Biomass Combustion and Health Effects

National Tribal Forum on Air Quality
May 22-24, 2012
Tulsa, OK

Curtis W. Noonan, Ph.D.
Associate Professor of Epidemiology
Center for Environmental Health Sciences
The University of Montana
Overview

• Particulate Matter (PM) Health-based Standards
• Sources of Biomass Combustion-derived PM
• Vegetative Fires
  – Respiratory versus cardiovascular health effects
• Global Health Burden and Biomass Smoke
  – Cookstoves and Health
• Wood stoves and Health
  – Ambient Biomass Smoke and Health
  – Indoor Biomass Smoke Intervention Effectiveness
• Are there effective and sustainable interventions for wood stove homes?
National Ambient Air Quality Standards for PM$_{2.5}$
National Ambient Air Quality Standards for PM$_{2.5}$
Biomass Smoke Sources of PM$_{2.5}$
“Particulate pollution affects more people globally on a continuing basis than any other air pollutant.” WHO, Health Guidelines for Vegetation Fire Events 2000.
National Ambient Air Quality Standards for PM$_{2.5}$

24-Hour (1997)  
24-Hour (2006)  
Annual  
2000 Fire, Daily Avg, Missoula  
2003 Fire, Daily Avg, Missoula
Study Design: Time Series

Monthly visits for asthma and average monthly PM$_{2.5}$, Missoula, MT 2000-2003

Study Design: Time Series

Monthly visits for asthma and average monthly PM$_{2.5}$, Missoula, MT 2000-2003

Monthly visits for asthma and average monthly PM$_{2.5}$, Missoula, MT 2000-2003
Relative risk for hospital visits per 10 $\mu$g/m$^3$ increase in PM$_{2.5}$
# Vegetative Fires and Health Outcomes: Selected Studies

<table>
<thead>
<tr>
<th>Geographic Location</th>
<th>Respiratory Health</th>
<th>Cardiovascular Health</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>California</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duclos et al., 1990</td>
<td>+ Incr. respiratory (ED visits)</td>
<td>- No assn. IHD, HF (Hosp ad)</td>
</tr>
<tr>
<td>Delfino et al., 2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>British Columbia</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moore et al., 2006</td>
<td>+ Incr. respiratory (MD visits)</td>
<td>- No assn. CVD (MD visits)</td>
</tr>
<tr>
<td>Henderson et al., 2011</td>
<td></td>
<td>- No assn. CVD (MD or Hosp)</td>
</tr>
<tr>
<td><strong>Australia</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper et al., 1994</td>
<td>- No assn. asthma (ED visits)</td>
<td>- No assn. CVD (Hosp ad)</td>
</tr>
<tr>
<td>Smith et al., 1996</td>
<td>- No assn. asthma (ED visits)</td>
<td></td>
</tr>
<tr>
<td>Johnston et al., 2002</td>
<td>+ Incr. asthma (ED visits)</td>
<td></td>
</tr>
<tr>
<td>Johnston et al., 2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morgan et al., 2010</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Challenges for studies of fire events

- Small numbers
- Episodic PM events
- Missing some PM$_{2.5}$ data
- Limited reliability of hospital record data
- Minimal individual-level data (e.g., zip code)
Other sources of exposure to biomass smoke: indoor cooking and heating

Cookstoves, primarily in developing country settings.

Wood stoves, used throughout the world and common in rural U.S. and some Native American communities.
Cookstoves: an important source of biomass smoke exposure and related health effects

• More than half of world’s population uses biomass for energy needs
• Primarily impacts women and infants

Household solid fuel use

Estimated Indoor PM$_{2.5}$ in Cookstove Homes

Naeher et al., Inhalation Tox. 2007.
Cookstoves: an important source of biomass smoke exposure and related health effects

• Demonstrated health effects:
  – Lower respiratory tract infections (e.g., pneumonia)
  – Chronic obstructive pulmonary disease (COPD)

• Other potential health effects:
  – Low birth weight
  – Blood pressure or heart disease?
  – Cognitive effects?
  – Cancer
  – Ocular disease

Global burden of disease

- World Health Organization estimated Disability-adjusted Life Years (DALYs) for specific risk factors.
- Indoor smoke from solid fuels fell was among the top 10 contributors to global DALYs.
- Exposure to indoor smoke from solid fuels may be responsible to 1.6 million + deaths.
- The majority of mortality and DALY attributed to indoor smoke from solid fuels is due to the risk of pneumonia among children under 5 years in developing countries.

Wood stoves: A community intervention
Policy: 2003 PM$_{2.5}$ Nonattainment Areas
National Ambient Air Quality Standards for PM$_{2.5}$
Community scale wood stove intervention: Libby, MT

• June 2005 to June 2007:
  – Initial phase, 260 old woodstoves replaced for free with new woodstoves

• January 2006 to March 2008: Voucher program
  – Approved appliance: $700
  – Installation: $300
  – Stove removal: $200
  – Early incentive: $100
  – Other: $700
  – Furnace: $1,400
  – MT tax credit: $500

• Total funding: $2.1 million
  – Grant and equipment from HPBA: $1 million
  – Senate appropriation: $1 million
  – EPA grant: $100,000
Ambient PM$_{2.5}$ and cumulative changeout of wood stoves in Libby, MT 2003 – 2009

Table 2  Proportion (%) of respondents by survey year according to selected characteristics

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boy</td>
<td>53.8</td>
<td>49.5</td>
<td>47.8</td>
<td>52.0</td>
</tr>
<tr>
<td>Girl</td>
<td>46.2</td>
<td>51.5</td>
<td>52.2</td>
<td>48.0</td>
</tr>
<tr>
<td><strong>Grade</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–2</td>
<td>20.2</td>
<td>18.5</td>
<td>17.9</td>
<td>21.6</td>
</tr>
<tr>
<td>3–4</td>
<td>22.6</td>
<td>19.6</td>
<td>19.1</td>
<td>23.0</td>
</tr>
<tr>
<td>5–6</td>
<td>24.4</td>
<td>16.6</td>
<td>22.6</td>
<td>19.8</td>
</tr>
<tr>
<td>7–8</td>
<td>32.8</td>
<td>19.2</td>
<td>15.3</td>
<td>11.9</td>
</tr>
<tr>
<td>9–10</td>
<td>—</td>
<td>26.1</td>
<td>17.9</td>
<td>13.0</td>
</tr>
<tr>
<td>11–12</td>
<td>—</td>
<td>—</td>
<td>7.2</td>
<td>10.7</td>
</tr>
<tr>
<td><strong>Type of heating</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood</td>
<td>43.3</td>
<td>42.2</td>
<td>43.3</td>
<td>41.6</td>
</tr>
<tr>
<td>Propane</td>
<td>29.9</td>
<td>24.2</td>
<td>27.0</td>
<td>24.9</td>
</tr>
<tr>
<td>Gas</td>
<td>3.7</td>
<td>3.9</td>
<td>4.4</td>
<td>3.5</td>
</tr>
<tr>
<td>Oil</td>
<td>20.5</td>
<td>21.4</td>
<td>21.2</td>
<td>16.0</td>
</tr>
<tr>
<td>Electricity</td>
<td>38.9</td>
<td>43.4</td>
<td>43.0</td>
<td>39.5</td>
</tr>
<tr>
<td>Tobacco use in home</td>
<td>36.7</td>
<td>32.9</td>
<td>30.8</td>
<td>33.6</td>
</tr>
<tr>
<td>Also responded in 2006</td>
<td>—</td>
<td>43.6</td>
<td>38.1</td>
<td>28.4</td>
</tr>
</tbody>
</table>
Adjusted odds ratio (95% CI) for effects of PM$_{2.5}$ and wood stove on parent-reported symptoms and infections over a four winter period.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Ambient PM$_{2.5}$ reduction† OR (95% CI)</th>
<th>Wood stove in home‡ OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheeze</td>
<td>0.73 (0.55 to 0.97)</td>
<td>1.04 (0.72 to 1.51)</td>
</tr>
<tr>
<td>Morning tightness of chest</td>
<td>0.93 (0.66 to 1.32)</td>
<td>0.63 (0.41 to 0.96)</td>
</tr>
<tr>
<td>Attack of shortness of breath</td>
<td>0.80 (0.54 to 1.17)</td>
<td>0.84 (0.52 to 1.35)</td>
</tr>
<tr>
<td>Shortness of breath after exercise</td>
<td>1.03 (0.77 to 1.38)</td>
<td>0.98 (0.68 to 1.40)</td>
</tr>
<tr>
<td>Wake up at night by an attack of shortness of breath</td>
<td>1.03 (0.61 to 1.71)</td>
<td>0.96 (0.50 to 1.86)</td>
</tr>
<tr>
<td>Wake up at night by an attack of coughing</td>
<td>0.90 (0.75 to 1.08)</td>
<td>1.05 (0.83 to 1.32)</td>
</tr>
<tr>
<td>Other symptoms and infections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Itchy/watery eyes</td>
<td>0.67 (0.55 to 0.81)</td>
<td>0.96 (0.76 to 1.22)</td>
</tr>
<tr>
<td>Sore throat</td>
<td>0.68 (0.57 to 0.82)</td>
<td>0.96 (0.78 to 1.18)</td>
</tr>
<tr>
<td>Cold</td>
<td>0.75 (0.60 to 0.92)</td>
<td>0.93 (0.74 to 1.18)</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>0.45 (0.27 to 0.76)</td>
<td>1.60 (0.85 to 3.03)</td>
</tr>
<tr>
<td>Influenza</td>
<td>0.48 (0.40 to 0.57)</td>
<td>0.98 (0.78 to 1.22)</td>
</tr>
<tr>
<td>Throat infection</td>
<td>0.55 (0.42 to 0.71)</td>
<td>0.83 (0.61 to 1.13)</td>
</tr>
<tr>
<td>Middle-ear infection</td>
<td>0.71 (0.49 to 1.03)</td>
<td>1.30 (0.81 to 2.07)</td>
</tr>
</tbody>
</table>

*Adjusted for age and community influenza rate. Two-year grade groupings are used as a surrogate for age.
†Per 5 µg/m³ decrease in average winter PM$_{2.5}$.
‡Absence of wood stove in home was used as the reference category.
How did the stove changeout program impact indoor air quality?
Issue: Can we intervene in woodstove homes to reduce indoor exposures and improve health?
Policy: Indoor PM Exposure?

PM$_{2.5}$ ($\mu$g/m$^3$)

- 24-Hour (1997)
- 24-Hour (2006)
- Annual

Libby WS Homes, 24-Hour Average
Average indoor PM$_{2.5}$ Following Wood Stove Change

- Pre Change: Mean (sd) = 45.0 (33.0) $\mu$g/m$^3$
- Post Change: Mean (sd) = 21.0 (19.2) $\mu$g/m$^3$

Homes

Noonan et al., Indoor Air 2012.
Inconsistent impact of wood stove upgrade on indoor air quality

<table>
<thead>
<tr>
<th>Study Area</th>
<th>No. Homes</th>
<th>Pre-change median PM$_{2.5}$</th>
<th>Post-change Median PM$_{2.5}$</th>
<th>Proportion of Homes with No Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Libby, MT$^1$</td>
<td>21</td>
<td>33</td>
<td>14*</td>
<td>33%</td>
</tr>
<tr>
<td>Nez Perce Reservation$^4$</td>
<td>15</td>
<td>29</td>
<td>17*</td>
<td>33%</td>
</tr>
<tr>
<td>Northern BC$^2$</td>
<td>15</td>
<td>13</td>
<td>12</td>
<td>40%</td>
</tr>
<tr>
<td>Western MT and Idaho$^3$</td>
<td>11</td>
<td>54</td>
<td>34</td>
<td>45%</td>
</tr>
</tbody>
</table>

* Significant average reduction.
1 Noonan et al., Indoor Air 2012.
2 Allen et al., Atmos Environ 2009.
3 Semmens et al., ISEE 2011.
What about in-home filter interventions?

![Graph showing reduction in indoor PM2.5 levels with filter interventions, indicating a 59% reduction.]
Air Filter Intervention: Cost and Compliance

Survey of usage in winter following participation (n=17)

- 9/17 still using continuously
- 5/17 partial use
- 3/17 no use
- Main complaints
  - Noise
  - Cost
- Poor compliance with rec. filter replacement

Semmens et al., ISEE 2012.
What other interventions could be considered in wood stove homes?
Components of a “Best-Burn Practices” Education Intervention

1. Preparing your wood supply
2. Using your wood stove
3. Maintenance
4. What and when to burn
Properly dried wood has cracks on the ends and sounds hollow when knocked against another piece of wood.
Wood supply

Burn Temperature

“Burning your stove without a thermometer is like driving without a speedometer.”
- Jerry Marquez, Libby, MT
“Best-Burn Practices” Education Intervention

Can efficacy be tested?
Acknowledgments

Libby, MT
• Kathi Hooper (Lincoln Cnty Health)
• Kirby Maki (Libby School District)
• Helena Cassidy (Asa Wood School)
• Kim Edlund (Asa Wood School)
• Margie O’Brien Johnson (Asa Wood)
• Ron Goodman (Libby Middle School)
• Keith Ivers (Libby Middle School)
• Gigi Scofield (Libby Middle School)
• Rik Rewarts (Libby High School)

Montana Dept Environ Quality
• Bob Habeck
• Eric Merchant
• Elton Erp

Nez Perce Reservation
• Johna Boulafentis (ERWM)
• Julie Simpson (ERWM)
• Angela Porter (NMPH)
• Tui Molinga (NMPH)

University of Montana
• Tony Ward
• Carolyn Hester
• Marcy McNamara
• Luke Montrose
• Erin Semmens
• Emily Weiler
• Desirae Ware

Colorado School of Mines
• William Navidi

University of Washington
• Lianne Sheppard

This research is supported by the Health Effects Institute (#4743-RFA04-4/06-4), the National Institute of Environmental Health Sciences (1R01E016336-01; 3R01ES016336-02S1 ), and NCRR (COBRE P20RR017670).
References

- http://www.epa.gov/burnwise/