Wood Burning and Health: What Should Clinicians Know?

Michael Brauer

Grand Rounds, Allegheny General Hospital
Pittsburgh, PA
November 19, 2013
Air pollution and health

• Air pollution (individual) risk is small...but large exposed population = large population risk
  – Smoking: Larger risk, smaller exposed population
• On **days** with worse air quality, more people die*
• In **more polluted cities**, people die earlier than in less polluted cities...
• ...and, in the **most polluted areas** of cities, there is an increased risk of dying

*out-of-hospital, >65 yrs

The benefits of policies to address population risk

- Air quality regulations benefit:cost ratios
  ~4:1 – 30:1
- Clean air rules responsible for majority of ALL estimated benefits (and costs) generated by Federal regulation
"...the overall evidence is consistent with a causal relationship between PM2.5 exposure and cardiovascular morbidity and mortality."
The carcinogenicity of outdoor air pollution

In October 2013, 24 experts from 11 countries met at the International Agency for Research on Cancer (IARC), Lyon, France, to assess the carcinogenicity of outdoor air pollution. This assessment was the last in a series that began with specific combustion products and sources of air pollution and concluded with the complex mixture that contains all of them. The results of this most recent assessment will be published as volume 109 of the IARC Monographs.

Outdoor air pollution is a mixture of multiple pollutants originating from a myriad of natural and anthropogenic sources. Transport, power generation, industrial activity, biomass burning, and domestic heating and cooking are the predominant anthropogenic sources in many locations. The risk of pollutants in outdoor air is usually linked to traffic or traffic emissions, in studies that were adjusted for tobacco smoking. However, most studies assessed exposure only by employment in occupations with potentially high exposure to outdoor air pollution, so the results did not weigh heavily in the evaluation.

The Working Group also reviewed evidence regarding the carcinogenicity of outdoor air pollution in experimental animals. As part of this process, the IARC’s earlier evaluations of diesel engine exhaust and of emissions from the combustion of coal and wood were updated and confirmed. All of these agents can be present in outdoor air and were shown previously to cause benign and malignant lung tumours in mice or rats.

Air pollution a leading cause of cancer - U.N. agency

By Kate Kelland and Stephanie Nebra

(Reuters) - The air we breathe is laced with cancer-causing substances and is being officially classified as carcinogenic to humans, the World Health Organization's cancer agency said on Thursday.

Air pollution really is cancerous, according to World Health Organization agency

By Marga Cheng, The Associated Press

OCTOBER 17, 2013

The World Health Organization (WHO) has issued a report on air pollution and cancer, saying that it is one of the leading causes of cancer worldwide. The report is based on a review of the scientific literature and includes data from over 300 studies from around the world. The report estimates that outdoor air pollution is responsible for 3.7 million deaths per year, with 80% of those deaths occurring in low and middle-income countries. The report also highlights the health effects of indoor air pollution, which is a major concern in many parts of the world.
Burden of disease attributable to 15 leading risk factors in 2010, expressed as a percentage of United States DALYs

- Dietary risks
- Smoking
- High body-mass index
- High blood pressure
- High fasting plasma glucose
- Physical inactivity
- Alcohol use
- High total cholesterol
- Drug use
- Ambient PM pollution
- Occupational risks
- Childhood sexual abuse
- Intimate partner violence
- Lead
- Low bone mineral density

USA (2010)

- IHD, Stroke, Lung Cancer, COPD, Lower Respiratory Infections

103,000 deaths/yr PM$_{2.5}$ (7305 deaths/yr ozone)

Among top risk factors (#8 deaths, #10 DALYs)

Lim et al. The Lancet 2012; 380:2224-2260
Wood biomass fuels in context

• Inexpensive, secure fuel
  – Increasing/fluctuating costs & taxes for fossil fuels
  – Energy independence

• Promoted by public policies as a renewable, GHG-neutral fuel

• Relatively unregulated source
  • federal regulations minimal
  • state scrutiny varies

• Impact on winter air quality coinciding with stagnation
• Exposure proximity, high “intake fraction”
• Health impacts largely absent from policy debate
• Solutions exist!
“Utility bills are now so expensive for Greek families that some have taken to burning wood to stay warm. The result is an eerie fog of smoke looming above the city.”
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Issues raised in response:

• Is biomass really inexpensive?
• Sufficient supply?
• Carbon neutrality
  • Stock replacement
  • Black Carbon
• Emissions of current technologies > emissions of oil, natural gas
  • need cleanest fuels/emissions controls when burned in populated areas and with distributed sources
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Primary PM Emissions

Pittsburgh Regional Environmental Threats Analysis Report (PRETA) - PM, 2012
Industrial Biomass Sources in PA

Figure 1. Biomass Facilities (with PM emissions in tons per year) in the Context of PM$_{2.5}$ and Ozone Attainment Status (dark grey indicates non-attainment with EPA air quality standards)

- Existing
- New/proposed

- 2-10
- 10-25
- 25-50
- 50-100


Slide courtesy, Pete DeCarlo, Drexel Univ.
Woodsmoke air quality impact

- Rochester, NY – Winter evenings
  - 30% of winter PM
- Seattle
  - ~30% heating season PM$_{2.5}$
- Fairbanks
  - 60 - 80% winter PM$_{2.5}$
- Atlanta
  - 11% annual PM$_{2.5}$
- Portland
  - 27% annual PM$_{2.5}$
- Las Vegas
  - 11 – 21% annual PM$_{2.5}$

Winter (November-April) mean: **1.6 µg/m$^3$**

Cold winter night (20% of year) mean: **8.5 µg/m$^3$**
Pennsylvania Air Monitoring

Monitoring Sites focused on populated areas:
- Cost
- Population

Little monitoring in areas most vulnerable to biomass emission exposure.

Missed in Models – Small sources not in inventory

AirNow data – Dots indicate monitoring site reporting real-time data
Also here: http://airnow.gov

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For typical drainage wind speed (1 m/s) maintained over a 3 hour period, upslope influence \(\sim 10\) km

Catchment modeling\(^1,2\) suggests upslope influence of \(4 - 8\) km

Semivariogram analysis\(^3\) suggests spatial extent of \(2.7\) km

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Biomass smoke and health: evidence

- Constituents/Composition ($\text{PM}_{2.5}$, aldehydes, PAHs)
- Toxicology
- High concentration, chronic exposures – developing countries
- High concentration acute/sub-chronic exposures – wildland firefighters
- Firesmoke, agricultural burning
- Controlled human exposures
- Residential woodsmoke epidemiology

- Very little direct research on health impacts of Industrial / Commercial / Institutional scale combustion
PM composition

“conventional”

Wood smoke soot

Wood smoke organic particles (low-temp combustion)

from Kocbach et al, Science of the Total Environment, 2005)

“advanced”

“Good” wood pellet combustion PM (alkali salt particles)

Temporal evolution of the AMS species and BC (top panel), their relative contributions (middle), and the HC concentration as ppm carbon (lower panel). The stars indicate the addition of wood logs to the fire. Concentrations are corrected for dilution.

M. F. Heringa; P. F. DeCarlo; R. Chirico; A. Lauber; A. Doberer; J. Good; T. Nussbaumer; A. Keller; H. Burtscher; A. Richard; B. Miljevic; A. S. H. Prevot; U. Baltensperger; Environ. Sci. Technol. 2012, 46, 11418-11425. DOI: 10.1021/es301654w Copyright © 2012 American Chemical Society
Correlation between the combustion chamber temperature and ROS concentration for logwood burning.

- ROS concentrations not measurable for pellet oven emissions.
- ROS concentrations of logwood burners high for starting conditions and at low temperatures.
- Low temperature logwood burner ROS concentrations > primary diesel emissions, cigarette smoke.

Animal/Cellular Toxicology

Inflammation: Medium Temp > High Temp
Low oxygen > High oxygen

Soluble inorganic ash particles:
- inflammation in cell culture
- no inflammation in animal inhalation studies
  - soluble and cleared from lungs

Cell cytoxicity:
  - > Diesel >  

adapted from: Kocbach Bølling et al. 2009
<table>
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<th>Combustion source</th>
<th>Emissions (mg/MJ)</th>
<th>Composition</th>
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<td>Open fireplace</td>
<td>160 – 910</td>
<td><img src="image1" alt="composition" /></td>
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<tr>
<td>Conventional woodstove</td>
<td>50 – 2100</td>
<td><img src="image2" alt="composition" /></td>
</tr>
<tr>
<td>Conventional log boilers</td>
<td>50 – 2000 (50 – 250)</td>
<td><img src="image3" alt="composition" /></td>
</tr>
<tr>
<td>‘Modern” woodstoves log/chip boilers</td>
<td>34 – 330 5 – 450</td>
<td><img src="image4" alt="composition" /></td>
</tr>
<tr>
<td>Pellet stoves/boilers</td>
<td>10 - 50</td>
<td><img src="image5" alt="composition" /></td>
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Controlled human exposure studies

• Subjects exposed to realistic (high) concentrations (~250 μg/m³) of woodsmoke for 4 hrs
  – Increases in measures of inflammation, oxidative stress post-exposure compared to clean air

• Pellet stove incomplete combustion
  - No inflammation
  - Early adaptive protective response


Biomass smoke epidemiology

“.....generally consistent relationship between exposure and increased respiratory symptoms, increased risk of respiratory illness, including hospital admissions and emergency room visits, and decreased lung function. Several studies suggest that asthmatics are a particularly susceptible subpopulation ....”

<table>
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<tr>
<th>Country</th>
<th>Study</th>
<th>Exposure</th>
<th>Outcome</th>
<th>Result</th>
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<td>New Zealand</td>
<td>McGowan (2002)</td>
<td>Outdoor PM$_{10}$ (90% from biomass in winter)</td>
<td>CVD admissions</td>
<td>+</td>
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<td>New Zealand</td>
<td>Barnett (2006)</td>
<td>Outdoor PM$_{10}$</td>
<td>CVD admissions</td>
<td>-</td>
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<tr>
<td>Chile</td>
<td>Sanhueza (2009)</td>
<td>Outdoor PM$_{10}$ (90% from biomass in winter)</td>
<td>CVD admissions, CVD mortality</td>
<td>+, +</td>
</tr>
<tr>
<td>Canada</td>
<td>Allen (2011)</td>
<td>Indoor PM$_{2.5}$ intervention study</td>
<td>Markers of inflam &amp; endothelial function</td>
<td>+</td>
</tr>
<tr>
<td>India</td>
<td>Ray (2006)</td>
<td>Biomass vs non biomass fuel use</td>
<td>Markers of thrombosis risk</td>
<td>+</td>
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<td>Turkey</td>
<td>Emiroglu (2010)</td>
<td>Biomass vs non biomass fuel users</td>
<td>Ventricular dysfunction</td>
<td>+</td>
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Woodsmoke & multiple health measures

• 15% increase in SGA birth
• 32% increase in otitis media
• 8% increase in bronchiolitis
• 15% increase in COPD hospitalization

• No associations with:
  – pre-term birth
  – asthma incidence
  – cardiovascular, COPD mortality

MacIntyre EA et al., Exposure to residential air pollution and otitis media during the first two years of life. Epidemiology. 2011 Jan;22(1):81-9.;
Clark NA et al., Effect of early life exposure to air pollution on development of childhood asthma. Environ Health Perspect 2010, 188(2): 118:284-290;

++ > traffic pollution, + ~traffic, - <traffic
• ~30% reduction in winter PM$_{2.5}$
• ↓ in childhood wheeze, itchy eyes, sore throat, cold, bronchitis, influenza, throat infections
• School absence associations inconsistent
Stove exchange and indoor levels

Factors contributing to indoor levels

- Emission
- Town
- Neighbours
- Mean Infiltration ~30% (10 – 70%)

Other sources

Resuspension

Deposition

“Leakage”

Air exchange

Fинф

Stove Use
- Operation
- Intensity
Air filtration

- Portable HEPA filters 60% ↓ in indoor PM$_{2.5}$
- ↑ endothelial function, ↓ inflammatory markers

• ~39% reduction in winter PM\textsubscript{10}
• ↓ winter cardiovascular (-19.6%) and respiratory (-27.9%) mortality
• Similar decreases not observed in control community

Policy implications

• Woodsmoke is an important source of air pollution in rural and urban areas
• Evidence for health impacts of magnitude similar to other widely recognized risk factors
  – e.g Otitis media incidence:
    • Eliminating woodsmoke: 10% reduction
    • Maternal smoking during pregnancy or secondhand smoke exposure: 2% reduction
    • Pneumococcal conjugate vaccine: ~ 6-7% reduction
• Suggests cost-effectiveness of exposure reduction
• Advanced technology combustion
  – derive max energy
  – Lower mass emissions
  – Lower toxicity
What can clinicians do?

• Consider woodsmoke as a potential risk factor for pregnant women and patients with recurring respiratory infections, otitis media, asthma, COPD

• HEPA filter air cleaners

• Community stove exchanges

• Advocacy for advanced combustion and emission controls in local decision-making regarding institutional-scale boilers
Thank you!

Questions?

michael.brauer@ubc.ca