Particulate Matter (PM) and Carbon Monoxide (CO) Exposure in the Nepal Cookstove Study

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Main Trial Study Design

• The Nepal Cookstove Intervention Project is a cluster-randomized, modified step-wedge trial nested in Nepal Nutrition Intervention Project- Sarlahi (NNIPS)

• Aim is to evaluate the impact of using enhanced, ventilated cookstoves to improve indoor air quality for maternal and child health

• Continuous PM, CO, and temperature/humidity were measured before and after new stove installation in eligible households for ~24hs

• 3,360 eligible households for pre-intervention
  – 5,121 children under age of 3
  – 3,700 married, child-bearing age females
  – 12,441 other adults
Pre-Trial Cookstove Evaluation Study

• Mock house built at study site
  – PM concentration and RH
  • Background and during simulated cooking event (water boil test)
  – Cooking concentration measurements adjusted for background, RH, and converted to PM$_{2.5}$ gravimetric equivalent
Comparison of Traditional Stove to Two Alternative

- Traditional, mud stove
- Alternative Mud Brick Stove Chimney (AMBS)
- Envirofit Stove (G3355) with Chimney
Comparison of Mud/Brick Stove with a Chimney to LPG and Envirofit Stoves

- Study Altered Envirofit Stove with Chimney
- Manufacturer Altered Envirofit Stove with Chimney
- LPG

Alternative Mud Brick Stove Chimney
## Analysis of Cookstove Performance

### Alternative Cookstoves vs. Traditional Stove

<table>
<thead>
<tr>
<th>Type of Measurement</th>
<th>Traditional Stove</th>
<th>Mud Brick Stove with Chimney</th>
<th>Envirofit G Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{2.5}$ Concentration (% Reduction)</td>
<td>Reference</td>
<td>Mean % (95% CI)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>60 (44, 72)**</td>
<td>50 (28, 65)**</td>
</tr>
<tr>
<td>Boiling Time (% Increase)</td>
<td></td>
<td>86 (72, 101)**</td>
<td>104 (88, 121)**</td>
</tr>
<tr>
<td>Fuel Use (% Increase)</td>
<td></td>
<td>39 (24, 55)**</td>
<td>6 (-5, 19)</td>
</tr>
</tbody>
</table>

- **p<0.001
- Analysis adjusted for fuel type and starting water temperature
### Study 2: Multivariate Analysis of Cookstove Performance

**Alternative cookstoves vs. Alternative Mud Brick Stove**

<table>
<thead>
<tr>
<th>Type of Measurement</th>
<th>Mud/Brick Stove with Chimney</th>
<th>Manufacturer Modified Envirofit</th>
<th>Locally Modified Envirofit</th>
<th>LPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{2.5}$ Concentration (% reduction)</td>
<td>Reference</td>
<td>39 (5, 60)*</td>
<td>39 (8, 60)*</td>
<td>✫</td>
</tr>
<tr>
<td>Boiling Time (% increase)</td>
<td>7 (-0.2, 14)</td>
<td>-0.2 (-8, 7)</td>
<td>49 (45, 53)**</td>
<td></td>
</tr>
<tr>
<td>Fuel Use (% decrease)</td>
<td>25 (17, 33)**</td>
<td>22 (14, 29)**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Analysis adjusted for fuel type and window/door status
- *p<0.05
- **p<0.001
- Resultant concentration was indistinguishable from background levels, therefore actual reduction is unknown.
Stoves Selected for Main Trial

Traditional Mud Stove

Improved Stove (Envirofit G3300/G3355)
Sampling Method

- DataRAM pDR-1000
- LASCAR CO data logger
- HOBO U10 Temperature and Humidity Data Logger
- Placed ~1 meter in front of the stove and ~1.5 meters off the floor
- Median sampling time is 21.5 h (Interquartile Range [IQR], 20.9—22.1) for PM and CO

http://tinyurl.com/low5k4w
http://tinyurl.com/kpmnu3f
http://tinyurl.com/mas9ukj
Distribution of Pre- and Post-Intervention PM$_{2.5}$ and CO

<table>
<thead>
<tr>
<th>Exposure</th>
<th># HH</th>
<th>Mean (95% CI)</th>
<th>Median (IQR)</th>
<th>95th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-installation</td>
<td>PM (μg/m$^3$)</td>
<td>2957</td>
<td>1424 (1377—1470)</td>
<td>1113 (627—1813)</td>
</tr>
<tr>
<td></td>
<td>CO (ppm)</td>
<td>2000</td>
<td>11.1 (10.7—11.5)</td>
<td>8.3 (4.6—14.6)</td>
</tr>
<tr>
<td>Post-installation</td>
<td>PM (μg/m$^3$)</td>
<td>2393</td>
<td>974 (928—1019)</td>
<td>690 (377—1215)</td>
</tr>
<tr>
<td></td>
<td>CO (ppm)</td>
<td>1623</td>
<td>6.8 (6.4—7.1)</td>
<td>4.1 (2.2—8.2)</td>
</tr>
</tbody>
</table>

Cumulative probability vs. Average CO Conc. (ppm)

Cumulative probability vs. Average PM conc. (μg/m$^3$)

Pre-SI
PM$_{2.5}$ during Cooking vs. Non-cooking

Start point: difference in two points higher than 0.4×daily average

Baseline: average of 20 mins before start point

End point: point lower than baseline + 0.2×daily average, and stops decreasing

Peaks shorter than 20 minutes apart would be identified as one cooking event

Peak shorter than 20 minutes would not be identified as a cooking event.

Sampling time
Distribution of Pre- and Post-Intervention Cooking and Non-cooking PM$_{2.5}$

<table>
<thead>
<tr>
<th>Exposure</th>
<th># HH</th>
<th>Mean (95% CI)</th>
<th>Median (IQR)</th>
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</tr>
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<tr>
<td><strong>Pre-installation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooking PM (μg/m$^3$)</td>
<td>2957</td>
<td>4769 (4603—4935)</td>
<td>3497 (2000—6006)</td>
<td>12569</td>
</tr>
<tr>
<td>Non-cooking PM (μg/m$^3$)</td>
<td>2957</td>
<td>345 (329—362)</td>
<td>218 (78—490)</td>
<td>1020</td>
</tr>
<tr>
<td><strong>Post-installation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooking PM (μg/m$^3$)</td>
<td>2393</td>
<td>3306 (3156—3456)</td>
<td>2281 (1240—4152)</td>
<td>9022</td>
</tr>
<tr>
<td>Non-cooking PM (μg/m$^3$)</td>
<td>2393</td>
<td>246 (221—272)</td>
<td>124 (54—293)</td>
<td>728</td>
</tr>
</tbody>
</table>
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