Epidemiological Tools to Evaluate Impacts of Air Pollution

Janice J. Kim, MD, MPH
Air Toxicology and Epidemiology Branch
OEHHA/Cal EPA
Oakland, CA
jkim@oehha.ca.gov
Overview of Topics

• Types of scientific studies used to determine health impacts of air pollution
• Epidemiology in a nut-shell
• Examples from the air pollution epidemiology literature
Investigations of Health Effects of Air Pollution

- Toxicology studies on animals or cell lines
- Controlled human exposure studies
- Epidemiological studies

Each method has advantages/disadvantages
Controlled Human Exposure Studies

• Advantages
  – Precise measures of exposure and response
  – No need to extrapolate toxicological studies in animals to humans

• Limitations
  – Few studies on more vulnerable populations
  – Small sample size and limited doses studied
  – Few studies of pollutant mixtures
  – Cannot predict effects of chronic exposures
Epidemiologic studies of Air Pollution

- Examines effects of air pollution in large human populations under real-world conditions

- Looks for association between the exposure of interest (e.g. level of ozone) and a health outcome using statistical methods
Epidemiologic studies of Air Pollution

Advantages:
• Studies real-world exposures (short and long term) and health responses in human populations
• Can examine vulnerable subgroups
• Can study pollutants that are heterogeneous, e.g. particulates, that have been historically difficult to study in the clinical/lab setting
Epidemiologic studies of Air Pollution

Limitations or challenges:

• Obtaining quality data on disease rates
• Exposure imprecise
• Need information on other risk factors for disease that are correlated with pollution (confounders)
• May be difficult to determine threshold (no effect level)
• Not optimal to elucidate mechanisms
• Other co-pollutants may also contribute
• Sample size needed to see an effect
General types of epidemiology studies include:

- **Longitudinal**
  - Prospective and Retrospective **Cohort**
  - **Case-control** (retrospectively determine exposures)
- **Cross-sectional** (snapshot across a population at one time period)
- **Panel Studies**
- **Time-Series Studies**
Epidemiological studies of Air Pollution

• **Studies of acute effects**
  – Panel study
    • Follow group of asthmatic children over time, measure lung function daily, air pollution daily.
    • Is ↑ ozone associated with ↓ lung function?
  – Time series – ↑ Pollutant from day to day and ↑ hospitalizations or # of deaths
Time Series Studies of PM

- Examine association over time in one area between daily changes in PM10 and daily counts of mortality or hospitalizations, controlling for other factors
- Can control for effects of weather, DOW, season
- Confounders (smoking, BMI) less of a problem
- Only effects of relatively short-term exposure are examined
- Measurement error can be a problem
Many time-series studies of PM and mortality conducted in hundreds of cities worldwide, over a wide range of climates, seasonal patterns, PM concentrations, co-pollutants, background health conditions, housing stock etc.

Consistent associations between daily average PM10 and PM2.5 (central-site monitor) and mortality.

Multi-city analyses using same methods to estimate average effect.
Prospective Cohort Study: 
The USC Children’s Health Study

1759 children in 12 communities with varying levels of air pollution follow 10 to 18 years old. Yearly lung function, resp health. Data on individual level risk factors (confounders)

Exposures: air pollution (O₃, NO₂, acid vapor, PM10, PM2.5, EC, OC) in communities carefully monitored

Determine community-averaged growth in measures of lung function

Community-Specific Average Growth in FEV$_1$ During the Eight-Year Period Plotted against Averaged Nitrogen Dioxide (NO$_2$) Levels

Many air pollutants correlated: difficult to ascribe effect to one pollutant

**Table 1.** Correlation of Mean Air-Pollution Levels from 1994 through 2000 across the 12 Study Communities. *

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>$O_3$ (10 a.m.--6 p.m.)</th>
<th>NO$_2$</th>
<th>Acid Vapor†</th>
<th>PM$_{10}$</th>
<th>PM$_{2.5}$</th>
<th>Elemental Carbon</th>
<th>Organic Carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>$O_3$</td>
<td>0.98</td>
<td>0.10</td>
<td>0.53</td>
<td>0.31</td>
<td>0.33</td>
<td>0.17</td>
<td>0.25</td>
</tr>
<tr>
<td>1-Hour maximal level</td>
<td>-0.11</td>
<td>0.35</td>
<td>0.18</td>
<td>0.18</td>
<td>-0.03</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>10 a.m.--6 p.m.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO$_2$</td>
<td></td>
<td>0.87</td>
<td>0.67</td>
<td>0.79</td>
<td>0.94</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>Acid vapor†</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td></td>
<td></td>
<td></td>
<td>0.79</td>
<td>0.87</td>
<td>0.88</td>
<td>0.76</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.95</td>
<td>0.85</td>
<td>0.97</td>
</tr>
<tr>
<td>Elemental carbon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.82</td>
</tr>
<tr>
<td>Organic carbon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Unless otherwise noted, values are the 24-hour average pollution levels. $O_3$ denotes ozone, NO$_2$ nitrogen dioxide, and PM$_{10}$ and PM$_{2.5}$ particulate matter with an aerodynamic diameter of less than 10 μm and less than 2.5 μm, respectively. † Acid vapor is the sum of nitric, formic, and acetic acid levels.

Community-Specific Proportion of 18-Year-Olds with Low FEV1 (80% of predicted) Versus Pollutants Averages (1994-2000)

Estimates of Exposure

- Many air pollution epidemiology studies assign exposures based on central site monitors.
- If the error is random, using an average community exposure will tend to underestimate the risks (i.e. will tend to bias towards not finding an effect of exposure).
- Better exposure assessments improve estimates of effect.
Refining Exposure Assessment in Epidemiology Studies

- Jerrett et al (2005) studied LA subset of ACS (22,905 people and 5,856 deaths)

- Refined PM2.5 exposure using sophisticated interpolation techniques, 23 monitoring sites.
  - The mortality estimates per 10 µg/m³ increase in PM2.5 were > 2X higher than risks found in earlier studies
  - Strongest for ischemic heart disease
Epidemiological studies to evaluate impacts from nearby sources
Traffic pollutants significantly higher near and downwind of busy roads

East Bay Children’s Respiratory Health Study: A Cross-sectional Design

• 1111 children in Alameda County, 10 elementary schools near and further from freeway. Health questionnaire, monitored neighborhood levels of traffic pollutants at school- fall & spring

• In an area with good regional air quality:
  – Levels of traffic pollutants up to 1.5 to 2x higher at locations near & downwind of freeway.
  – Children from schools/neighborhoods with ↑ levels of traffic pollutants have an ↑ risk of bronchitis and current asthma

Residential Exposure to Petrochemicals and Risk of Leukemia <29 years old): Use of GIS tools

- Case-control study in Kaohsiung, southern Taiwan. 4 petrochemical plants, high air toxics; cases (171), population-based controls (410)

- Exposure opportunity score: (mobility of subject, length of stay, monthly prevailing wind direction, within 3 km of refinery (inverse distance wt), multiple refineries considered)

Residential Exposure to Petrochemicals and Risk of Leukemia <29 years old):

Use of GIS tools

• Mapped residences
• Determine exposures

• ↑ adj Odds Ratios for leukemia
  – OR: 1.54 (1.14, 2.09) in 20-29 year olds per unit exposure score

Limitation: hard to determine relevant exposure for risk assessment
Map of the study area, Kaohsiung, southern Taiwan, Republic of China, 1997-2003

Epidemiological studies: insights into subpopulations at risk and mechanism

- **Diet:** RCT 158 children in Mexico City (high ozone) with moderate to severe asthma. Antioxidants vs placebo. Monitored lung function. (Romieu et al. Am J Respir crit Care Med. 2002; 166:703-9)
  - Placebo: ↑ ozone assoc with lower lung function
  - Antioxidants: No relation between ozone and lung function

- **Genetics:** Asthmatics with genetic deficiency of GSTM1 more susceptible to ozone: (Romieu et al. Thorax, 2004; 59: 8-10)
  - RCT - same group above genotyped.
  - Placebo group:
    - GSTM1 null – susceptible to ozone
    - GSTM1 positive – no significant effect of ozone
  - Antioxidant group
    - Protective effect of antioxidant stronger in GSTM1 null
Epidemiology Studies of Air Pollution-Datagaps: Effect Modifiers

Can other lifestyle/societal factors increase susceptibility to air pollution?

- SES: “Preterm birth: the interaction of traffic-related air pollution with economic hardship in Los Angeles neighborhoods:

- Chronic stress ?: “Synergistic Effects of Traffic-Related Air Pollution and Exposure to Violence on Urban Asthma Etiology”
  Clougherty et al. Env Health Perspect 2007; 115: 1140–1146
Epidemiology Studies of Air Pollution- Datagaps: Co-Pollutants

• Diseases are multi-factorial and environmental exposures can be synergistic: examples
  – Lung Cancer: Radon & smoking
  – Lung Cancer: Asbestos & smoking
  – Liver Cancer: Aflatoxin & hepatitis B virus

• Is there interaction between co-pollutants from same or multiple sources?
Thank you