Indoor Air Pollution measurement options

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exposure assessment pyramid
overview of options

1. Biomarkers
2. Direct EA of HH members with personal monitoring
3. Indirect EA of HH members using time activity & microenvironment measurements
4. HH IAP in one or more microenvironments without time activity
5. HH Fuel use, housing & stove characteristics in purposeful surveys
6. HH fuel use from large-scale general surveys, such as the census
7. Regional/National Fuel Use

Accuracy Cost
what characteristics can be measured?

- Ventilation (Air Exchange Rate)
- Indoor Concentrations
- Breath levels
- Personal Exposures
- Outdoor or Total emissions
- Indoor emissions
- Fuel & stove use patterns; Time-activity patterns
what pollutants can be measured?

- Particulate matter
- Carbon monoxide
- Nitrogen oxides
- Sulfur oxides
- Aldehydes
- More, but analysis & interpretation difficult

Outdoor or Total emissions
- CO₂
- Methane

Ventilation
CO is best

Breath levels
CO is easiest

Indoor Concentrations

Personal Exposures

Indoor emissions
when to measure?

- **Duration**
  - Cooking time
  - Morning to evening
  - ~24 h
  - ~48 h
  - ~7 day

- **Different Seasons**

- Generally much variation in a single household during short-term measurements = longer monitoring is better
sampling intervals

- Grab sample
- Integrated sample (average)
- Continuous (idea of peaks)
why measure indoor air pollution?

• Determine:
  – Distribution of exposures
  – Demographic characteristics affecting exposures

• Evaluate if interventions worked:
  – Fuel, stove, ventilation, education, etc.
  – Immediate
  – Over time

• Relate indoor air quality to health outcomes
“technical” solutions

- Better Ventilation
  - Windows: ~10-30% reduction in IAP
  - Hoods: ~25-70%

- Better Stoves
  - Chimneys: ~30-90%
  - Fuel efficiency: - 30% to 30%
  - Combustion efficiency (varies)

- Better Fuels
  - Gases & liquids:~80-99%
common IAP
measurement methods
the dynamic duo

Carbon Monoxide
• Bag collection, lab analysis
• Color-change diffusion tubes
• Electro-chemical monitors

Particulate Matter (PM)
• Gravimetric (pump & filter)
• Light-scattering monitors
indoor & personal carbon monoxide measurement methods

- **Diffusion tubes**
  - Small (can be worn by participant)
  - Indicated by stain length in tube
  - Measures total exposure, not continuous

- **Electrochemical sensors**
  - Small, lightweight, can be worn easily by most participants
  - CO concentration determined by measuring current of a small fuel cell
  - Precision of 0.2-2 ppm

biological carbon monoxide measurement methods

• Exhaled breath (measured in ppm or COHb)

• Blood carboxyhemoglobin
  - Optical Methods (CO-oximetry)
  - Gas chromatography (gold standard)

ambient, indoor & personal particulate matter measurement methods

- pump & filter
- light-scattering devices
- many others
Self-governing programmable pump
Chargeable battery (battery charger not shown)
Airflow calibrator
Cyclone for size selection
Filter cassette
Petri dishes for transporting filters

heavy & bulky
limited data (one average number)
slow (weeks to obtain results)
expensive (~$40 per datum, >$10k capital cost)

real-time data-logging devices,
but can be fragile & expensive
PM measurement options:
light scattering instruments

• Continuous
  – TSI Dusttrak ($6500/unit)
  – TSI SidePak ($5400/unit)
  – Thermo Electron/MIE Personal DataRam ($4250/unit)
  – UCB Particulate Monitor (~$350/unit, to be determined)
<table>
<thead>
<tr>
<th></th>
<th>Air Pump</th>
<th>Keeps Time</th>
<th>Size Selection</th>
<th>Minimum Detection Limit</th>
<th>Detection Method</th>
<th>Cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pump &amp; filter</strong></td>
<td>yes</td>
<td>no</td>
<td>specify with cyclone</td>
<td>depends on balance &amp; volume sampled</td>
<td>gravimetric</td>
<td>~$1000/pump &amp; cyclone plus $40/sample</td>
</tr>
<tr>
<td><strong>TSI Dusttrak</strong></td>
<td>no</td>
<td>yes</td>
<td>PM2.5 PM10</td>
<td>~1 µg/m³</td>
<td>light scattering</td>
<td>$6500/unit</td>
</tr>
<tr>
<td><strong>UCB Particle Monitor</strong></td>
<td>no</td>
<td>yes</td>
<td>~0.5µm-5µm</td>
<td>~50 µg/m³</td>
<td>light scattering</td>
<td>~$350/unit (to be determined)</td>
</tr>
<tr>
<td><strong>Grimm Aerosol Monitor</strong></td>
<td>no</td>
<td>yes</td>
<td>0.3 - &gt;10µm</td>
<td>1 µg/m³</td>
<td>laser light scattering</td>
<td>$17,000</td>
</tr>
</tbody>
</table>
Both devices require use of personal computers & software to launch & download data.

**Gastec CO diffusion tubes**
- integrated
- simple
- relatively cheap

**HOBO CO monitor**
- continuous
- datalogging
- no direct readout
- many weeks/battery

**UCB Particle Monitor**
- continuous
- datalogging
- no direct readout
- temperature
- humidity
- 1 week+/battery
- small particle sensitivity
- no sensitivity to larger PM

**Personal or area monitors**
How does the HOBO CO data logger work?

- Electrochemical sensor
  - Converts CO gas to an electric signal
how does the electrochemical sensor work?

• 2 electrodes immersed in a highly conductive electrolyte solution (sulfuric acid)

• CO, in the present of O₂, is converted to CO₂

• voltage drop across resistor is measured using Ohm’s law (V=IR)

• voltage related to CO concentration

http://www.monox.com/
## HOBO CO logger specifications

<table>
<thead>
<tr>
<th>nominal range (ppm)</th>
<th>resolution (ppm)</th>
<th>maximum error (0°-40°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 125</td>
<td>0.5</td>
<td>±10.5 ppm ± 12% of reading</td>
</tr>
<tr>
<td>0 to 500</td>
<td>2.0</td>
<td>±12 ppm ± 12% of reading</td>
</tr>
<tr>
<td>0 to 2000</td>
<td>8.0</td>
<td>±18 ppm ± 12% of reading</td>
</tr>
</tbody>
</table>

Source: [http://www.onsetcomp.com/](http://www.onsetcomp.com/)
48 Hours of Continuous Carbon Monoxide Monitoring in a Guatemalan Home Using an Open Fire for Cooking, (HOBO monitor, ppm)
comparison of open fire & improved stove: carbon monoxide levels (HOBO monitor)

Open Fire

Plancha
how does the UCB light scattering chamber work?
Temperature & Humidity Sensor

Data Logger
Dust Track and UCB Measurement in Guatemala
(minute by minute comparison in an Open Fire House)

- Dust Track
- Mean of 15 UCBs with 1 Std Dev

Avg mass DT = 2.6+/-.53 mg/m³
Avg mass 15 UCBs = 1.9+/-.42 mg/m³

R² ~ 0.9
what do the smoke levels during 24 hours in an open fire home look like?

Although the HOBO-CO and UCB-PM monitors measure different pollutants - CO and small particles - both show the patterns of stove usage in the home.
CO & particle measurements agree well with each other in preliminary data from ten Mexican households (Gira)

$y = 5.8206x + 0.4654$

$R^2 = 0.9881$

48-h mean concentrations
limitations to CEIHD kit

- HOBO CO logger
  - requires recalibration
  - eventually replace sensor ($25)
  - lots of data

- CO dosimeter tube ($5/tube)
  - imprecise
  - one-time use
  - expensive for large studies

- UCB particle monitor
  - requires zeroing at every use
  - needs careful cleaning
  - new technology (not traceable to national standards)
  - lots of data

- None produce a physical sample
4 points to remember

• IAP measurements necessary for validating effectiveness of improved stoves

• many IAP measurement options that vary in cost and accuracy (tradeoffs)

• choice of method depends on context (purpose, capacity, finances)

• all methods require data management & quality assurance/quality control plans

thanks…
What new information did you learn about available indoor air pollution monitoring instruments?
extras
outdoor

**carbon monoxide measurement methods**

- **NDIR method: Nondispersive infrared technique**
  - EPA reference method
  - Automated and continuous
  - Based on specific absorption of infrared radiation by the CO molecule (4.6 \( \mu \text{m} \))
  - Stationary

- **Gas Chromatography**
  - Flame Ionization: CO converted to CH4, passed through flame ionization detector (FID), resulting signal proportional to amount of CO in air
  - Mercury Liberation

- **Tunable Diode Laser Spectroscopy**
- **Resonance Fluorescence**

Partial Contents of Shell Foundation HEH IAP Monitoring Kit

Particles: ~$1800
---6 UCB P-3 particle monitors with pre-installed firmware and long-term batteries
---Software for desktop or laptop PC to launch, download, and manipulate data from monitors (CD-ROM)
---Ziploc bags for zeroing monitors before and after each use
---12 9V batteries for initial operation (additional alkaline batteries to be supplied locally)

Carbon monoxide: ~$2000
---6 Onset-HOBO datalogging CO monitors for routine monitoring
---1 “Gold-standard” Onset-HOBO CO monitor for calibration only
---Software for desktop or laptop PC to launch and download HOBOs (CD-ROM)
---7 extra batteries (additional 3V calculator-type batteries to be supplied locally)
---100 CO diffusion tubes for integrated sampling
---10 double labels and caps for diffusion tubes (plus six holders)
---Static free bags to protect HOBOs
Pre- and Post- Fieldwork Calibration Tests, Berkeley, 2003

$y = 0.97x + 0.23$  
$R^2 = 0.998$

$y = 0.75x - 0.73$  
$R^2 = 0.995$

$y = 0.99x + 0.44$  
$R^2 = 0.995$

$y = 0.69x - 0.69$  
$R^2 = 0.994$

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True concentration (standards: 0.5, 10.3, 24.9, 60ppm)

Measured concentration (2 m in average)

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Linear (hco_675_post-fieldwork)
Linear (hco_675_pre-fieldwork)
Linear (hco_678_post-fieldwork)
Linear (hco_678_pre-fieldwork)
## HOBO CO Logger Specifications

<table>
<thead>
<tr>
<th>Measurement Range:</th>
<th>Nominal Range (ppm)</th>
<th>Actual Range (ppm)</th>
<th>Resolution (ppm)</th>
<th>Typical Accuracy*** (over 0° to 40°C)</th>
<th>Maximum Error (over 0° to 40°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 125</td>
<td>0.2 to 124.3</td>
<td>0.5</td>
<td>±4.5 ppm ±7% of reading</td>
<td>±10.5 ppm ±12% of reading</td>
<td></td>
</tr>
<tr>
<td>0 to 500</td>
<td>1 to 497.1</td>
<td>2.0</td>
<td>±6 ppm ±7% of reading</td>
<td>±12 ppm ±12% of reading</td>
<td></td>
</tr>
<tr>
<td>0 to 2000</td>
<td>4 to 1988</td>
<td>8.0</td>
<td>±12 ppm ±7% of reading</td>
<td>±18 ppm ±12% of reading</td>
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**Physical shocks or rapid changes in ambient pressure may show up as spikes in the data.**

**Battery life is shorter when CO levels average 10 ppm or more. For example, battery life is 6 months at average concentrations of 100 ppm.**

***The CO sensor is temperature compensated over the entire operation range. In addition to specifications above, for temperatures 0° to 20°C readings may be lower by as much as 5% or 5 ppm, whichever is greater. For temperatures 20° to 40°C, the readings may be higher by as much as 5% or 5 ppm, whichever is greater.
Figure 3.3. Air exchange rates in two Indian village houses as determined by decay of CO concentrations. Closing the window in the kitchen of house B resulted in a lowering of air exchange rate.
Ventilation experiment (Data From HH07, Kaldari, India, July, 2003)

\[ y(P_1) = -19.56x + 1.22 \quad R^2 = 0.88 \]

\[ y(P_2) = -13.06x + 2.50 \quad R^2 = 0.99 \]

\[ y(P_3) = -9.58x + 1.25 \quad R^2 = 0.96 \]

\[ y(P_4) = -11.06x + 2.08 \quad R^2 = 0.99 \]

Source: Seema Bhangar