Effectiveness of actions to improve air quality: Does airshed management really work?

Michael Brauer

North Central BC Clean Air Forum
Prince George   March 6-7, 2013
Airshed management

• Integrated, multistakeholder approach
• Focus on **airshed actions** within regional / national / global context
• Health as a key goal

Why assess effectiveness?

• Inform (better) future policies
  – Compare alternatives

• Cost effectiveness
  – Including costs of implementing ineffective measures

• Identify unintended consequences

• Demonstration to stakeholders that actions were effective and worthwhile
Some questions to consider

• Do we need a local study?
• Do we need to assess impacts on health? (vs air quality)
• What can modeling tell us?
\[
\text{inhalation intake fraction} = \frac{\text{mass inhaled}}{\text{mass emitted}}
\]
Air pollution and health

• Air pollution (individual) risk is small…but large exposed population = large population risk
  – Drug abuse, Radon: 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
Global Burden of disease attributable to 20 leading risk factors in 2010, expressed as percentage of global disability-adjusted life years, both sexes

3.2 million deaths/yr
Among top global risk factors
9th overall (4th in East Asia [China]; 6th in South Asia [India +])

Lim et al. The Lancet 2012; 380:2224-2260
7,200 deaths/yr PM$_{2.5}$ (340 deaths/yr ozone)
Among top risk factors (#8 deaths, #11 DALYs)


Canadian Census Cohort (1991 – 2001)

2.1 million subjects

Includes rural populations

Associations at VERY low PM$_{2.5}$ levels

- Min: 1.9 $\mu$g/m$^3$
- 5$^{th}$: 4.2
- Mean: 8.7
- IQR: 6.2

Adjustment for multiple individual-level, contextual covariates
Respiratory Disease Associated with Community Air Pollution and a Steel Mill, Utah Valley

C. Arden Pope III, PhD

Abstract: This study assessed the association between hospital admissions and fine particulate pollution ($PM_{10}$) in Utah Valley during the period April 1985–February 1988. This time period included the closure and reopening of the local steel mill, the primary source of $PM_{10}$. An association between elevated $PM_{10}$ levels and hospital admissions for pneumonia, pleurisy, bronchitis, and asthma was observed. During months when 24-hour $PM_{10}$ levels exceeded 150 $\mu$g/m$^3$, average admissions for children nearly tripled; in adults, the increase in admissions was 44 per cent. During months with mean $PM_{10}$ levels greater than or equal to 50 $\mu$g/m$^3$ average admissions for children and adults increased by 89 and 47 per cent, respectively. During the winter months when the steel mill was open, $PM_{10}$ levels were nearly double the levels experienced during the winter months when the mill was closed. This occurred even though relatively stagnant air was experienced during the winter the mill was closed. Children's admissions were two to three times higher during the winters when the mill was open compared to when it was closed. Regression analysis also revealed that $PM_{10}$ levels were strongly correlated with hospital admissions. They were more strongly correlated with children's admissions than with adult admissions and were more strongly correlated with admissions for bronchitis and asthma than with admissions for pneumonia and pleurisy. (Am J Public Health 1989; 79:623–628.)

FIGURE 2—Monthly Mean and 24-Hour High $PM_{10}$ (fine particulate pollution) Levels, Utah Valley, April 1985–January 1988

FIGURE 3—Actual and Estimated Hospital Admissions, April 1985 through January 1988, Utah Valley
Early air quality management

- Emission reductions
- Tall stacks
- Smoke control
- Centralized heating
- Zoning

False Creek, Vancouver, in 1939 (noon)

2012 annual average PM$_{2.5} \approx 4$ µg/m$^3$

Dublin, Ireland
Early air quality management

- Emission reductions
- Tall stacks
- Smoke control
- Centralized heating
- Zoning

2012 annual average PM$_{2.5}$ ≈ 4 µg/m$^3$
Effect of Air-Pollution Control on Death Rates in Dublin, Ireland

- 5.7% decrease in total non-trauma deaths
- 15.5% decrease in respiratory deaths
- 10.3% decrease in cardiovascular deaths

controlling for temperature, humidity, day of week, respiratory epidemics, death rates in the rest of Ireland

Sale of coal is banned

“Modern” air quality management (1980s-1990s)

• Urban airshed approach: emphasis on overall emissions reductions
  – Little attention to land use
  – Regional air quality
  – Ozone, Acid rain

• Focus on motor vehicles as a proportion of total emissions
  – Engine technology
    • Catalytic converters, fuel injection
    • Inspection and maintenance programs
    • Fuel quality

• Point source emissions controls
  • Scrubbers, catalysts, improved efficiency
Hong Kong

Reductions in air pollution accounted for up to 15% of increased life expectancy (2.7 years)
The benefits of policies to address population risk

• Air quality regulations benefit:cost ratios
  \(\sim 4:1 - 30:1\)

• Clean air rules responsible for majority of ALL estimated benefits (and costs) generated by Federal regulation
Challenges in intervention assessment

• Association or causation?
• Consider impacts of actions focused on other (non-health) goals...
  ...otherwise may miss co-benefit opportunities requires multisectoral partnerships
• Evaluate unintended health consequences of other actions
22% decrease in peak weekday morning traffic counts

11 - 44% decrease in asthma acute care events

• Similar reductions in ozone in surrounding region.
• Both meteorologic conditions and reduced traffic may have played a role in the observed reduction in ozone in Atlanta.
• Little or no evidence of reduced ED visits during the Olympics.
• Intervention strategy not sustainable as a pollution-reduction strategy
Challenges in intervention assessment

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E-Z pass and premature birth

Reductions in traffic congestion generated by E-Z Pass reduced incidence of prematurity (10.8%) and low birth (11.8%) among mothers within 2km of a toll plaza.

http://www.nber.org/papers/w15413  NATIONAL BUREAU OF ECONOMIC RESEARCH
Challenges in intervention assessment

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  requires multisectoral partnerships
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Air Quality Impacts of Climate Mitigation: UK Policy and Passenger Vehicle Choice

- Reduction in fuel use, CO$_2$ emissions
- Increase in particle emissions
- 90 additional air pollution deaths / year
- Changes in vehicle mass distribution
- Missed opportunity for simultaneous reduction in vehicle-crash fatalities

Modeling

Table 3 Comparison of predicted (Expected) and observed (Real) mortality reductions (%) associated with the observed decrease in pollutant levels (µg/m³) in each intervention study

<table>
<thead>
<tr>
<th>Study</th>
<th>City/area</th>
<th>Assessed pollutant</th>
<th>All-cause Real (%)</th>
<th>Expected (%)</th>
<th>Respiratory Real (%)</th>
<th>Expected (%)</th>
<th>Cardiovascular Real (%)</th>
<th>Expected (%)</th>
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</thead>
<tbody>
<tr>
<td>Clancy et al. (2002)</td>
<td>Dublin</td>
<td>BS</td>
<td>-5.7</td>
<td>-2.1</td>
<td>-15.9</td>
<td>-2.8</td>
<td>-10.3</td>
<td>-1.4</td>
</tr>
<tr>
<td>Rich et al. Abstract, 2009</td>
<td>Cork</td>
<td>BS</td>
<td>-7</td>
<td>-1</td>
<td>-8</td>
<td>-1.3</td>
<td>-13</td>
<td>-0.7</td>
</tr>
<tr>
<td>Pope et al. (1992)</td>
<td>Utah Valley (Steel mill)</td>
<td>PM₁₀</td>
<td>-3.2</td>
<td>-0.6</td>
<td>-4.3</td>
<td>-0.7</td>
<td>-2</td>
<td>-0.7</td>
</tr>
<tr>
<td>Pope et al. (2007)</td>
<td>Utah Valley (Copper smelter)</td>
<td>SO₂</td>
<td>-2.5</td>
<td>-0.2</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a</td>
<td>n.a</td>
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<tr>
<td>Hedley et al. (2002)</td>
<td>Hong Kong</td>
<td>SO₂</td>
<td>-2.1</td>
<td>-1.4</td>
<td>-3.9</td>
<td>-2.3</td>
<td>-2</td>
<td>-1.9</td>
</tr>
</tbody>
</table>


Stockholm Congestion Charge Scheme
- 12% reductions in NOx on highest-traffic roads
- 27 deaths avoided/year (+other health benefits)

The local scale

• Residential woodsmoke
  – low hanging fruit?

• Traffic-related air pollution
  – Opportunities to link with other built environment initiatives (physical activity, climate change) to improve population health
• ~39% reduction in winter PM$_{10}$
• ↓ winter cardiovascular (-19.6%) and respiratory (-27.9%) mortality
• Similar decreases not observed in control community

• ~30% reduction in winter PM$_{2.5}$
• ↓ in childhood wheeze, itchy eyes, sore throat, cold, bronchitis, influenza, throat infections
• School absence associations inconsistent

Cautionary tales – the impact of the economic context

(Bulkley Valley) **Woodstove Exchange Study**

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<table>
<thead>
<tr>
<th>Decrease in Median Levoglucosan 2007-2012 (ng/m³)</th>
<th>Cumulative Stoves Exchanged (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stoves Exchanged per 1000 population</td>
<td>Levoglucosan/PM2.5 Ratio (%)</td>
</tr>
<tr>
<td>0</td>
<td>Burns Lake</td>
</tr>
<tr>
<td>10</td>
<td>Houston</td>
</tr>
<tr>
<td>20</td>
<td>Smithers</td>
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<td>30</td>
<td>Telkwa</td>
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<td>110</td>
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<td>120</td>
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</tbody>
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**Air filtration**

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

Coronary heart disease (CHD) mortality: Black Carbon

Interventions

• Just because something should work, doesn’t mean it will....
  ....Sometimes, things you don’t expect to work, will provide benefits

• Most effective interventions are prolonged, slow and costly...but still cost-effective!

• Non-linearity

• Importance of measurement and analysis
Interventions

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Thank you!

Questions?

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