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Bicycle Facilities and the Uptake of Air Pollution by Active Travelers

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Bicycle Facilities and the Uptake of Air Pollution by Active Travelers

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Bicycle Facilities and the Uptake of Air Pollution by Active Travelers

RESEARCH TEAM

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Lorne Isabelle, Senior Res. Assoc.
Outline

1. Goals
2. Data Collection
3. Intake/Uptake
4. Modeling Results
5. Conclusions
6. Next Steps
Urban Bicyclists’ Pollution Uptake

Framework

Adapted from Ott, Stieneman & Wallace, 2007

Vehicle Emissions → Air Quality

Inhalation

Traveler Exposure

Uptake

Health Effects

Urban Bicyclists’ Pollution Uptake
Urban Bicyclists’ Pollution Uptake
Data Collection

- 75 breath VOC samples
- 13 days
- 3 subjects
- 123 compounds
On-Road Sampling Example

Paired subjects; ambient & breath VOC (20-30 minutes, 3-5 miles)
Sampling Equipment

- TVOC
- Smart phone
- Cameras
- Cycle computer
- Sampler Pump
- Sample Cartridge
- PM
- CO₂
- ACE Device
- Breath Bags
- CO
- Urban Bicyclists’ Pollution Uptake
Breath Sampling

• Developed as medical screening
• End-tidal breath good proxy for blood concentrations
  – Low water-solubility VOC
  – Hydrocarbons like benzene, toluene,...
• Requires *very precise* instrumentation
• New standard for analysis with GC/MS
On-Road Sampling
Exposure Data coverage

~40 hours of data over 13 days
- GPS and sensor data 1 second resolution
- Breath & ambient samples 30 minutes
Inhalation

Exposure Concentration $\frac{mg}{m^3}$

Breath Rate $\frac{m^3}{sec}$

Duration $sec$

Intake Dose $mg$

$$V_T \times f_B$$

$$\left( \frac{m^3}{breath} \right) \times \left( \frac{breaths}{sec} \right)$$

Urban Bicyclists' Pollution Uptake
Bicyclists’ Exertion

• External work
  – Speed & acceleration
  – Weight & slope
  – Wind & drag
  – Rolling resistance (tires, road)

• Personal factors (minor effects)
  – Basal metabolic rate
  – Fitness (exercise response)
Bicyclist Uptake Studies

- Blood/urine samples (x1)
  - Metabolites of BTEX compounds (VOC)
  - Urban bikers > rural bikers
- Induced sputum samples (x1)
  - Lung-deposited black carbon
  - Bicyclists > transit riders
- Modeled uptake (x3)
  - Doses increases with exertion
PSU Uptake Research

• New approach
• High-resolution intake/uptake measurement
• Breath sampling in bags
Some Exposure Results

Urban Bicyclists' Pollution Uptake

m,p-Xylene
Ethylbenzene
Toluene
Benzene

Avg. Ambient Conc. Normalized to Tabor

0 1 2 3 4 5
Results Ambient & Breath

Urban Bicyclists’ Pollution Uptake

Benzene

% concentration increase (vs. Tabor)

Ambient

Breath

Major Arterial
Local
I-205
Regression - SURE Models

- Each of the select compounds is its own equation (same specification)
- Error correlations across equations for each observation are allowed
- Advantage: better use of the available information
Regression - SURE Models

Dep. Variables: breath/ambient concentrations

1. Benzene
2. Toluene
3. Ethylbenzene
4. m,p-Xylene
5. o-Xylene
6. 1,3,5-Trimethylbenzene
7. 2-Ethyltoluene
8. 1,2,4-Trimethylbenzene
9. 1,2,3-Trimethylbenzene
Breath concentrations

\[ C_{breath} = \beta_0 + \beta_1 C_{ambient} + \beta_2 C_{preAmbient} + \beta_3 \frac{C_{preBreath}}{C_{preAmbient}} \]

- “History” impacts are significant
- Ambient coefficient 1.5 to 2.5 times bigger than preAmbient

\[ \beta_1 > \beta_2 \]
Change of Breath concentrations

\[
\Delta C_{\text{breath}} = \beta_0 + \beta_1 \Delta C_{\text{ambient}} + \beta_2 \frac{C_{\text{preBreath}}}{C_{\text{preAmbient}}} + \beta_3 TVOC_{CV}
\]

(+)  (-)  (-)

- “History” impacts are still significant
- Rate of change negatively affected by high relative breath concentrations
- High variability in \( TVOC_{CV} \) reduces breath concentrations

Clearance impacts?
Policy/design implications?
Breath/Ambient concentration as a function of **Road Type**

\[ C_{breath} = \beta_0 + \beta_1 \text{RoadType} \]

\[ C_{ambient} = \beta_0 + \beta_1 \text{RoadType} \]

- Road type is a dummy variable (5 different types of roads, Tabor the reference)
- Road type is a much better predictor of ambient than breath concentrations
- Arterials have 1.5 to 2.5 higher ambient concentrations than local/bike paths
- Major arterials 25% more than minor

- Non-linear AADT impacts?
Wrapping up

• The method works: exposure predicts breath concentrations
  – Breath elasticity to exposure: 0.3-0.5
• Significant history effects
• Significant road-type effects
• Minimal subject-specific effects
Future Work

We have a novel data set of direct uptake measurements

– Much more analysis work to do!

1. AADT impacts
2. Policy and Design Implications
3. Bicycle network/facility design guidance for pollution dose impacts
4. Extend to pedestrians
Thank you!


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