Using air pollution sensors carried by cyclists and pedestrians to capture the spatio-temporal variability of air pollution in Toronto

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Objectives
Spatial analysis of exposure to traffic-related air pollution at birth and childhood atopic asthma in Toronto, Ontario
K. Shankardass, C. M. Jerrett, S. D. Duff

Environment International
Volume 74, January 2015, 1-2

Exposure to traffic-related air pollution and developing breast cancer among women in eight Canadian provinces: A case–control study
Perry Hystad, Paul J. Villeneuve, Mark S. Goldberg, Dan L. Burke, Kenneth Johnson, the Canadian Cancer Registries Epidemiology Research Group

Neurobehavioral effects of exposure to traffic-related air pollution and transportation noise in primary school children
Elise van Kempen, Paul Fischer, Nicole Janssen, Danny Hou, Kamp, Stephen Stansfeld, Flemming Cassee

Air pollution boosts heart attack risk
Public health significantly affected by air quality

Journal of Toxicology and Environmental Health, Part A: Current Issues
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/uteh20

The Association Between Chronic Exposure to Traffic-Related Air Pollution and Ischemic Heart Disease

Perinatal Exposure to Traffic-Related Air Pollution and Atopy at 1 Year of Age in a Multi-Center Canadian Birth Cohort Study
Hind Sbihi, Ryan W. Allen, Allan Becker, Jeffrey R. Brook, Piush Mandhane, James A. Scott, Malcolm R. Sears, Padmaja Subbarao, Tim K. Takaro, Stuart E. Turvey, and Michael Brauer
Motivation

- The development of air pollution surfaces is crucial for a better understanding of population exposure.

- Live air pollution data can be used to investigate the effect of traffic management on air pollution hot spots (e.g. low emission zones).

- Mobile monitoring campaigns provide unparalleled coverage of an urban area.
The rise of portable air pollution monitors coupled with GPS devices

Aeroqual sensor (NO2 and O3)

DiscMini (UFP)

MicroAeth (BC)

enables....
...mobile monitoring and panel studies

BUT....
Some hypotheses have not been tested and many questions regarding the role of air pollution sensors remain unanswered.

- Sensors need calibration

- Is air pollution data collected in an ad-hoc way useful to capture the spatio-temporal variability of air pollution in an urban area?
Comparing the performance of various data collection protocols
- Fixed points
- Pedestrians
- Cyclists
- Panel
Four data collection protocols conducted in the same campaign
Panel study

- Gold standard for measuring exposure
- Recruiting participants from the general population
- Personal exposure measured throughout the day, monitors are close to the body
- Physiological measures conducted to relate with acute health effects
Panel study

Are you a healthy, non-smoking adult between 18-60? Are you willing to participate in a study of traffic related air pollution and health effects?

Would you consider wearing air pollution monitors and health sensors as you walk around the city on two separate days?

Help us better understand the potential health effects of traffic pollution in Toronto!

This study was approved by the research ethics board of the University of Toronto. For volunteering, please contact airpollution.health.study@gmail.com, alternatively, call 416-458-1737. Compensation would total $60.
Participants arrive at the study site, undergo baseline health measures, and go about their day, then come back at the end of the day.

Can we predict their exposures without having to conduct personal measurements?

What is the error associated with potential mis-classification of exposure?
Fixed points
Fixed points

- 96 points
- Intersections and mid-block locations
- 6 visits per point, different times of day
- 20 minutes per visit
- Traffic counts (passenger car, passenger truck, light duty truck, transit bus, SHT, LHT, school bus, coach bus) and cyclists
- UFP, BC, noise

<table>
<thead>
<tr>
<th>Time block</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7 am to 11 am</td>
</tr>
<tr>
<td>2</td>
<td>11 am to 3 pm</td>
</tr>
<tr>
<td>3</td>
<td>3 pm to 7 pm</td>
</tr>
</tbody>
</table>
Pedestrian routes designed to overlap with fixed locations
Pedestrian routes designed to overlap with fixed locations

- 23 routes
- 7 to 10 km each
- Covered of 200Km of unique roads
- Average of 6 repetitions
- Different times of day
- Total of 1080 km
- Data processed per road segment (approx. 4,000 unique road segments)
Cycling routes
Cycling routes

- 10 routes, 24 to 31 km each
- 270 km covered in total
- Partial overlap with pedestrian routes
- Each route was repeated 6 to 8 times, at least once per time block
- Total of 1860 km
- Approx. 3,900 road segments

<table>
<thead>
<tr>
<th>Time block</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7 am to 9 am</td>
</tr>
<tr>
<td>2</td>
<td>9 am to 11 am</td>
</tr>
<tr>
<td>3</td>
<td>11 am to 1 pm</td>
</tr>
<tr>
<td>4</td>
<td>1 pm to 3 pm</td>
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<tr>
<td>5</td>
<td>3 pm to 5 pm</td>
</tr>
<tr>
<td>6</td>
<td>5 pm to 7 pm</td>
</tr>
</tbody>
</table>
Preliminary analysis of cycling data
Database

- Every GPS point is given a unique ID and associated with:
  - Air pollution level
  - Road segment (approx. 3900)
  - Day
  - Time
  - Meteorology (wind speed, direction, RH, temperature)

- Average air pollutant concentration per segment per visit is the outcome variable (UFP, BC, noise)

- Coefficient of variation for each segment/visit
Allocating GPS points to road segments
Land-use and built environment around each road segment
Land-use and built environment around each road segment
List of LU + BE characteristics

Buffers of 25, 50, 100, 200, 300, 500, 1000m

- Distance from the shore (m) (d_shore)
- Distance from the closest rail line (m) (d_railline)
- Distance from the closest major road (m) (d_majrd)
- Distance from the closest highway (m) (d_highway)
- Distance from the closest airport (m) (d_airport)
- Distance to the closest NOx emitting chimney (m) (d_NPRI_NOx)
- Distance to the closest PM emitting chimney (m) (d_NPRI_PM)
- Area of the buildings (m²) (build_25m to build_1000m)
- Area of the commercial land use (m²) (com_25m to com_1000m)
- Area of the governmental and institutional land use (m²) (gov_25m to gov_1000m)
- Area of the resource and industrial land use (m²) (ind_25m to ind_1000m)
- Area of the open area land use (m²) (open_25m to open_1000m)
- Area of the parks land use (m²) (park_25m to park_1000m)
- Area of the residential land use (m²) (resid_25m to resid_1000m)
- Area of the waterbody land use (m²) (water_25m to water_1000m)
- Length of the bus routes (m) (busline_25m to busline_route_1000m)
- Length of the major roads (type 4) (m) (majrd_25m to majrd_1000m)
- Length of the highways (types 1, 2 and 3) (m) (highway_25m to highway_1000m)
- Length of the roads (types 1, 2, 3, 4, 5 and 6) (m) (roads_25m to roads_1000m)
- Number of bus stops (count) (bus_25m to bus_1000m)
- Number of intersections (count) (inter_25m to inter_1000m)
- Number of trees (count) (trees_25m to trees_1000m)
- Population (count) (pop_500m to pop_1000m)
- Average height of buildings (m) (build_height_25m to build_height_100m)
- Maximum height of buildings (m) (max_build_height_25m to max_build_height_100m)
- Number of NOx emitting chimneys (count) (NPRI_NOx_25m to NPRI_NOx_1000m)
- Number of PM emitting chimneys (count) (NPRI_PM_25m to NPRI_PM_1000m)
- Length of rail lines (m) (rai_25m to rai_1000m)
### Descriptive statistics (by segment)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std Dev</th>
<th>Min</th>
<th>25&lt;sup&gt;th&lt;/sup&gt;</th>
<th>50&lt;sup&gt;th&lt;/sup&gt;</th>
<th>75&lt;sup&gt;th&lt;/sup&gt;</th>
<th>100&lt;sup&gt;th&lt;/sup&gt;</th>
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<tbody>
<tr>
<td><strong>Average ultrafine particles (particles / cm&lt;sup&gt;3&lt;/sup&gt;)</strong></td>
<td>23436</td>
<td>15837</td>
<td>500</td>
<td>14447</td>
<td>19969</td>
<td>28603</td>
<td>376766</td>
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<tr>
<td><strong>Average Black Carbon (ng/m&lt;sup&gt;3&lt;/sup&gt;)</strong></td>
<td>1761</td>
<td>2839</td>
<td>15</td>
<td>757</td>
<td>1235</td>
<td>1822</td>
<td>103046</td>
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<tr>
<td><strong>LAeq (dB)</strong></td>
<td>72.83</td>
<td>4.06</td>
<td>55</td>
<td>71</td>
<td>73</td>
<td>75</td>
<td>89</td>
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</tbody>
</table>
UFP along bicycle facilities
AM UFP Count
- 500 - 15,000
- 15,000 - 20,000
- 20,000 - 30,000
- 30,000 - 557,545

Image © 2016 TerraMetrice
Image NDAA
Imagery Dates 5/22/2015
43°42'29.32" N 79°23'41.33" W elev 166 m eye alt 36.73 km
Early models of air pollution along cycling facilities
<table>
<thead>
<tr>
<th>Model</th>
<th>For LN of UFP average for increase of IQ if not otherwise indicated</th>
<th>Mean Change</th>
<th>95% CI for Mean Change</th>
<th>Mean Change</th>
<th>95% CI for Mean Change</th>
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<tr>
<td></td>
<td>Mixed effect model Model 35</td>
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<tr>
<td>AIC</td>
<td>GLM Model 36</td>
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<tr>
<td>Adjusted $R^2$</td>
<td>0.2591</td>
<td>0.3566</td>
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<tr>
<td>Windspeed</td>
<td>-0.26</td>
<td>-0.27, -0.24</td>
<td>-12.15</td>
<td>-13.17, -11.11</td>
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<tr>
<td>timeblock - A (6, 7 and 8) - Reference</td>
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<td></td>
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<tr>
<td>timeblock - B (9 and 10)</td>
<td>-0.32</td>
<td>-0.35, -0.28</td>
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<td>timeblock - C (11 and 12)</td>
<td>-0.07</td>
<td>-0.12, -0.03</td>
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<tr>
<td>timeblock - D (13 and 14)</td>
<td>0.04</td>
<td>0.00, 0.08</td>
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<td>timeblock - E (15 and 16)</td>
<td>-0.30</td>
<td>-0.34, -0.26</td>
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<td>timeblock - F (17, 18 and 19)</td>
<td>-0.31</td>
<td>-0.35, -0.26</td>
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<tr>
<td>Relative Humidity</td>
<td>-0.11</td>
<td>-0.13, -0.09</td>
<td>-8.65</td>
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<tr>
<td>$d_{airport}$</td>
<td>-0.15</td>
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<td>build_1000m</td>
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<td>0.10, 0.14</td>
<td>11.95</td>
<td>9.53, 14.43</td>
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<tr>
<td>$d_{park_{1000m}}$</td>
<td>-0.019</td>
<td>-0.036, -0.003</td>
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<tr>
<td>max_build_height_25m</td>
<td>0.06</td>
<td>0.03, 0.08</td>
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<tr>
<td>$d_{NPRI_NOx}$</td>
<td>-0.05</td>
<td>-0.07, -0.02</td>
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<td>trees_750m</td>
<td>0.11</td>
<td>0.08, 0.13</td>
<td>14.93</td>
<td>11.39, 18.59</td>
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<tr>
<td>$d_{shore}$</td>
<td>-0.05</td>
<td>-0.06, -0.03</td>
<td>-8.00</td>
<td>-9.82, -6.16</td>
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<tr>
<td>$d_{majrd}$</td>
<td>-0.017</td>
<td>-0.021, -0.014</td>
<td>-3.07</td>
<td>-4.00, -2.14</td>
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<td>$d_{npri_nox}$</td>
<td>-0.014</td>
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<td>gov_1000m</td>
<td>0.04</td>
<td>0.03, 0.05</td>
<td>4.63</td>
<td>2.93, 6.35</td>
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<td>highway_25m</td>
<td>0.0008</td>
<td>0.0005, 0.0011</td>
<td>0.12</td>
<td>0.07, 0.16</td>
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</tr>
</tbody>
</table>
Developing predictive models
What is the potential of human-centric air pollution sensing in producing reliable air pollution maps?
What is the potential of human-centric air pollution sensing in producing reliable air pollution maps?

To evaluate the potential of embedded network of monitors in the generation of urban air quality maps useful for quantifying population exposure patterns.