cigs/day</td>
<td>10.44 (7.30-14.94)</td>
<td>1.61 (1.27-2.03) 1.58 (1.32-1.89) 1.72 (1.46-2.03) 18</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>4-7 (5.5) cigs/day</td>
<td>8.03 (5.89-10.96)</td>
<td>1.64 (1.37-1.96) 1.73 (1.51-1.97) 1.84 (1.63-2.08) 66</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>8-12 (10) cigs/day</td>
<td>11.63 (9.51-14.24)</td>
<td>2.07 (1.84-2.31) 2.01 (1.84-2.19) 2.10 (1.94-2.28) 120</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>13-17 (15) cigs/day</td>
<td>13.93 (11.04-17.58)</td>
<td>2.18 (1.89-2.52) 1.99 (1.77-2.23) 2.08 (1.87-2.32) 180</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>18-22 (20) cigs/day</td>
<td>19.88 (17.14-23.36)</td>
<td>2.36 (2.19-2.55) 2.42 (2.28-2.56) 2.52 (2.39-2.66) 240</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>23-27 (25) cigs/day</td>
<td>23.82 (18.80-30.18)</td>
<td>2.59 (2.19-2.75) 2.33 (2.02-2.69) 2.33 (2.03-2.67) 300</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>28-32 (30) cigs/day</td>
<td>26.62 (22.54-31.91)</td>
<td>2.22 (1.97-2.49) 2.17 (1.98-2.38) 2.39 (2.19-2.60) 360</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>33-37 (35) cigs/day</td>
<td>26.72 (18.58-38.44)</td>
<td>2.28 (1.91-2.47) 2.52 (1.98-3.19) 2.83 (2.28-3.52) 420</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>38-42 (40) cigs/day</td>
<td>30.63 (25.79-36.38)</td>
<td>2.30 (2.05-2.59) 2.37 (2.16-2.59) 2.61 (2.40-2.84) 480</td>
</tr>
<tr>
<td>ACS-present analysis</td>
<td>43+ (45) cigs/day</td>
<td>39.16 (31.13-49.26)</td>
<td>2.00 (1.62-2.48) 2.17 (1.84-2.56) 2.37 (2.04-2.76) 540</td>
</tr>
<tr>
<td>ACS-air pol. original</td>
<td>24.5 µg/m³ ambient PM$_{2.5}$</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>ACS-air pol. extend</td>
<td>10 µg/m³ ambient PM$_{2.5}$</td>
<td>1.14 (1.04-1.23)</td>
<td>1.18 (1.14-1.23) 1.12 (1.08-1.15) 1.09 (1.03-1.16) 0.18</td>
</tr>
<tr>
<td>HSC-air pol. original</td>
<td>18.6 µg/m³ ambient PM$_{2.5}$</td>
<td>1.21 (0.92-1.69)</td>
<td>-----</td>
</tr>
<tr>
<td>HSC-air pol. extend</td>
<td>10 µg/m³ ambient PM$_{2.5}$</td>
<td>1.21 (0.92-1.69)</td>
<td>-----</td>
</tr>
<tr>
<td>WHI-air pol.</td>
<td>10 µg/m³ ambient PM$_{2.5}$</td>
<td>1.24 (1.09-1.41)</td>
<td>-----</td>
</tr>
<tr>
<td>SGR-SHS</td>
<td>Low-moderate SHS exp.</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>SGR-SHS</td>
<td>Moderate-high SHS exp.</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>SGR-SHS</td>
<td>Live with smoking spouse</td>
<td>1.21 (1.13-1.30)</td>
<td>-----</td>
</tr>
<tr>
<td>SGR-SHS</td>
<td>Work with SHS exposure</td>
<td>1.22 (1.13-1.33)</td>
<td>-----</td>
</tr>
<tr>
<td>INTERHEART</td>
<td>1-7 hrs/wk SHS exp.</td>
<td>-----</td>
<td>1.24 (1.17-1.32)</td>
</tr>
<tr>
<td>INTERHEART</td>
<td>Live with smoking spouse</td>
<td>1.28 (1.12-1.47)</td>
<td>-----</td>
</tr>
</tbody>
</table>
Generalized Exposure-Response: Outdoor Air, SHS, and Smoking and Heart Disease

IHD risks from combustion particles
Annual average PM2.5 in ug/m3

Relative Risk

CRA, 2011
Generalized Exposure-Response: Outdoor Air, SHS, and HAP

Pneumonia from combustion particles
Annual average PM2.5 in ug/m^3

Annual Incidence

Solid Fuel Zone
Secondhand Tobacco Smoke
Outdoor Air Pollution

CRA, 2011
What can we learn from smoking?

- Open wood cookfire equivalent to roughly 400 cigs/hour of emissions
- Not as bad as sticking burning stuff in your mouth (active smoking), but
- Worse than someone doing so near you (passive smoking)
- Thus, diseases from cigarettes can be expected to be found for HAP as well.
Biggest impacts from smoking

- Chronic obstructive lung disease
- Lung cancer
- Heart disease and stroke

- All associated with HAP
What other cancers from smoking?

- “Traditional” smoking cancers: oral cavity, pharynx, larynx, oesophagus, pancreas, urinary bladder, and renal pelvis
- Newly confirmed cancers: nasal, sinus, nasopharynx, stomach, liver, kidney, uterine cervix, oesophagus, and leukaemia

Review of Epi Evidence: Lung Cancer, 2004
Cervical Cancer and Household Air Pollution

Three papers; two done in Honduras, one in Columbia
Infectious disease and smoking

- pneumonia
- TB
- meningococcal disease
- otitis media
- influenza

*Archives of Internal Medicine, 2004*
Tuberculosis and Indoor Biomass and Kerosene Use in Nepal: A Case–Control Study

Amod K. Pokhrel,1 Michael N. Bates,1 Sharat C. Verma,2,3 Hari S. Joshi,3* Chandrashekhar T. Sreeramareddy,3** and Kirk R. Smith1

1School of Public Health, University of California–Berkeley, Berkeley, California, USA; 2Regional Tuberculosis Center, Ram Ghat, Pokhara, Nepal; 3Department of Community Medicine, Manipal Teaching Hospital, Manipal College of Medical Sciences, Pokhara, Nepal
Other impacts of smoking

- preterm delivery,
- stillbirth,
- low birth weight, and
- sudden infant death syndrome (SIDS)
- lower bone density in older women.
- cataracts
- IQ and cognitive impacts (SHS)

CDC, 2012
Pooled birth weight difference (low minus high exposure): Adjusted estimates (Boy and Tielsch have GA)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Lower Exposure</th>
<th>Higher Exposure</th>
<th>Mean Difference</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
<td>Mean</td>
</tr>
<tr>
<td>Boy 2002</td>
<td>2,835</td>
<td>533</td>
<td>357</td>
<td>2,772</td>
</tr>
<tr>
<td>Mishra 2004</td>
<td>3,271</td>
<td>1,448</td>
<td>766</td>
<td>3,096</td>
</tr>
<tr>
<td>Siddiqui 2008</td>
<td>2,812</td>
<td>404</td>
<td>80</td>
<td>2,730</td>
</tr>
<tr>
<td>Thompson 2005</td>
<td>2,805</td>
<td>579</td>
<td>366</td>
<td>2,723</td>
</tr>
<tr>
<td>Tielsch 2009</td>
<td>2,819</td>
<td>453</td>
<td>646</td>
<td>2,715</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>2215</td>
<td></td>
<td>11740</td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: $\chi^2 = 2.85, \text{ df} = 4 (P = 0.58); I^2 = 0\%$
Test for overall effect: $Z = 6.74 (P < 0.00001)$

All estimates: +96.6g (68.5, 124.7)
Excluding self-reports +93.1g (64.6, 121.6)

CRA: Pope et al., 2010
Neurodevelopmental performance among school age children in rural Guatemala is associated with prenatal and postnatal exposure to carbon monoxide, a marker for exposure to woodsmoke.

Linda Dix-Cooper\textsuperscript{a}, Brenda Eskenazi\textsuperscript{b}, Carolina Romero\textsuperscript{c}, John Balmes\textsuperscript{a,d}, Kirk R. Smith\textsuperscript{a,*}

\textsuperscript{a} Division of Environmental Health Sciences, School of Public Health, University of California, Berkeley, CA 94720-7360, USA
\textsuperscript{b} Center for Environmental Research and Children’s Health (CERCH), School of Public Health, University of California, Berkeley, CA, USA
\textsuperscript{c} Centro de Estudios en Salud Universidad Del Valle, Guatemala
\textsuperscript{d} Division of Occupational and Environmental Medicine, Department of Medicine, University of California, San Francisco, CA, USA
Bottom Lines

- We understand the risks of combustion particles not only from a large number of studies in households, but also from studies of outdoor air pollution, secondhand smoke, and active smoking.
- Over time, we can expect that nearly every effect found in smokers will be found from household smoke, but a lower risk levels.
- We no longer refer to it as “indoor” air pollution because the exposures occur not only inside, but around the house, down the street, and indeed regionally – “secondhand cook smoke”
Perfect Storm for Health Impacts

- Highly polluting activity
- Half of world households
- Several times a day
- Just when people are present
- Most vulnerable (women and young children) most likely to be there
Just because we know it’s a risk, does not mean we know how to fix it

• **1964**: Surgeon General’s Report but Framework Convention on Tobacco Control was 2005 and not all countries yet signed up and impacts growing

• **~1900**: Mosquito-born disease cause established, but still 1.4 million die of malaria today

• **~1890**: causation of health risk from human waste in drinking water firmly established: still today one-third of world population without adequate sanitation/water
Why is it so hard?

• What we know works, but gas and electricity (piped water/flush toilets), not “affordable” by the poor.
• Other technologies difficult and less effective and insufficient profits for private sector to enter
• Particularly difficult because of the high component of behavioral change required
• Easy unhealthy alternatives available – gathered biomass (and open defecation)
• Yet, the fact that 60% of the world is now protected, gives us reason to think we can protect the other 40%
What to do

• Will take a new type of research and development, however, both sophisticated and rigorous, to develop and test the interventions in ways to convince the health community

• And completely different levels of funding, for example the kinds of large intervention trials done for vaccines, water/sanitation, bednets, etc. – $10s of millions each
If it doesn’t take fifty years, it isn’t worth doing.*

*Attributed to Albert Einstein

- Let us hope, however, that in 2030 we are not like poor water/sanitation today, i.e., 120 years from when causation was accepted by most people, but still killing millions annually.

*Attributed to Albert Einstein
Summary

- Worst thing to do is stick burning stuff in your mouth – 5+ million premature deaths
- Next worse is burning in your house – 2+ million deaths
- Next worse is having someone else nearby sticking in their mouth – 400k+ deaths
- Even bad to have on your planet – 2+ million deaths from outdoor air pollution
- And climate change risks
- Chimneys do not help the last two—need to stop producing the pollution at all.
Many thanks to

Guatemala Ministry of Health, NIEHS, WHO, Griffin Trust, Daniele Agostino Derossi Foundation

Publications and presentations on website – easiest to just “google” Kirk R. Smith