Personal Exposure to Hazardous Air Pollutants in Minneapolis and St. Paul

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Outline

- HAPS: PM2.5 and VOCs
- Study design
- Communities and Sources
- Personal (P), Indoor (I), and Outdoor (O) VOC results
- PIO PM2.5 results
- Risks, Summary, & Conclusions
Why Study This?

• **Health effects**
  – Many VOCs (volatile organic compounds) have estimated cancer risks in the range of concern
  – Particulate matter: elevated mortality and morbidity in the elderly and infirm (caveat: other criteria pollutants may matter)
    • Results vary: Schwartz (1994) vs. Moolgavkar et al. (1997)

• **Assess the validity of central site monitors as regulatory/decision tools**

• **Air pollution epidemiology studies and misclassification**
  – how much do pollutant exposures vary within people over time?
Measurement Issues
Source: Pirkle et al. 1995, JEAEE 5(3): 405-424
PM$_{2.5}$: 112 24-hour periods
VOCs: 58 48-hour periods

Personal
PM$_{2.5}$ OVM

Indoor
PM$_{2.5}$ OVM

Outdoor
PM$_{2.5}$ OVM

Neighborhood
PM$_{2.5}$ (FRM) OVM
VOC Canister
N=3
Study Communities
Phillips Neighborhood Monitoring Site

PM$_{10}$

VOCs

PM$_{2.5}$
3M Personal Organic Vapor Monitor (OVM)
## VOCs Measured

### VOCs Measured with OVM Badges (and FRM)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>a-Pinene</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>b-Pinene</td>
</tr>
<tr>
<td>Chloroform</td>
<td>Styrene</td>
</tr>
<tr>
<td>p-Dichlorobenzene</td>
<td>Tetrachloroethylene (PERC)</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>Toluene</td>
</tr>
<tr>
<td>d-Limonene</td>
<td>Trichloroethylene</td>
</tr>
<tr>
<td>Methylene Chloride</td>
<td>m,p-Xylene</td>
</tr>
<tr>
<td></td>
<td>o-Xylene</td>
</tr>
</tbody>
</table>
PM2.5 Measurements

• Central sites: FRM
• Personal and Indoor at home: MSP impactors, pumps, time dairies
• Flow rates O>I>P
• Detection Limits: P>I>O
• Pretty good (but not perfect) temporal match
Number of People/Samples
(Non-Smoking Adults)

VOCs: 71 Subjects
• 2-18 samples per subject
• 58 48-hr sampling periods
  – P = 288
  – I = 292
  – O = 132

PM2.5: 29 Subjects
• 7-15 samples per subject
• 112 24-hr sampling periods
  – P = 332
  – I = 294
  – O = 270
VOC Sources and Emissions
Outdoor VOC Sources

- **Point Sources** - large stationary sources inventoried individually (424 in metro)
- **Mobile Sources** - cars, trucks, planes, trains, boats, construction equipment, farm equipment, off-road vehicles, lawn and garden equipment, etc. (apportioned to census tracts)
- **Area Sources** - smaller stationary sources inventoried collectively (22 categories apportioned to census tracts)
<table>
<thead>
<tr>
<th></th>
<th>Point Source Emissions (%)</th>
<th>Mobile Source Emissions (%)</th>
<th>Area Source Emissions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>1%</td>
<td>73%</td>
<td>26%</td>
</tr>
<tr>
<td>Chloroform</td>
<td>26%</td>
<td>0%</td>
<td>74%</td>
</tr>
<tr>
<td>Dichloromethane</td>
<td>21%</td>
<td>0%</td>
<td>79%</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>5%</td>
<td>85%</td>
<td>10%</td>
</tr>
<tr>
<td>Styrene</td>
<td>55%</td>
<td>44%</td>
<td>1%</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>14%</td>
<td>0%</td>
<td>86%</td>
</tr>
<tr>
<td>Toluene</td>
<td>5%</td>
<td>58%</td>
<td>37%</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>66%</td>
<td>0%</td>
<td>34%</td>
</tr>
<tr>
<td>Xylenes</td>
<td>7%</td>
<td>59%</td>
<td>34%</td>
</tr>
</tbody>
</table>
Primary VOC Sources Indoors
(source: Wallace 1991*)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroform</td>
<td>Chlorinated water, especially when heated as in showering, dishwashing, etc.</td>
</tr>
<tr>
<td>p-Dichlorobenzene</td>
<td>Mothballs, toilet block deodorizers, other consumer products (check labels), chemical manufacturing industry</td>
</tr>
<tr>
<td>α- and β-Pinene</td>
<td>Cleaning products, room fresheners</td>
</tr>
<tr>
<td>d-Limononene</td>
<td>Cleaning products, room fresheners</td>
</tr>
</tbody>
</table>

VOC Measurement
Results:
P, I, O
Personal VOC Range Plots
Indoor VOC Range Plots
Indoor Range plots

Personal Range Plots
## VOC Measurement Results

\( (\mu g/m^3) \)

<table>
<thead>
<tr>
<th></th>
<th>Outdoor</th>
<th></th>
<th>Indoor</th>
<th></th>
<th>Personal</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50th</td>
<td>90th</td>
<td>50th</td>
<td>90th</td>
<td>50th</td>
<td>90th</td>
</tr>
<tr>
<td>Benzene</td>
<td>1.3</td>
<td>3.3</td>
<td>1.9</td>
<td>15</td>
<td>3.2</td>
<td>18</td>
</tr>
<tr>
<td>p-Dichlorobenzene</td>
<td>0.1</td>
<td>0.2</td>
<td>1.4</td>
<td>8.9</td>
<td>0.4</td>
<td>5.1</td>
</tr>
</tbody>
</table>
How well do Outdoor and Personal Agree?

How well do Indoor and Personal Agree?
VOC Results: PIO

- Consistent P>l>O observed for 13 of 15 chemicals
  - Exceptions: Carbon Tetrachloride, Chloroform
- I does better than O
- Underestimation is greater at the upper end of the exposure distribution
- Central sites under estimate actual exposures for urban residents even when measured in their own community
Longitudinal VOC Results

• How well do O levels predict I and P within people over time?
• Mixed model approach:
  – Adjust for season and community effects
  – Address issue of within person and within monitoring period autocorrelation
Longitudinal VOC Results

- **Benzene:**
  - P-O median $r=0.59$ (range -0.85-0.99)
  - P-I median $r=0.86$ (range -0.26-0.99)

- **p-Dichlorobenzene**
  - P-O median $r=0.00$ (range -0.72-0.98)
  - P-I median $r=0.57$ (range -0.54-0.99)
Longitudinal VOC Results (con.)

• Within person variability typically spanned at least an order of magnitude
• Between person variability typically spanned 2 or more orders of magnitude
• I a better predictor of P than O, especially in the upper third of the exposure distribution
PM2.5
Measurement Results:
P, I, O
Personal, Indoor and Outdoor PM$_{2.5}$ ($\mu$g/m$^3$)
Indoor Measurements Within Subjects
Personal Measurements Within Subjects
PIO PM2.5 Results

• O did not vary substantially by community
• Consistent P>I>O observed for most subjects
• Cross-sectional correlations for P-O pairs low and, but I-O (0.27) and P-I (0.51) higher.
• “Personal cloud” substantial: average is 5.7 µg/m³, but mean of means = 15.7 µg/m³.
  – Varies by activities, working outside of home
• Central sites under estimate actual PM2.5 exposures for urban residents even when measured in their own community.
## PM2.5 Longitudinal Correlations

<table>
<thead>
<tr>
<th>Model (Med. n, range)</th>
<th>Median Correlation</th>
<th>Range of Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>P=O (n=11; 7-15)</td>
<td>0.02</td>
<td>-0.52-0.94</td>
</tr>
<tr>
<td>I=O (n=10; 7-13)</td>
<td>0.25</td>
<td>-0.45-0.88</td>
</tr>
<tr>
<td>P=I (n=9; 5-11)</td>
<td>0.45</td>
<td>-0.55-0.98</td>
</tr>
</tbody>
</table>
Sensitivity Analysis: Longitudinal PM$_{2.5}$ Correlations
PM$_{2.5}$ Longitudinal Results

- 29 nonsmoking subjects with 7-15 days of P/I matched with O measurements
- Longitudinal correlations: P-I high, I-O moderate, P-O low
- In these healthy non-smoking adults personal exposure to PM25 does not correlate strongly with outdoor central site monitors
Risks/Context

• VOC health benchmarks
  – HRVs, other sources

• PM2.5 Ambient Standard
  – 65 µg/m³ 24-hr std
  – 15 µg/m³ annual average
### VOCs: Concentrations & Health Benchmarks

<table>
<thead>
<tr>
<th>Compound</th>
<th>Health Benchmark ($\mu$g/m³)</th>
<th>O ($\mu$g/m³) 50th (90th)</th>
<th>I ($\mu$g/m³) 50th (90th)</th>
<th>P ($\mu$g/m³) 50th (90th)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>1.3ᵃ</td>
<td>1.3 (3.3)</td>
<td>1.9 (15.3)</td>
<td>3.2 (18.3)</td>
</tr>
<tr>
<td>p-DCB</td>
<td>0.9ᵇ</td>
<td>0.1 (0.2)</td>
<td>0.2 (1.5)</td>
<td>0.4 (5.1)</td>
</tr>
</tbody>
</table>

ᵃMN HRV, upper bound 1 in 100,000 lifetime risk for 70 yrs
ᵇCALEPA, upper bound 1 in 100,000 lifetime risk for 70 yrs
Summary/Conclusions:

• Generally for measured VOCs/PM2.5:  
  \[ P > I > O \]

• Relatively high P-O/P-I longitudinal correlation coefficients mean that in healthy adults the variability in VOC exposures can be reasonably predicted within individuals over time.

• This was not true for PM$_{2.5}$, probably because of low outdoor variability and activity patterns of the working adult population

• Risk assessments based on outdoor VOC measures appear to seriously underestimate lifetime cancer risks from these compounds
Acknowledgements

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