Particulate Matter Health Effects
- Biomass Burning

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Biomass Smoke Sources

• Indoor
  – Woodstoves and boilers
  – Coal, pellet stoves
  – Fireplaces
  – Other heating devices
  – Not well ventilated

• Outdoor
  – Wood smoke (particularly inefficient burning)
  – Boilers
Biomass Smoke Sources

Outdoor-Indoor infiltration: Air pollution is not limited to the outdoors

Similar to smoking, generating air pollution can affect not only you, but others around also

– Wood smoke can make children, adults, and the elderly sick to varying degrees
Components of Biomass Smoke

- **Particulate matter**
- Carbon monoxide
- Nitrogen Oxides, Ammonia, Sulfur Dioxide
- Aldehydes, Benzene
- Polycyclic Aromatic Hydrocarbons
  - *e.g.* benzo(a)pyrene
- Other chemicals and elements
Particulate Matter (PM) Size

HUMAN HAIR
50-70 μm (microns) in diameter

PM$_{2.5}$
Combustion particles, organic compounds, metals, etc.
< 2.5 μm (microns) in diameter

PM$_{10}$
Dust, pollen, mold, etc.
< 10 μm (microns) in diameter

90 μm (microns) in diameter
FINE BEACH SAND

Image courtesy of the U.S. EPA
Particulate Matter and Components

Enter Lung and Reach Other Body Parts
Health Implications of Particulate Matter Exposure*

**Short Term**
- Asthma exacerbation
- Irritation
- Stroke
- Heart attack
- Hospitalization
- Death
- School days lost

**Long Term**
- Decline in lung function
- Lung cancer
- Heart disease
- Premature death

*Possibly wood smoke as well
Susceptible and Vulnerable Populations

- Elderly, children
- Pre-existing heart and/or respiratory disease, allergies
- Certain genetic polymorphisms (e.g., antioxidant related genes)
- Healthy subjects may also be affected; some may not
- Working or living downwind of heavy wood smoke burning
- Living in housing with indoor wood smoke burning or other fuel combustion that results in high concentrations of pollutants
- Labored breathing (heavy work, exercise)
Harvard Six Cities Cohort Study

- U.S. cohort (1975-1988)
  - 8111 subjects (25-74 years old).
  - Six US Cities with varying air pollutant levels
- Controlled for sex, age, high school education, smoking, occupational exposure to dust and

Dockery et al., 1993. (329:1753-9, NEJM)
PM$_{2.5}$ and Long-term mortality across Six Cities

City-specific Mortality Rate Ratios vs. Annual (yearly average) PM$_{2.5}$ concentrations

- Mortality Rate Ratios among Cities (PM$_{2.5}$)
  - 1.26 (95% CI: 1.08-1.47) → All-cause mortality
  - 1.37 (95% CI: 1.11-1.68) → Cardiopulmonary mortality

Dockery et al., 1993. (329:1753-9, NEJM)
American Cancer Society Cohort –
Long-term mortality

• Nationwide U.S. cohort since 1982
  – Information from ~360,000-500,000 persons

• Investigated pollutant - long-term mortality associations

• Controlled for 44 individual and ecological covariates (e.g., BMI, smoking, income, education, A/C prevalence)

Krewski et al., 2009. HEI Report #140 (Latest cohort update)
Some factors associated with mortality

• Increased PM2.5 $\rightarrow$ Increased mortality
• Higher unemployment $\rightarrow$ Increased Mortality

• More AC Use $\rightarrow$ Decreased mortality
• Higher household income $\rightarrow$ Decreased mortality

Source: Krewski et al., 2009. HEI Report #140
Health Effects of Wood Smoke (Atlanta, GA)

• Sarnat et al. (2008)
• Investigated association between source of PM2.5 pollution and emergency department visits (3 years of data)
• Calculated Relative Risk (RR) – the ratio of probability of emergency visit in those exposed to PM2.5 versus non-exposed
  – If RR larger than 1.00, then bad health effects are possible)
Figure 3. RRs and 95% CIs per IQR increase from same-day lag models for the association of ED visits for all CVD with daily source-apportioned ambient PM$_{2.5}$ (Atlanta, GA, November 1998–December 2002).

Environmental Health Perspectives, Sarnat et al. (2008)
Result

$\text{PM}_{2.5}$ from **biomass combustion** (forest burning and residential wood combustion), **diesel**, and **gasoline** associated with increased risk of emergency department visits for cardiovascular disease.
Short-Term Health Effects of Wood Smoke (Christchurch, NZ)

- McGowan et al. (2002)
- Investigated association between hospitalization rate for adults/children with cardiac and respiratory disorders and PM$_{10}$ (1988-1998)
- > 90% of PM comes from the city’s 47,000 wood burners and open fires during winter
- Winter PM = 4 X Summer PM
Risk of Hospital Admissions associated with PM10

• Increased risk of
  – Heart Failure
  – Acute Respiratory Infections
  – Asthma
  – Chronic Lung Disease
  – Pneumonia/influenza

• No Increased risk of
  – Appendicitis
  – Ischemic heart disease
  – Dysrhythmia

McGowan et al., 2002
Wood Smoke and Children’s Health

• Wood smoke associated with decreased lung function tests results in children (6-13 years old) in wood smoke-impacted area of Seattle (Allen et al., 2008)

• 1,100 Old Wood Stove changeout intervention in Libby, Montana suggests a relation between decreased school absences and decreased air pollution levels (Noonan et al., 2011)
Wood Burning Temperature
Toxicity of smoke

Increased toxicity to cells
Decreased survival of cells

Bolling et al., 2012
Boiler/Stove Selection Can Make a Difference

Relative Emissions of Fine Particles

* Average emissions (lbs/MMBtus of heat output) for heat source type. Data from US EPA
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Thanks!