Evolution of Traffic-Related Atmospheric Pollutants Near Roadways

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Background

- Traffic-related atmospheric pollutants (TRAP) are believed to adversely impact the health of populations living and working near roadways.
- Approximately 4 million (~13%) Canadians live within 100 m of a major road.
- Estimation of the exposure of these populations to TRAP in challenging as concentrations of TRAP vary both spatially and temporally.
Objectives

• To evaluate concentration gradients of traffic-related pollutants as a function of distance (3-280m) from a highway
• To characterize size evolution of ultrafine particles (UFP) from the highway
• To quantify the number size distribution of non-volatile particle cores using a thermodenuder (TD) system
• To identify chemical properties and mixing status using a single particle mass spectrometry
Measurements

- Thermodenuder (TD) at 250°C
- FMPS/TD-FDMS (5 min interval)
- ATOFMS/TD-ATOFMS (5 min interval)
- APS
- DustTrak (PM2.5 and PM1)

- Aethalometer (Black carbon, BC)
- Particle bound PAH monitor
- Gas analyzers
- Met system (WD, WS)
- GPS & Webcam
• On average, \(~53\%\) of total UFP number concentration decayed between 15m and 27m, while most (\(~90\%\)) of traffic-related UFP (< 25nm) disappeared at 280m from the highway.
Evolution of UFP Size Distribution

- ~90% of traffic-related 10 nm UFP decayed exponentially with increasing distance (15m to 280m).
- 55~67% decay of 10 nm particles between 15m and 27m.

Enhanced particle decay due to coagulation/condensation onto preexisting particles.
Distance Decay Gradient in UFP

\[ y = 2565 + 23459 \exp\left(-\frac{x-15}{13}\right) \]
## Decay gradients (%/10m) of TRAPs

<table>
<thead>
<tr>
<th></th>
<th>Aug. 26</th>
<th></th>
<th>Aug. 19</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15-27m</td>
<td>27-280m</td>
<td>15-27m</td>
<td>27-280m</td>
</tr>
<tr>
<td><strong>UFP$_{25}$ (&lt;25 nm)</strong></td>
<td>45</td>
<td>3.6</td>
<td>53</td>
<td>3.6</td>
</tr>
<tr>
<td><strong>UFP (25-100nm)</strong></td>
<td>43</td>
<td>3.0</td>
<td>8</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>UPF (100-500nm)</strong></td>
<td>32</td>
<td>2.4</td>
<td>35</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>UFP (8-500nm)</strong></td>
<td>44</td>
<td>3.4</td>
<td>(26)</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>Black Carbon</strong></td>
<td>na</td>
<td>2.8</td>
<td>na</td>
<td>1.7</td>
</tr>
<tr>
<td><strong>p-PAH</strong></td>
<td>na</td>
<td>3.2</td>
<td>na</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>PM$_{2.5}$</strong></td>
<td>na</td>
<td>0.7</td>
<td>na</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>PM$_{2.5}$ (µg m$^{-3}$)</strong></td>
<td>2</td>
<td></td>
<td>16</td>
<td></td>
</tr>
<tr>
<td><strong>Average WD (°)</strong></td>
<td>280</td>
<td></td>
<td>240</td>
<td></td>
</tr>
<tr>
<td><strong>Average WS (m/s)</strong></td>
<td>5.1</td>
<td></td>
<td>3.4</td>
<td></td>
</tr>
</tbody>
</table>
Micro-Scale UFP Gradients within 20m

- Overall 31%/10m decrease in the total UFP number
- Highest decay rate for nuclei mode particles (Dp ~10nm)
  - ~39%/10m for 10nm
  - ~24%/10m for 20nm

Using two FMPSs
6-run average at each location
# Decay Gradients (%/10m) of UFP

<table>
<thead>
<tr>
<th>%/10m</th>
<th>Sep. 1</th>
<th>Aug. 26</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3-9m</td>
<td>9-15m</td>
</tr>
<tr>
<td>UFP (&lt;25 nm)</td>
<td>59</td>
<td>29</td>
</tr>
<tr>
<td>UFP (25-100nm)</td>
<td>39</td>
<td>23</td>
</tr>
<tr>
<td>UPF (100-500nm)</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>UFP (8-500nm)</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>PM$_{2.5}$ (µg m$^{-3}$)</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Average WD (°)</td>
<td>260</td>
<td></td>
</tr>
<tr>
<td>Average WS (m/s)</td>
<td>6.7</td>
<td></td>
</tr>
</tbody>
</table>
Aerosol Dynamic Processes

Near

Condensation
Coagulation
Evaporation
Dilution

3.0% / 10m
(27-280m)

Far

Coagulation
+ Dilution Only

2.4% / 10m
(27-280m)
Size Distribution of Non-Volatile UFP

- Mostly no shift in the size distributions of non-volatile UFP
- Mode of non-volatile particles: 20-30nm, 70-80m (aggregates)
Traffic-related Particle Type Profiles

- Aerosol conditioned with a TD and without TD
- Collected from 5:30 am to 9:30 am
- At Sites B (27m) and C (280m)
  - AB : Non-TD particles at Site B (27 m from the highway)
  - AC : Non-TD particles at Site C (280 m from the highway)
  - TB : TD particles at Site B (27 m from the highway)
  - TC : TD particles at Site C (280 m from the highway)
- ART-2a Clustering Analysis
Evolution of Particle Types

- Common particle types
  - K-rich
  - OCECNOxSOx
  - ECOC
  - Ca-rich

- Unique particle type
  - EC-soot (only at 27m)
  - OCEC (only at 280m)

Background particle types: K-rich
Common Particle Types

- OC fragments (m/z 43, 44, 53, 55), C12n+, C12n-, Ba137/138, Ca, organic nitrogen, phosphate, nitrate, sulphate
- Diesel-like particles

**OCECNOxSOx**

- Strong Ca/CaO, Na, organic fragments (m/z 55), Ba1375/137, C12n-, Phosphate, nitrate, no sulphate
- Fuel additives (i.e., Ca, Ba) and lubricant oil (Phosphate) from likely gasoline

Observed at both sites, 27 m and 280 m from the highway
Transformation of Particle Types

- Clearer C12n+, weak C12n-, organic fragments, weak negative spectra, less sulphate
- Gasoline-like particles

ECOC → OCEC

253m

- Strong similarity in the positive spectra with the ECOC type
- Many organic fragments in both pos. and neg. spectra
- Increase of condensable vapors and/or coagulation of organics
EC-soot (soot aggregates)

- Only observed at Site B (at 27m) w/o TD
- Fresh soot aggregates formed from small soot monomers coated with volatile matters, i.e., water layers
- Diesel-related particle type
- Size mode: 0.2 ~ 0.5 µm

DECREASED SIZE  
CONSERVED MASS  
INCREASED NUMBER

27m-280m or TD at 250 ºC

DECREASED SIZE  
CONSERVED MASS  
SAME NUMBER
Summary

• On average, the decay rates of the total traffic-related UFP number concentrations from a highway were found to be ~50%/10m (3-15m), ~40%/10m (15-27m), and 3%/10m (27-280m).

• The decay rates varied by particle sizes, pre-existing particles, and wind speeds.

• There was no significant shifts in the size distributions of non-volatile UFP, except for possible break-down of fresh soot aggregates.

• The ATOFMS/TD-ATOFMS system identified non-volatile traffic-related particle types, OCECNOxSOx, ECOC, Ca-rich and a unique type, EC-soot only at near highway.
Acknowledgements

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