Modeling highway-generated air pollution in a residential urban neighborhood

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About 10% of the United States population lives within 100 m of a highway.

Accurate exposure estimates to quantify health effects require knowledge of the spatial and temporal variations in highway-generated air pollution.
Objectives

► Develop a model that predicts highway-generated air pollution concentrations on an hourly basis with 20 m x 20 m spatial resolution.

► Use the model to assign personal exposures to highway-generated air pollution.
Methodology

► Conduct intensive air pollution monitoring in a mobile research lab.
► Develop a model to extrapolate from individual monitoring events to all meteorological and traffic conditions in the study area.
► Combine model results with personal time-activity histories to estimate exposures.
Research Lab

- PNC, particle size distribution, NO/NO\textsubscript{X}, CO, PPAH, BC, PM\textsubscript{2.5}
# Instrumentation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle number</td>
<td>condensation particle counter</td>
</tr>
<tr>
<td>concentration</td>
<td></td>
</tr>
<tr>
<td>Particle size distribution</td>
<td>scanning mobility particle sizer</td>
</tr>
<tr>
<td>NO/NO(_x)</td>
<td>chemiluminescence analyzer</td>
</tr>
<tr>
<td>CO</td>
<td>gas filter correlation analyzer</td>
</tr>
<tr>
<td>PPAH</td>
<td>photoelectric aerosol sensor</td>
</tr>
<tr>
<td>Black carbon (BC)</td>
<td>aethalometer</td>
</tr>
<tr>
<td>PM(_{2.5})</td>
<td>laser photometer</td>
</tr>
</tbody>
</table>
Data Collected

► Collect data representing all typical weather conditions.

► Currently have data from 6-hour blocks on >35 days representing:
  ▪ Weekdays, Saturdays, Sundays
  ▪ Summer, Fall, Winter, Spring
  ▪ Morning and Afternoon
Ultrafine Particles

► Diameter <100 nm.

► More toxic per unit mass than particles with larger diameters (e.g., Dockery et al., 2007).

► Currently, in the USA, particles are regulated by mass (PM$_{2.5}$, PM$_{10}$), not number.
Wind direction: NW  
Wind speed: 3-23 mph  
Temperature: 22.8-23.5 °F

400 m buffer

Particle Number Concentration (#/cc)
- <28,000
- 28,000 - 60,000
- 60,000 - 89,000
- 89,000 - 120,000
- 120,000 - 277,000

January 6, 2010  
05:30-06:30
California Line Source Dispersion Model (CALINE4) Overview

- Gaussian model designed to model CO.
- Inputs: Meteorology, source strength, and site geometry.
- Output: Pollutant concentrations at designated receptors.
- Predicts air quality impacts within 500 m of source.
Source Strength

- Reported as emission factors.
  - e.g., g/vehicle-mile
- Usually tabulated.
- Since tables don’t exist for ultrafines…
  … we fit the emission factor to data as a model parameter (after Gramotnev et al., 2004).
Emission Factor Calibration

Somerville, MA Jan. 6, 2010 07:30-08:30

Distance from I-93 centerline, m

Particle number concentration, #/cc

-600 -400 -200 0 200 400 600

-600 -400 -200 0 200 400 600

-600 -400 -200 0 200 400 600

Measurements

Model
Emission Factor Results

<table>
<thead>
<tr>
<th>Study</th>
<th>Emission factor (×10^{14} particles/veh-mile)</th>
<th>particle size range (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>This study</td>
<td>9–18</td>
<td>7 – 225</td>
</tr>
<tr>
<td>Gramotnev et al., 2003</td>
<td>4.5</td>
<td>&lt;100</td>
</tr>
<tr>
<td>Birmili et al., 2009</td>
<td>3.4 (±0.3)</td>
<td>&lt; 500</td>
</tr>
<tr>
<td>Zhu and Hinds, 2005</td>
<td>8.3</td>
<td>7 – 1,000</td>
</tr>
</tbody>
</table>
Some possible explanations for our relatively high emission factor

- Noise barriers shield neighborhoods from highway-generated pollution.
- Colder temperatures than other studies.
- Vehicle speeds may also play a role.
Comparison of Modeled and Measured CO Results
Conclusions

► Generally good agreement between model results and measurements.
► Large variation on 1-hour timescale.
► Noise barrier and hills likely have strong effect on highway-generated pollutant mixing.
► More sophisticated models (e.g., QUIC) are needed to accurately predict concentration variations over complex urban terrain.
Next Steps

- Validate emission factor estimate using additional days of data.
- Develop Quick Urban & Industrial Complex (QUIC) Dispersion Model to include noise barrier and elevation.
- Determine which other roads may significantly contribute to particle levels.
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