Household Energy, Black Carbon, Climate, and Health

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2009 International Workshop on Black Carbon in Latin America

International Council on Clean Transportation, Instituto National de Ecologia, Centro Mario Molina

Mexico City, Oct 19, 2009
Road Map

• BC inventories for household fuel: framing issues
• Household fuel’s health impacts: pneumonia in children
• What interventions are needed for health and climate?
Black Carbon Emissions

All BC and OC data from T. Bond’s inventory
Feb 2009
Inventories for CO2, CH4, and N2O

Carefully parsed into “natural and “human-caused” as well as “pre-industrial and post-industrial”

Not done yet for BC, OC, and Sulfate.
Total Black Carbon Emissions in 2000

Source: T Bond Database, V 7.1.1 Feb 2009
Plus Bond et al., 2004

- Forest and Grassland: 38.4%
- Household: 24.7%
- Transport: 16.6%
- Industry: 19.0%
- Ships and Aircraft: 1.7%
- Power: 0.7%
- Waste Burning: 4.1%
- Ag Burning: 0.3%

Total: 7900 gigagrams

Controllable? Large fraction is not
One-third of methane emissions from natural sources – not put into anthropogenic group by IPCC
In CO₂ Inventories: rest is considered non-controllable or?
Pre-industrial but perhaps increased since

No forest or grass fires

Controllable Black Carbon Emissions in 2000
Source: T Bond Database, V 7.1.1 Feb 2009

Total: 5300 gigagrams

Household 36.8%
Ag Burning 6.2%
Waste Burning 0.5%
Power 1.1%
Ships and Aircraft 2.5%
Transport 24.7%
Industry 28.3%

Unequivocably Post-1750
~36% of total BC
~57% of controllable
Really four categories

- Natural – not amendable to human interventions (e.g., some wildfires)
- Pre-industrial but amendable to human interventions (e.g., household biomass fuel burning)
- Post-industrial (e.g., essentially all fossil fuel use)
- Net of the cooling from organic carbon particles
Intimately linked: Generally not possible to control one without the other
Ozone Total in 2005 (IPCC forcing).

Equivalent to 471 ppm CO$_2$

(on top of CO$_2$ background ~270 ppm)

May be a bit bigger if less historical emissions are determined.
Tropospheric Ozone Portion

Years

Months

Weeks

Decades to centuries

Could be a bit bigger if more forest and grass fires are seen to be controllable

Recommended Accounting

Controllable PIC Emissions Plus CO₂ Radiation Forcing in 2005

W/m²

0

0.5

1

1.5

2

CO₂

1.56

CH₄

0.66

0.20

CO+NMVOC

0.14

0.13

BC-OC

0.24

0.31

“IPCC”

“Ram/Car”
The climate change problem is caused not only by too much complete combustion of fossil fuels (CO2), but also by too much incomplete combustion of all fuels (PIC).
Combustion Particles: The Oldest Pollutant

- Oldest: first measured and regulated
  - First Royal Air Pollution Commission in history
    • Appointed in 1265, completed its report in 1306
    • (setting the standard for expert committees)
    • Recommended banning coal burning in London
    • Duly taken up 650 years later by the authorities (1956)
    • (setting the standard for policy response)
  - First systematic measurements in London in 1800s: on fire stations
  - First exposure response relationships for air pollutants
Combustion PM: The Newest Pollutant

• mechanisms of creation and impact are still not clear,
• effects of separate constituents, e.g., black carbon, still uncertain
• new health standards being implemented,
• new measurement methods being developed,
• even basic metrics in some doubt
• major impacts on regional and global climate now recognized
• difficult tradeoffs now discussed between climate and health goals
Energy flows in well-operating traditional woodfired cookstove

A Toxic Waste Factory!!

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

Smith et al., 2000
Toxic Pollutants in Biomass Fuel Smoke from Simple (poor) Combustion

• Small particles: Includes 3-10% BC
• 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 aromatics such as \textit{benzo(\textit{\gamma})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}

\textit{Naheer et al. 2007, JIT}
Size Distribution of Biomass Smoke Particles

Figure 2.2. Size distribution of woodsmoke and dungsmeke particles. Measurements taken in the East-West Center simulated village house as reported in Smith et al. (1984b). (Figure prepared by Premlata Menon.)

Source: Smith, Apte et al. 1984
National Household Solid Fuel Use, 2000
Áreas prioritarias por uso residencial de leña en México - 2000

Áreas accesibles de 10km de radio alrededor de localidades y 3km al costado de caminos
Productividad media de madera para energía por hectárea por año.

Índice de Prioridad por uso de Leña (IPL)

- Alto: 322 municipios
- Medio: 329 municipios
- Bajo: 402 municipios
- Sin Datos: 713 municipios
- Error: 625 municipios

Obras en ArcGIS 8.2 utilizando ArchMap.
The climate change problem is caused not only by too much complete combustion of fossil fuels (CO2), but also by too much incomplete combustion of all fuels (PIC).
~One-third of net black carbon and carbon monoxide emissions globally come from household fuels

~One-sixth of ozone causing pollutants

~One-twentieth of methane
20-month average ground-level PM2.5 from satellite data
Oldest Pollution Source in Human History
By definition

How Big the Health Impact Globally?
WHO, 2004

Global Burden of Disease from Top 10 Risk Factors
plus selected other risk factors

- Underweight: 4.9 million premature deaths/y
- Unsafe sex: 1.6 million premature deaths/y (~two-thirds in children; one-third in women)
- 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 in 2000

WHO, 2004
Cognitive Effects?

ALRI/Pneumonia (meningitis)

Asthma

Low birth weight

Early infant death

Cognitive Effects?

Chronic obstructive lung disease

Interstitial lung disease

Cancer (lung, NP, cervical, aero-digestive)

Blindness (cataracts, trachoma)

Tuberculosis

Heart disease

Diseases for which we have some epidemiological studies
Acute Lower Respiratory Infection (ALRI) in a Guatemalan Infant

Pneumonia from acute lower respiratory infections (ALRI)

Chief cause of death among the world’s children (~2 million per year). Thus, it is the chief global cause of lost healthy life years.

Well-accepted risk factors (malnutrition, micro-nutrient deficiencies, other diseases, crowding, chilling) do not account for its scale.
<table>
<thead>
<tr>
<th>Tip de Estudio</th>
<th>N*</th>
<th>OR</th>
<th>95% IC</th>
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<td>1.06, 1.54</td>
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<td>Cohorte</td>
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<td>2.12</td>
<td>1.06, 4.25</td>
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<td>Caso-control</td>
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<td>1.97</td>
<td>1.47, 2.64</td>
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<td>1.49</td>
<td>1.21, 1.85</td>
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<td>Todos</td>
<td>26</td>
<td>1.78</td>
<td>1.45, 2.18</td>
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*Número de estimaciones disponibles

Dherani et al., 2008
Bull WHO

26 estudios hechos alrededor del mundo muestran que niños viviendo en hogares con contaminación intradomiciliar, producida por combustibles para cocinar, padecen de 80% más de neumonía.
El Primer Estudio Randomizado De Aire Contaminado*

Después de una búsqueda del mundo, se escogió un sitio en el Altiplano de Guatemala

* En poblaciones normales
RESPIRE: (Randomized Exposure Study of Pollution Indoors and Respiratory Effects)

Highland Guatemala

Traditional 3-stone open fire  Plancha chimney wood stove
Effect of Plancha on PM2.5

Log Scale

- 1000
- 100
- 10
- 1

48-h ug/m³

Open fire

Plancha

Kitchen

~90% Reduction, sig.
~ 50% reduction in child exposures
Reasons that child personal exposures did not lower as much as kitchen levels:

--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
Effect of Plancha on PM2.5

- Kitchen
  - Open fire: ~90% Reduction, sig.
  - Plancha: ~20% reduction, ns

- Bedroom
  - Plancha: ~20% reduction, ns
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/krsmith
Heart Disease Risk
Pope et al, 2009

Exposure from smoking
≤3, 4-7, 8-12, 13-17, 18-22, and 23+
cigarettes/day

Second hand cigarette smoke:
Stars, from 2006 Surgeon General Report
and INTERHEART study (Teo et al. 2006)

And air pollution:
Hex, from Womens Health Initiative cohort,
includes all first cardiovascular events,
(Miller et al. 2007);
Diamonds, from ACS cohort
(Pope et al. 1995, 2002, 2004);
Triangles, Harvard Six Cities cohort
(Dockery et al. 1993; Laden et al. 2006)
<table>
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<tr>
<th></th>
<th>CO/CO2</th>
<th>NCE**</th>
<th>Eff %</th>
<th>CO g/kg</th>
<th>PM g/kg</th>
<th>Relative PM/meal</th>
<th>Less PM/meal</th>
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<tbody>
<tr>
<td><strong>Traditional</strong></td>
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<tr>
<td>Coal*</td>
<td>0.12</td>
<td>89.3%</td>
<td>25</td>
<td>166</td>
<td>1.6</td>
<td>23%</td>
<td>4.3x</td>
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<tr>
<td>Biomass*</td>
<td>0.15</td>
<td>87.0%</td>
<td>18</td>
<td>92</td>
<td>5.0</td>
<td>100%</td>
<td>1</td>
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<td><strong>Biomass Stove Winners</strong></td>
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<td>Linhong</td>
<td>0.011</td>
<td>98.9%</td>
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<td>2.2</td>
<td>0.22</td>
<td>2.2%</td>
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<td>Luoyang</td>
<td>0.019</td>
<td>98.1%</td>
<td>35.9</td>
<td>4.4</td>
<td>0.24</td>
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<td>Zhenghong</td>
<td>0.019</td>
<td>98.1%</td>
<td>32.6</td>
<td>5.1</td>
<td>0.24</td>
<td>2.7%</td>
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<td>Daxu</td>
<td>0.020</td>
<td>98.1%</td>
<td>32.6</td>
<td>5.8</td>
<td>0.28</td>
<td>3.1%</td>
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* Typical values       ** Nominal combustion efficiency
## Chinese National Stove Contest - 2007

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* Typical values       ** Nominal combustion efficiency

Compared to traditional biomass stove

32-45 times less mass of small particles per meal in lab

* Typical values       ** Nominal combustion efficiency
Blower

Hot water

Retail cost
~$80

CO2-eq
Savings
~$60/y
Current Cost-effective Region In Mexico
Adapted from Parry, 2009

**WATER**
- Increased water availability in most tropics and high latitudes
- Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes
- 0.4 to 1.7 billion
- 1.0 to 2.0 billion
- 1.1 to 3.2 billion
- Additional people with increased water stress

**ECOSYSTEMS**
- Increasing amphibian extinction
- Increasing coral bleaching
- Increasing species range shifts and wildfire risk
- About 20 to 30% species at increasingly high risk of extinction
- Most corals bleached
- Terrestrial biosphere tends toward a net carbon source, as:
- Major extinctions around the globe
- ~15%
- ~40% of ecosystems affected

**FOOD**
- Crop productivity
- Decreases for some cereals
- Increases for some cereals
- Mid to high latitudes
- About 31% loss of coastal wetlands
- All cereals decrease
- Decreases in some regions

**COAST**
- Increased damage from floods and storms
- Additional people at risk of coastal flooding each year
- 0 to 3 million
- 2 to 15 million
- About 31% loss of coastal wetlands
- Substantial burden on health services

**SINGULAR EVENTS**
- Local retreat of ice in Greenland and West Antarctic
- Long term commitment to several metres of sea level rise due to ice sheet loss
- Ecosystem changes due to weakening of the meridional overturning circulation
- Leading to reconfiguration of coastlines world wide and inundation of low-lying areas

**Global mean annual temperature change relative to 1980-1999 (°C)**

- The Co-benefits Potential

Emission peak 2035; T peaks 2100 at c. 3 deg C
“Wood is the fuel that heats you twice” - ?

- Actually four times
- Chopping
- Burning
- Fever from pneumonia
- Global warming
- Bottom line: combustion particles of all types have major impacts on health
“The Health Implications of the Shorter-lived Greenhouse Pollutants: Black Carbon, Sulfate, and Ozone”

Includes first published long-term cohort study of BC health effects – 66 US cities over 18 years

Smith KR, Jerrett M, Anderson R. et al. (Series on the impact on public health of strategies to reduce GHGs)


Thank you

All presentations and pubs available at http://ehs.sph.berkeley.edu/krsmith