Application of Personal, Spatio-Temporal Exposure Assessment for Asthmatic Children in Denver, Colorado

Colby Adams¹, Kate Marquart², Matt Strand², Nathan Rabinovitch², and John Volckens¹

(1) Department of Environmental and Radiological Health Sciences, Colorado State University, Fort Collins, CO;
(2) National Jewish Health, Denver, CO

I. Abstract

A novel, temporospatially-referenced sampling method that integrated real-time particulate matter (PM) monitors, global positioning system (GPS) receivers, ambient temperature monitors and a geographical information system (GIS) was used to monitor PM exposures of elementary-age, asthmatic children. Thirty-two children carried the sampler for four consecutive 22 hr periods (Mon – Thur) during two distinct weeks throughout the school year, resulting in over 150 daily samples. The time-referenced signals (10-sec records) for fine particulate matter concentration, ambient temperature, and location were synchronized and merged within a GIS to analyze and visualize the children’s exposures. Temporospatially-based algorithms were applied to apportion exposure data into four microenvironments: school, home, morning transit and afternoon transit. This method allowed examination of personal exposure patterns as a function of time, location, and activity with spatial resolution on the order of meters and temporal resolution on the order of seconds. With this technique, we generated an ‘exposure budget’ detailing the contribution of various microenvironments to a child’s daily intake of PM. Such resolution was previously impossible with traditional, time-integrated filter measurements. Personal PM levels were greatest at home, followed by morning transit, afternoon transit and school (p<0.01). Correlations between personal, microenvironmental PM levels and wide-area measurements (i.e., community-based monitors) demonstrate the need for more precise exposure assessment techniques, especially to inform the design of effective interventions. Substantial ‘peak exposure’ events were detected during a child’s morning commute to school; such peak events may contribute to asthma worsening.

II. Materials and Methods

Study Cohort
- 32 Asthmatic Children in Denver, CO:
  - Attending the Kunsberg School at National Jewish Health
  - Aged 6-12 years
- Current diagnosis of moderate or severe asthma

Exposure Assessment

- Figure 1. Multi-Sensor Backpack Apparatus
  - Pump (BGI Omnis, 6.8 L/min)
  - Teflon Sampling Filter (37mm, gravimetric analysis)
  - Cyclone (KTL 2.05; PM₁.₅)
  - Direct-Reading PM Monitor (Thermo, pDR-1200)
  - GPS Receiver (Garmin 60Cx, WAAS-enabled)
  - Thermometer (Thermo Record TR-52)

- Each Child:
  - Two, 4-day Sampling Events
  - Urinary LTE₄ (daily @ 12pm)
  - Inhaler Use Records
  - Activity Questionnaire
  - Pulmonary flow testing

- 10-second data averages

Exposure Apportionment

- Merge PM, GPS, Temp data streams (based on recorded time-stamp)
- Data Entered into GIS Database
- Define Spatial Buffers
  - Around each home
  - Around school
- Time-Based Rules (data quality check)
  - At home (9pm-5am)
  - At school (9am-3pm)
  - Transit (any other time)
- Four location/activity apportionments
  - At Home
  - At School
  - Morning commute (am transit)
  - Afternoon commute (pm transit)

- Table 1. Pearson coefficients (hourly average)

<table>
<thead>
<tr>
<th>Location/activity</th>
<th>PM₁.₅ School Monitor</th>
<th>PM₁.₅ Metro Denver Monitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit (am)</td>
<td>0.16</td>
<td>0.18</td>
</tr>
<tr>
<td>At School</td>
<td>0.14</td>
<td>0.18</td>
</tr>
<tr>
<td>Transit (pm)</td>
<td>0.17</td>
<td>0.11</td>
</tr>
<tr>
<td>At Home</td>
<td>0.06</td>
<td>0.06</td>
</tr>
</tbody>
</table>

- Figure 3. Street-map overlay of one child’s personal PM levels. Each circle represents a 30-second average exposure of at the subject’s location throughout a single day. Circle color indicates the location-activity of exposure and circle size indicates the relative magnitude of measured PM₁.₅ levels.

- Figure 4. Histograms of average, personal PM₁.₅ levels (entire cohort) by location/activity. Exposures appear log-normally distributed. Median levels of personal PM₁.₅ range from 4-10 µg/m³.

- Figure 5. Box-Whisker plots of personal PM₁.₅ levels (entire cohort) by location/activity. Higher levels measured (on average) for morning commute compared to afternoon commute
  - Home: Highest overall
  - School: Lowest overall
  - Measured personal levels span many orders of magnitude (log-normal)

III. Results

A Typical 22-hr ‘Exposure Track’

- Figure 6. Cumulative distributions of personal PM₁.₅ levels as a function of child location/activity

IV. Future Work

- Analyze health effect associations
  - Urinary LTE₄, FEV, inhaler vs. personal, area PM levels
- Examine individual exposures
  - Mixed models, smoking homes, transit routes
- Analyze ‘peak’ exposure events
  - Are exposure peaks associated with acute health effects?

The authors wish to thank Dr. Philip Riggs with his assistance with the exposure apportionment. This work was funded in part by a grant from the CI3/CWBS College Research Council (Volckens) and grant ES015510 from the NIEHS (Rabinovitch). Contact: john.volckens@colostate.edu