Health effects and exposure risk of wood smoke

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Overview

Perception

Health effects

Exposure
Health effects

“The sentiment that woodsmoke, being a natural substance, must be benign to humans is still sometimes heard. It is now well established, however, that wood-burning stoves and fireplaces as well as wildland and agricultural fires emit significant quantities of known health-damaging pollutants, including several carcinogenic compounds.”

– Naehler et al. 2007

Woodsmoke Health Effects: A Review
Scientific analysis

• Air pollution from biomass combustion associated with a range of adverse respiratory health impacts

• Weight of the evidence indicates woodsmoke particles are hazardous to human health
  – animal and in vitro toxicology
  – human exposure data
  – epidemiologic studies of wildfires and of household wood combustion
Individual constituents of woodsmoke

- At least 5 chemical groups classified as known human carcinogens, others categorized probable or possible human carcinogens by IARC
- At least 26 chemicals listed HAPS by EPA
- PAHs, benzene, aldehydes, respirable PM, CO, NOx, and other free radicals
- Health impacts of these constituents well characterized in thousand of studies
- Modes of toxicity: Asphyxiant, irritant, carcinogenic, mutagenic, allergenic, neurotoxic, oxidative stress and inflammation, redox activity
Woodsmoke PM$_{2.5}$

Among the currently regulated pollutants in woodsmoke, fine particles (PM$_{2.5}$) serve as the best exposure metric in most circumstances.

Wood smoke particles are generally $< 1$ $\mu$m, peak in the size distribution 0.15 - 0.4 $\mu$m

Little evidence to suggest reduced or altered toxicity from woodsmoke particles relative to the more commonly studied urban air PM.
Wood smoke epidemiology

Exposure to the concentrations and durations of woodsmoke associated with residential woodburning is likely to cause a variety of adverse respiratory health effects:

– Increases in respiratory symptoms, lung function decreases, visits to emergency departments, hospitalizations.

Biological plausibility supported by:

– toxicology literature, controlled exposure studies, biomass burning data
Study examples

Michigan, two groups of kids, with and without wood stoves. Significant differences for severe symptoms of persistent airway irritation (Honicky et al. 1985)

Seattle, high and low wood smoke areas. Significant respiratory differences for kids aged 1-5 (Browning et al. 1990)

Klamath Falls, OR children high and low exposure during woodburning season (upwards of 80% of PM). Lung function decreased in high exposure area, but not the low exposure area (Heumann et al., 1991)

Seattle, RR for 30 ug/m3 \( \uparrow \) PM\(_{10}\) 1.12 (1.04-1.20) \( \sim \) 85% of wintertime PM mass was woodsmoke (Schwartz et al. 1993)

CT and VA: each hour-per-day use of a fireplace was associated with cough, sore throat, chest tightness, and phlegm. Use of a fireplace for 4h would increase the risk of such symptoms by about 16–20% (Triche et al. 2005)

REVIEW: no reason to think that the adverse impacts of acute woodsmoke exposure would be less than those associated with other sources of ambient PM (Boman et al. 2003)
Wood smoke toxicology

• Short-term effects on pulmonary immune defense mechanisms. Likely target seems to be the macrophage, a primary defense of the deep lung.

• Effects most dramatic after acute, high-dose exposure. More study needed regarding long-term exposure to lower concentrations of woodsmoke.

• Most available animal studies indicate that exposure results in significant impacts on the respiratory immune system and at high doses can produce long-term or permanent lesions in lung tissues.

• Woodsmoke is mutagenic and possibly carcinogenic in laboratory and field studies.

• No toxicological data examining the effects of woodsmoke on cardiovascular outcomes.

Zelikoff et al. 2002, Naeher et al. 2007
OWF risk assessment

Carcinogenic polycyclic aromatic hydrocarbons in wood smoke

– 7-fold increase in cancer risk for lower bound
– 2 orders of magnitude increase for upper bound

Acute non-cancer

– 24-hr averaging of PM not an appropriate health-based metric for these sources
– Hourly emission levels of health concern

Brown et al. 2007
Exposure

Area-wide ambient, neighborhood / local, indoor

Image: Environment Canada
Importance of woodsmoke emissions in Canada by province – emissions as a % of total provincial/territorial total

http://www.ec.gc.ca/science/sandejan99/article1_e.html
Northeast magnitude of exposure to RWC

\[ \text{previous monitoring} + \text{terrain} + \text{meteorology} + \text{climate} + \text{demography} + \text{inventory} = \text{public health concern} \]
Monitoring studies in Northeast

Over past 25 yrs, studies show that:

1. RWC has disproportionate adverse effects on ambient air quality relative to other fuel sources.


2. In populated areas, emissions can be chronic and severe.

Recent studies in PNW: much of the exposure to outdoor particles can occur indoors (Anuszewski et al., 1998; Allen et al. 2003, 2004)
Sexton et al. (1984) and Sanborn et al. (1981, 1982)

- Population ~2000 (1982), ~5,000 today
- Waterbury, VT    Winooski River, confluence of 2 valleys
- Night-time temperature inversions; pollution buildup severe
- 50% residents used wood fuel (28% primary); 55% used oil.
- Estimated emissions: RWC 10.2 tons, Roil 0.2 tons
- ~85% households with stoves operate them all day, everyday
- RWC accounted for up to 40% of ambient TSP.
- Elevated hourly night-time levels in excess of 100 µg/m³.
Wood burning redux

“Uncertain oil supplies and steep price increases for petroleum and natural gas have led to increased use of alternative fuels for home heating.”

– Lipfert and Dungan, Science, 1983
Terrain: River valleys
Former water economy: historical mill towns, factory towns, hamlets
Demography

Even small hamlets and towns can have high population densities

Dolgeville, NY. Population ~2,200; 1,200 persons/mile$^2$
Meteorology and climate

– Northeast areas prone to night-time diurnal inversions

  even a small number of woodstoves can affect a large fraction of a community

  – Tasmania study: 45% of homes burn wood as main source of heat → 85% of city’s PM10. Valley with nighttime inversions (Luhar et al. 2006)

– Northeast climate: can get very cold
Inventory

• New England has the highest per capita woodstove ownership in the U.S.

• The NE Census Region (New England, NJ, NY, PA) consumes over twice the number total cords of wood in woodstoves per year than the Midwest, South, or West (Houck et al. 2001).
18% landmass, 88% population

6% landmass, 72% population
And finally....
Nearly ideal to maximize exposure from emissions

- Human breathing zone emission points
- Plumes observed low to ground
- Microscale fumigation and impingement
- Anecdotal evidence of less than ideal fuels
- Fence line source locations
- Proliferation in populated areas
- Commercial scale applications
Sir, your community is in compliance with the 24-hr PM standard and the owner of the smoke stack has a model Title V permit. I’m sorry your smoke alarm goes off every week and your wife has to go to the ER sometimes.
Real world factors

Forget about the porridge. I made Goldilocks stew.
Ingredients*

- Available fuel \( ^a \)
- Maintenance, operator control, fuel treatment \( ^b \)
- Civic harmony or discord \( ^c \)
- Topography and meteorology \( ^d \)
- Others… \( ^e \)

* Ingredient quantities typically vary depending upon intrinsic circumstances
  a The *unknowable* unknowns?
  b Can be subject to exceptionally wide and creative interpretation
  c Consult your local enforcement officials or small town contacts for stories
  d Can be conveniently ignored by typical Gaussian Plume-based models
  e If time permits, ask audience for their own “secret ingredients” and favorite recipes
Summary

Known adverse health effects associated with residential woodsmoke exposure

Exposure scales and potential magnitude important to understand and quantify to inform regulatory decision making

Perception of woodsmoke as natural and benign can hinder promulgation of effective public health measures
Thank you!