Estimating Community Health Impacts of Increased Residential Biomass Combustion Emissions in Pennsylvania

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Overview

- Motivation
- Process of health impact assessment
- Application to increased residential biomass combustion in PA
- Limitations and uncertainties
- Conclusion

Motivation

- Recent attention to transition to renewable energy economy
  - Greenhouse gas emissions associated with burning fossil fuels
  - Limited reserves will eventually lead to scarcity
- Burning biomass or biomass products offers a source of renewable energy
  - Energy output needs to be larger than *total* energy inputs, including fossil fuel inputs to chemical fertilizers, transportation of resources, etc.

Motivation

  - Locally-produced resources more energy efficient
  - PA has the agricultural capacity to produce large amounts of biomass
- But what impact would increased biomass combustion emissions have on public health?
  - Composition of biomass combustion emissions and their toxicological properties discussed previously
  - Focus on $PM_{2.5}$

Framework for health impact assessment

- Standard methodology for PM air pollution discussed by Martuzzi et al. (2003)
- Formula:

$$E = (dRR)(C)(B)(P)$$

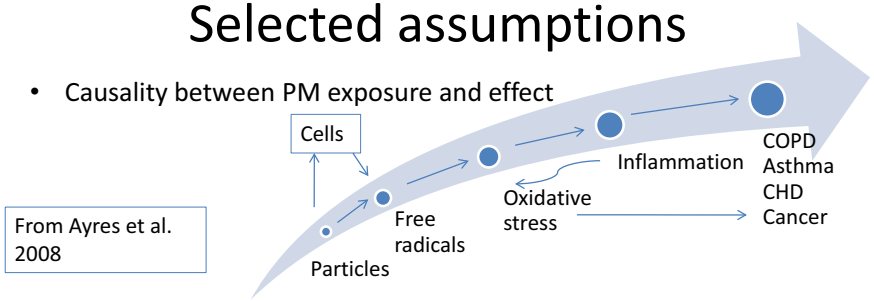
  - E is the attributable number of cases for a given health outcome
  - dRR is the relative risk of a given health outcome associated with a per unit change in exposure level
  - C is the difference in exposure level (same units as dRR)
  - B is the rate observed in the population
  - P is the population size exposed to C

Objective

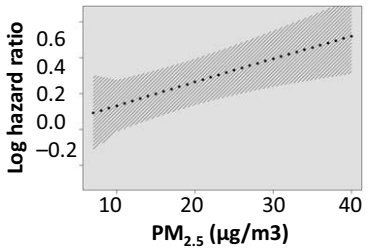
- Identify uncertainties in health impact assessment process
- How many cases would be caused if concentrations were increased by X?
  - Y greater cases observed *if* the association observed in epidemiologic studies is entirely causal and *if and when* the rates observed in the reference population are achieved following increase in exposure

Selected assumptions

- Causality between PM exposure and effect



- Linearity between baseline and elevated dose
  - Supporting evidence accumulating (Schwartz et al. 2008, Pope et al. 2009)
- Reversibility and latency
  - Acute wood-burning PM effects within 2-4 days (Ito et al. 2006); chronic $PM_{2.5}$ mortality effects within 1 year (Puett et al. 2009)



Example application to PA

- What information is available?
  - Population size (P) from US Census
  - Current age-adjusted rates (B) from PA Dept. of Health (EpiQMS; EPHTN) for selected outcomes
  - Difference in exposure (C) from emissions estimates and exposure modeling
  - Relative risks (dRR) from epidemiologic literature on several biomass combustion-related health outcomes, acute and chronic
    - Health outcomes for dRR and B must match

Population at risk (P)

- From US Census
  - PA total population: ~12.4 million persons
  - Assume an additional 30% of PA households begin to operate residential wood combustion, so 3.73 million persons at risk

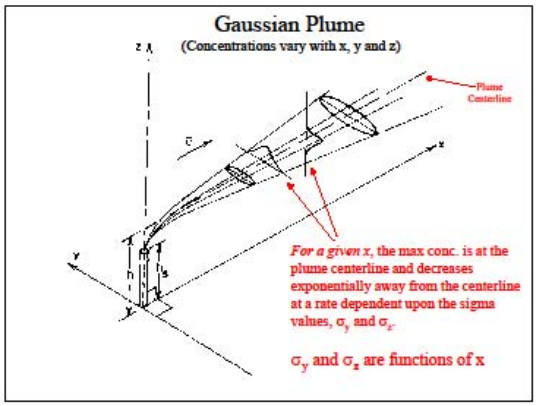
Observed prevailing rate (B)

- Rate in the population exposed to current levels
- Outcomes
  - Acute
    - Cardiovascular deaths per year
    - Asthma hospitalizations per year
  - Chronic
    - Total pneumonia/influenza deaths per year
    - Fatal coronary heart disease (CHD) deaths per year
  - State level (PA) age-adjusted rates for 2006

Exposure increment (C)

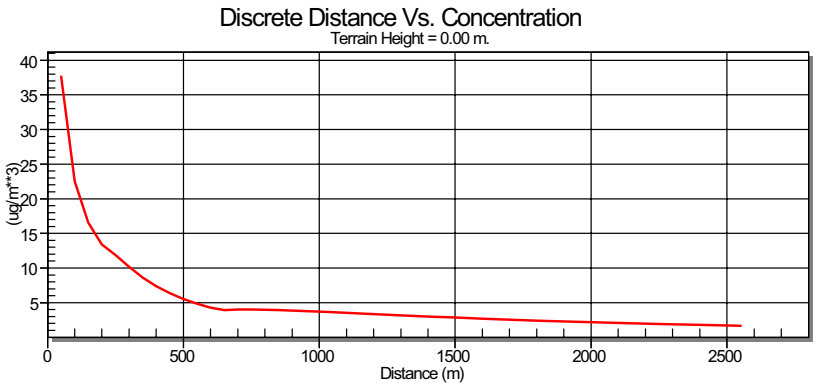
- Typical emissions rate of 52 g $PM_{2.5}$/hr
  - Using 5H emission factor of 17.3 (g/kg) and 3 kg/hr burn rate from USEPA Residential Wood Combustion report (Houck and Tiegs 1998, p. 20)
- Assumed use:
  - 12 hours/day, 5 months/year
- Emissions in tons/year = 1.05 E-1; 1.44 E-2 g/sec
- Gaussian point-source plume dispersion model
  - Dispersion parameters from screening version of USEPA ISC (SCREEN3)
  - Standard combination of meteorological inputs used
  - Grid of all receptor points within 3 km of point-source (98% decay)
- Increase in outdoor concentrations due to a new point- source at residence
  - Mean within 36 km^2 impacted area: 0.056 $\mu g/m^3$

Gaussian dispersion

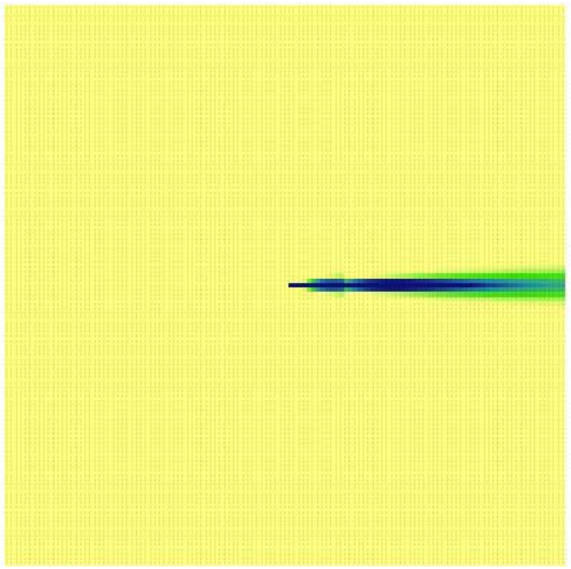


From Guenther class notes, LETE

Decay function (downwind)



Gaussian dispersion on grid (36 km^2)



Relative risk (dRR)

- Select 'key study' for each outcome
- Use tracer or biomass source contribution where possible
- Acute
  - Daily cardiovascular mortality and $PM_{2.5}$ K in CA (Ostro et al. 2007)
  - Asthma hospitalizations and $PM_{2.5}$ in Seattle, WA (Sheppard et al. 1999)
- Chronic
  - Pneumonia/influenza deaths and annual $PM_{2.5}$ in the US (Pope et al. 2004)
  - Fatal coronary heart disease (CHD) and annual $PM_{2.5}$ in the northeast and midwest US (Puett et al. 2009)

Epidemiologic results from key studies

- Reported relative risks converted to dRR per $\mu g/m_3$ $PM_{2.5}$
- Ostro et al. 2007: 5.3% increase in CVD deaths
- Sheppard et al. 1999: 0.34% increase in asthma hospitalizations
- Pope et al. 2004 (1999-2000, driven by never smokers): 2.0% increase in pneumonia/influenza deaths
- Puett et al. 2009: 10.2% increase in fatal CHD deaths

Epidemiologic results that support, but don't match

- Sarnat et al. 2008: $PM_{2.5}$ from biomass burning in Atlanta, GA and CVD ED visits: RR 2.7% (95%CI 1.7-3.7) per IQR; dRR of 2.8%
  - Increased respiratory ED visits not detected
- Ostro et al. 2009: $PM_{2.5}$ K and respiratory hospital admissions in children: RR 4% (95%CI, 0.3-7.7) per IQR; dRR of 13%
- Suggestive evidence of increased total non-accidental mortality (Ito et al. 2006; Mar et al. 2006)

Calculation of excess attributable cases

$$E = (dRR)(C)(B)(P)$$

Outcome	dRR	C (μg/m³)	B (per 1E5)	P (millions)	E
CVD deaths	1.053	0.056	302.5	3.73	643
Asthma hospitalizations	1.0034		951.0		1,985
Pneumonia/ influenza deaths	1.02		18.2		39
CHD deaths	1.102		154.8		352

Conclusions

- If 30% of PA households began to burn wood in small combustion appliances, at the assumed emission rate and dispersion characteristics, the expected number of additional cases per year would be:
  - 643 additional CVD deaths
  - 1,985 additional asthma hospitalizations
  - 39 additional pneumonia/influenza deaths
  - 352 additional CHD deaths

Limitations

- Uncertainties in:
  - Emission rates
  - Exposure modeling
  - All susceptible subpopulations captured?
    - Ostro et al. 2009:$PM_{2.5}$ associated with respiratory hospital admissions in children (dRR: 1.13)
    - Respiratory hospital admissions data by age not currently available for PA but may be important
  - Generalizability of epidemiologic results
    - Only recent US studies used

Future work

- Explore effects of uncertainties
  - Confidence limits and error propagation
  - Monte-carlo analysis?
- Expand current approach
  - To the county level to identify 'hot-spots' due to large numbers cases
  - To include other pollutants: CO, benzene, acrolein, PAHs, etc.
  - To other source types with differing emission characteristics

Questions

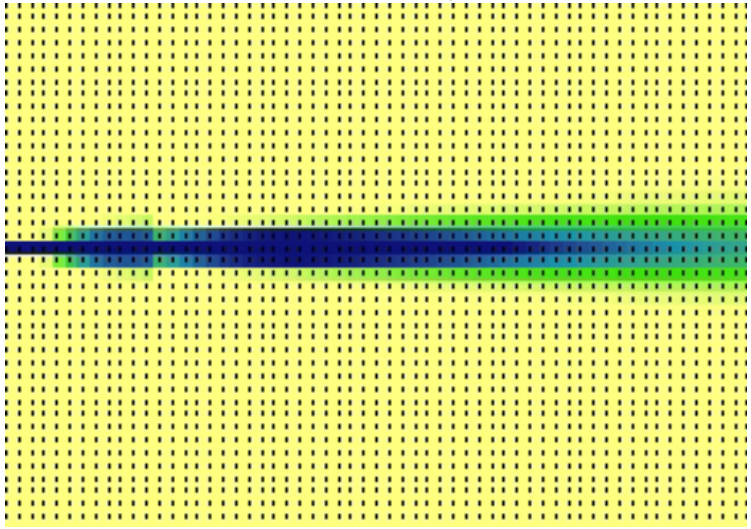
USEPA SCREEN3 model point-source inputs

- Emission rate = 0.0144 g/sec
- Stack height = 3 m
- Stack inside diameter = 0.5 m
- Stack gas exit velocity = 2 m/s
- Stack gas temperature = 394.3 K (250 deg F)
- Ambient temperature= 293 K (67.7 deg F)
- Receptor height above ground = 2 m
- Urban/rural option = Rural

Questions about assessing $PM_{2.5}$ health effects

- Is $PM_{2.5}$ mass appropriate indicator of biomass combustion emissions?
  - If so, is a linear dose-response appropriate?
  - If not, what is appropriate threshold?
- What are relevant health endpoints?
  - Does this adequately protect susceptible subpopulations such as asthmatics/children?

Gaussian dispersion on grid (36 km^2) close-up



Formula for converting to dRR

- dRR (per $\mu g/m^3$) = (RR – 1) / ΔC
- $PM_{2.5}$ K to $PM_{2.5}$ total mass ratio of 25.5 from Sarnat et al. 2008 used to convert $PM_{2.5}$ K to $PM_{2.5}$

Caveat

- The attributable number of cases, E, may not be fully realized, though, due because of the assumption of full causality
- If, instead, the exposure-disease association takes place through intermediate steps, wherein addition of one factor in the chain results in only a limited increase in the following factor, E may overestimate (adapted from (Martuzzi et al. 2003))