Air Pollution
Epidemiology

Lima, Peru
July 9 –12, 2001
Mark Raizenne

Air Pollution Health Effects
Pyramid

Mortality
Hospital admissions
Emergency room visits
Physician office visits
Reduced physical performance
Medication use
Respiratory symptoms
Impaired lung function
Sub-clinical (subtle) effects

severity of effect

proportion of population affected
Susceptible populations

- Infants (pre-natal?)
- Children
- Elderly
- Persons with cardio-respiratory disease
- People who exercise, work or are physically active outdoors

Anatomy of the Respiratory System
Epidemiologic Methods

• Objectives
  – To determine if a pollutant or source of air pollution poses a hazard to human health (Is there a risk to health?)
  – To characterize the exposure-response relationship (At what level of exposure is the risk acceptable?)
  – To examine responses of potentially susceptible populations/individuals to pollutant exposures (Protect the most sensitive?)

Study Designs

• Ecological Designs
  – Variations in pollution across geographic areas
  – “Groups” are studied – all have the same exposure
  – Time Series – repeated measures in time

• Cross-Sectional Designs
  – Specific population or sub-populations (“panels”)
  – Assess health status - exposure at one point in time

• Cohort Studies Design
  – Follow health and exposure of individuals or populations over time (weeks, months, years)
  – Used for acute and chronic health effects

• “Natural and Opportunistic” Studies
  – Non-investigator initiated change in exposure (increase or decrease)
Association to Causality

- Strength of association
  - Strong associations more likely causal
- Consistency
  - Repeated observation of association
- Specificity
  - Association is with a single effect
- Temporality*
  - Exposure precedes response
- Exposure - Response
- Biological plausibility
  - Relevant biological response

Pollution Episode
(London, England)

![Graph showing Deaths and Pollution over December, 1962]
Pollution Episode
(Toronto, Canada)

Ontario Respiratory Hospital Admissions
(Burnett et al., 1994)
Toronto Non-Accidental Mortality due to air pollution (1980-1994)

- Gases: 67%
- Fine PM: 23%
- Coarse PM: 10%

Toronto Cardio-respiratory Hospitalization 1980-1994

- Gases: 80%
- Fine PM: 12%
- Coarse PM: 8%
Ozone hospitalization and Infants (Burnett et al., 2001)

• Time-series on Hospitalization for Acute Respiratory Diseases, 1980-1994
• Young children (< 2 years)
• Toronto, O$_3$: 5-day average of 1h-max of 45 ppb, (May-August)
• 35% (19-52%) increase in the daily hospitalization rate for respiratory problems

Effect of Summertime Ozone Exposure on Hospitalization for Respiratory Problems in Children Under the Age of Two Years (Toronto, 1980-1994)
Traffic Controls and Asthma during Atlanta Olympic (1996)

• 23% ↓ in morning and 10% ↓ in weekend traffic

• Reduction of pollutants:
  13% - O₃, 19% - CO, and 7% - NO₂

• Reduction of 42% of ERVs and hospitalizations for children’s asthma

• Significant decrease in the burden of asthma during this period

Air Pollution, Aeroallergens and Cardiorespiratory Emergency Department Visits in Saint John, Canada

Assessing Health Effects, Health Costs, and Quality of Life Impacts using Enhanced Administrative Data
Saint John
- population 130,000
- universal health care
- 2 EDs
- long range transport
- large refinery
- 2 pulp mills
- unique topography

Emergency Department Data

CARDIAC CONDITIONS
- angina
- myocardial infarction
- conduction disturbance
- dysrhythmia
- congestive heart failure

RESPIRATORY CONDITIONS
- asthma
- COPD
- respiratory infections
Environmental Data

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Aeroallergens</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gases</strong></td>
<td>Fungal Spores</td>
</tr>
<tr>
<td>CO, H$_2$S, NO$_2$, O$_3$, SO$_2$, TRS</td>
<td>ascomycetes, basidiomycetes, deuteromycetes</td>
</tr>
<tr>
<td><strong>Particulate Matter</strong></td>
<td>Pollens</td>
</tr>
<tr>
<td>PM$<em>{10}$, PM$</em>{2.5}$, H$^+$, SO$_4^{2-}$</td>
<td>ferns, grasses, trees, weeds</td>
</tr>
</tbody>
</table>

Summary data on ED visits
1992-1996

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Number of Visits</th>
<th>Visits per Day</th>
<th>% Admitted to Hospital</th>
<th>Mean Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angina/ Myocardial Infarction</td>
<td>2,435</td>
<td>1.8</td>
<td>90.7</td>
<td>65.4</td>
</tr>
<tr>
<td>Congestive Heart Failure</td>
<td>1,312</td>
<td>1.0</td>
<td>74.4</td>
<td>75.6</td>
</tr>
<tr>
<td>Dysrhythmia</td>
<td>1,096</td>
<td>0.8</td>
<td>41.0</td>
<td>62.8</td>
</tr>
<tr>
<td>ALL CARDIAC</td>
<td>4,843</td>
<td>3.5</td>
<td>76.0</td>
<td>67.6</td>
</tr>
<tr>
<td>Asthma</td>
<td>4,771</td>
<td>3.5</td>
<td>14.9</td>
<td>22.8</td>
</tr>
<tr>
<td>COPD</td>
<td>1,761</td>
<td>1.3</td>
<td>44.1</td>
<td>68.0</td>
</tr>
<tr>
<td>Respiratory Infections</td>
<td>8,446</td>
<td>6.2</td>
<td>17.7</td>
<td>30.5</td>
</tr>
<tr>
<td>ALL RESPIRATORY</td>
<td>14,978</td>
<td>10.9</td>
<td>19.8</td>
<td>32.5</td>
</tr>
<tr>
<td>TOTAL</td>
<td>19,821</td>
<td>14.4</td>
<td>33.0</td>
<td>41.0</td>
</tr>
</tbody>
</table>
## Summary Air Pollution Data

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Units</th>
<th>Daily Average</th>
<th>Maximum Hourly Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Maximum</td>
</tr>
<tr>
<td>CO</td>
<td>ppm</td>
<td>0.5</td>
<td>2.1</td>
</tr>
<tr>
<td>H₂S</td>
<td>ppb</td>
<td>1.1</td>
<td>21.0</td>
</tr>
<tr>
<td>NO₂</td>
<td>ppb</td>
<td>8.9</td>
<td>35.0</td>
</tr>
<tr>
<td>O₃</td>
<td>ppb</td>
<td>22.9</td>
<td>49.0</td>
</tr>
<tr>
<td>SO₂</td>
<td>ppb</td>
<td>6.7</td>
<td>60.0</td>
</tr>
<tr>
<td>TRS</td>
<td>ppb</td>
<td>1.0</td>
<td>23.0</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>ug/m³</td>
<td>14.0</td>
<td>70.3</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>ug/m³</td>
<td>8.5</td>
<td>53.2</td>
</tr>
<tr>
<td>H⁺</td>
<td>nmol/m³</td>
<td>25.7</td>
<td>284.0</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>nmol/m³</td>
<td>31.1</td>
<td>208.0</td>
</tr>
<tr>
<td>COH</td>
<td>10⁻³ ln ft</td>
<td>0.2</td>
<td>1.5</td>
</tr>
</tbody>
</table>

## PERSONAL EXPOSURE
**Time Activity Patterns**

![Bar chart showing time activity patterns for different age groups (Study Subjects, Adults, Youth, Children) in indoors, outdoors, and vehicle settings.]

**Personal/ Fixed Site Data**

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Mean</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(nmol/m³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SO₄²⁻ (personal)</strong></td>
<td>62</td>
<td>29.8</td>
<td>171.1</td>
</tr>
<tr>
<td><strong>SO₄²⁻ (fixed site)</strong></td>
<td>28</td>
<td>49.1</td>
<td>214.3</td>
</tr>
<tr>
<td><strong>H⁺ (personal)</strong></td>
<td>62</td>
<td>17.1</td>
<td>83.1</td>
</tr>
<tr>
<td><strong>H⁺ (fixed site)</strong></td>
<td>28</td>
<td>37.6</td>
<td>121.8</td>
</tr>
</tbody>
</table>
TIME SERIES ANALYSIS

Methods

- single day values of environmental variables up to lag 10 days
- multi-day averages up to 7 days in length
- single and multivariate models
- adjusted for temporal cycles using non-parametric smooth function
- adjusted for weather allowing for non-linearity
Conclusion

- More consistent association with ED visits for gases (especially ozone) than PM
- Consistently strong negative effect of hydrogen ion
- Larger magnitude of effect on cardiac than respiratory visits
- Significant association of aeroallergens with warm season asthma visits
- Evidence of effect modification, susceptible subgroups
24 Cities Study

- Pulmonary function measured in schools in 22 communities
- Adjusted for sex, age, height, and weight
- 3.5% reduction in FVC (95% CI 2.0 to 4.9) associated with H+ (range 52 nmoles/m3)

24 Cities Study

- Percentage of children with low FVC
  - <85% Predicted
  - Overall 5.7%
- Adjusted for sex, age, height, and weight
- Odds Ratio for low FVC
  - 2.9 (CI 2.0-4.3)
24 Cities Lung Function Acid vs PM2.1 Associations

Adolescent (Pilot) Follow-up Study Locations

Penticton
- population 50,000
- minimal small local pollution sources
- occasional wood burning & forest fires

Saint John
- population 130,000
- long range transport
- large refinery
- 2 pulp mills
Table 1. Characteristics of Study Subjects By Community and Gender

CHARACTERISTICS OF STUDY SUBJECTS BY COMMUNITY AND GENDER
Mean (SD) or Percentages

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Saint John Males</th>
<th>Saint John Females</th>
<th>Penticton Males</th>
<th>Penticton Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Subjects</td>
<td>295</td>
<td>271</td>
<td>177</td>
<td>192</td>
</tr>
<tr>
<td>Age (years)</td>
<td>17.99 (0.63)</td>
<td>17.94 (0.57)</td>
<td>17.69 (0.76)</td>
<td>17.70 (0.61)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177.35 (6.70)</td>
<td>164.01 (5.81)</td>
<td>178.45 (6.49)</td>
<td>165.60 (5.70)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73.76 (12.55)</td>
<td>62.02 (10.98)</td>
<td>71.46 (13.44)</td>
<td>62.33 (11.23)</td>
</tr>
<tr>
<td>FVC (L)</td>
<td>5.40 (0.70)</td>
<td>3.95 (0.55)</td>
<td>5.73 (0.96)</td>
<td>4.30 (0.62)</td>
</tr>
<tr>
<td>FEVI (L/sec)</td>
<td>4.59 (0.61)</td>
<td>3.41 (0.93)</td>
<td>4.94 (0.78)</td>
<td>3.78 (0.59)</td>
</tr>
<tr>
<td>MMEF (L/sec)</td>
<td>4.71 (1.06)</td>
<td>3.75 (0.90)</td>
<td>5.31 (1.24)</td>
<td>4.29 (0.96)</td>
</tr>
<tr>
<td>Ever Asthma¹</td>
<td>20.0%</td>
<td>19.9%</td>
<td>14.7%</td>
<td>17.7%</td>
</tr>
<tr>
<td>Current Asthma²</td>
<td>11.9%</td>
<td>17.3%</td>
<td>9.6%</td>
<td>13.5%</td>
</tr>
<tr>
<td>Current Smoking</td>
<td>39.3%</td>
<td>41.0%</td>
<td>20.9%</td>
<td>35.9%</td>
</tr>
</tbody>
</table>

1. Ever diagnosed as asthmatic by a physician.
2. Ever diagnosed as asthmatic by a physician, and active symptoms in past year.
Are all particles created equal?

- Focus on particulate mass mainly due to availability of exposure data used in health studies
- Mass is not likely the only characteristic of particle-phase pollution that is toxic
- Mixtures of pollutants represent the health risk of significance
- Individual risk - risk factors - susceptibility

Environmental Health - Path Forward

- Focus in on the most toxic elements/components to health
- Exposure data is essential and critical
- Identify those at greatest risk
- Acute Chronic responses
- Emerging challenges
  - thresholds
  - mixtures
  - susceptibility
  - community specific
  - regional
  - global
Summary

• Air pollution – health studies are dependent on valid and high quality air pollution measurements (regional, local and personal)
• Epidemiologic studies are essential to characterize and estimate the risk posed to health by air pollution
• Epidemiologic studies in “unstudied” populations and regions are needed to improve the quantification of the health risks of air pollution
• Many “acute studies” – few chronic health studies – with significant effects at low levels, the risks to health of chronic low level exposures are important public health and environmental health issues