Monitoring of indoor and outdoor levels of BTEX and petroleum tracer compounds in Edmonton homes

Md. Aynul Bari, Dr.-Ing.

School of Public Health, University of Alberta

Co-Author: Dr. Warren Kindzierski, Ph.D., P.Eng.

CPANS Conference, Edmonton

May 26, 2015
Background

- Indoor air quality is an important determinant of health.

- Several studies have been conducted across Canada (e.g., Quebec City, Windsor, Regina, Halifax etc.) in order to compare baseline data and upgrade Health Canada’s Indoor Air Quality Guidelines.

- Most epidemiological studies assume outdoor air as a risk factor and are not free from bias because they ignore exposure from indoor air quality.
Indoor Environment and Time-Activity – Mean Amounts of Time Spent in Various Microenvironments for North American Adults

### BTEX and petroleum-related VOCs

<table>
<thead>
<tr>
<th>BTEX</th>
<th>Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>9.5 d</td>
</tr>
<tr>
<td>Toluene</td>
<td>2.1 d</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>1.7 d</td>
</tr>
<tr>
<td><em>m,p</em>-Xylene</td>
<td>12 h</td>
</tr>
<tr>
<td><em>o</em>-Xylene</td>
<td>20 h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alkane</th>
<th>Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethane</td>
<td>47 d</td>
</tr>
<tr>
<td>Propane</td>
<td>11 d</td>
</tr>
<tr>
<td>Butane</td>
<td>4.9 d</td>
</tr>
<tr>
<td>Isobutane</td>
<td>5.5 d</td>
</tr>
<tr>
<td>Pentane</td>
<td>3.0 d</td>
</tr>
<tr>
<td>Isopentane</td>
<td>3.2 d</td>
</tr>
<tr>
<td>Hexane</td>
<td>2.2 d</td>
</tr>
<tr>
<td>2-Methylpentane</td>
<td>2.2 d</td>
</tr>
<tr>
<td>3-Methylpentane</td>
<td>2.2 d</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alkene</th>
<th>Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethene</td>
<td>1.4 d</td>
</tr>
<tr>
<td>1-Butene</td>
<td>8.8 h</td>
</tr>
<tr>
<td><em>cis</em>-2-Butene</td>
<td>4.9 h</td>
</tr>
<tr>
<td>1,3-Butadiene</td>
<td>4.2 h</td>
</tr>
</tbody>
</table>
Objective

To characterize indoor and outdoor exposure to BTEX and petroleum tracer compounds in Edmonton homes.
Methodology: sampling and analysis

- Winter and summer 2010.
- Nine consecutive 7-day sampling period per season (5-6 homes per period).
- Homes sampled were stratified by age – residences grouped into five construction year strata.
  
  - ≤ 1946
  - 1946 – 1960
  - 1961 – 1980
  - 1981 – 2000
  - ≥ 2001

OX- Oxford  OT- Ottewell
WM- Westmount  ST- Strathearn
SA- Spruce Avenue  FH- Falconer Heights
PD- Parkdale  TT- Terwillegar Towne
TC- Thorncliff  TS- Terwillegar South
GB- Gold Bar
Methodology: sampling and analysis

- VOCs sampled for 24 h using Summa canisters.
- A total of 193 VOC species were analyzed by gas chromatography-mass spectrometry (GC-MS).
Methodology: Questionnaires

Baseline Questionnaire data:
- Year of construction.
- Heating and cooking systems.
- Renovations, e.g. painting, varnishing.
- Purchase of furniture.
- Nearby outdoor sources.
- Storage of paints and solvents.

Daily Diary Questionnaire data:
- Environmental Tobacco Smoke (ETS); burning of candles, incense.
- Use of moth repellents.
- Use of cleaning products and air fresheners.
- Window opening and air conditioner use.
- Cooking (type, duration) and use of exhaust fan.
- Use of dishwasher, laundry.
Results – BTEX levels at Edmonton homes

<table>
<thead>
<tr>
<th></th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor (n = 337)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor (n = 332)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor (n = 328)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor (n = 324)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Concentration (μg/m³)

- **Indoor**: (n = 337)
- **Outdoor**: (n = 332)
- **Indoor**: (n = 328)
- **Outdoor**: (n = 324)

**BTEX**

Geometric mean

- **max**
- **median**
- **75th %ile**
- **25th %ile**
- **min**
Indoor BTEX levels at Edmonton homes

Winter

Summer

BTEX Indoor

Concentration (μg/m³)

Benzene
Toluene
Ethylbenzene
m,p-Xylene
o-Xylene
Median BTEX levels in different construction year strata of Edmonton homes

Winter

- Indoor
- Outdoor

Summer

- Indoor
- Outdoor

Indoor:
Significant variation ($p$-value: <0.0001)

Indoor:
Significant variation ($p$-value: 0.002)
Median winter BTEX levels in Canadian homes (indoors)

No IAQ guidelines
Median ranged: 0.5 – 2.2 μg/m³
Indoor/outdoor (I/O): 1.5 – 2.4

<table>
<thead>
<tr>
<th>City</th>
<th>Study period</th>
<th>No. of homes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edmonton</td>
<td>2010</td>
<td>74</td>
<td>This study</td>
</tr>
<tr>
<td>Quebec City</td>
<td>Jan–April 2005</td>
<td>96</td>
<td>Héroux et al. 2008</td>
</tr>
<tr>
<td>Regina</td>
<td>2007</td>
<td>146</td>
<td>Health Canada 2010</td>
</tr>
<tr>
<td>Canadian Survey</td>
<td>2009–2011</td>
<td>3857</td>
<td>Zhu et al. 2013</td>
</tr>
</tbody>
</table>
Median winter BTEX levels in Canadian homes (indoors)

Toluene

Canadian IAQ guideline: 2300 μg/m³

Toluene/Benzene (T/B): 1.5–3.0 (vehicle)

Edmonton outdoors, T/B: 1.7 – 3.5

No Canadian IAQ guidelines

Ethylbenzene

μg/m³

Edmonton 2010
Ottawa 2002/03
Windsor 2005/06
Quebec City 2005
Regina 2007
Canadian Survey 2009-2011
Canadian Survey 1991/92

μg/m³

Edmonton 2010
Ottawa 2002/03
Windsor 2005/06
Quebec City 2005
Regina 2007
Canadian Survey 2009-2011
Canadian Survey 1991/92

1.5
1.1
1.1
2.5
1.1
1.2
6.5
Median winter BTEX levels in Canadian homes

No Canadian IAQ guidelines
European Commission: 200 μg/m³

I/O ratios of BTEX at Edmonton homes: 2 – 9

Predictors of BTEX:
- product use, paints, building materials
- Evaporative emissions from attached garages
- Vehicle combustion gases
Tracers of petroleum-related emissions

% of species apportioned to factor

Bari et al. 2015. Build. Environ. 90, 114–124
Results – alkane levels at Edmonton homes

Winter 2010

<table>
<thead>
<tr>
<th>Alkane</th>
<th>Median μg/m³</th>
<th>Min–Max μg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethane</td>
<td>33.8</td>
<td>1.2–1466</td>
</tr>
<tr>
<td>Propane</td>
<td>19.6</td>
<td>1.6–383</td>
</tr>
<tr>
<td>Butane</td>
<td>12.4</td>
<td>0.2–358</td>
</tr>
<tr>
<td>Isobutane</td>
<td>15.2</td>
<td>0.1–1171</td>
</tr>
<tr>
<td>Pentane</td>
<td>5.1</td>
<td>0.7–31</td>
</tr>
<tr>
<td>Isopentane</td>
<td>10.6</td>
<td>1.4–123</td>
</tr>
</tbody>
</table>
Median alkane levels in different construction year strata

Indoor:
Significant variation ($p$-value: <0.0001)

Indoor:
Not significant ($p$-value: 0.09)
Alkane levels in Canadian homes

Indoor

Outdoor

μg/m³

Edmonton (N=74)
Windsor (N=48)
Regina (N=146)

μg/m³

Edmonton (N=74)
Windsor (N=48)
Regina (N=146)
Comparison of alkane levels in 2010 Edmonton IAQ study with Edmonton east and central (NAPS)

<table>
<thead>
<tr>
<th>2010 Median μg/m³</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Edmonton IAQ</td>
<td>Edmonton (NAPS)*</td>
</tr>
<tr>
<td></td>
<td>Indoor</td>
<td>Outdoor</td>
</tr>
<tr>
<td>Butane</td>
<td>12.4</td>
<td>5.3</td>
</tr>
<tr>
<td>Isobutane</td>
<td>15.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Pentane</td>
<td>5.1</td>
<td>1.6</td>
</tr>
<tr>
<td>Isopentane</td>
<td>10.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Hexane</td>
<td>1.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Heptane</td>
<td>1.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Octane</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>2-Methylpentane</td>
<td>1.9</td>
<td>0.7</td>
</tr>
<tr>
<td>3-Methylpentane</td>
<td>1.2</td>
<td>0.5</td>
</tr>
<tr>
<td>2,2-Dimethylbutane</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Cyclopentane</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Methylcyclopentane</td>
<td>0.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Cyclohexane</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Methylcyclohexane</td>
<td>0.9</td>
<td>0.3</td>
</tr>
</tbody>
</table>

*NAPS data (Environment Canada, 2010)
Alkane levels in Edmonton neighborhoods

Central (~ 4 km)
PD-Parkdale
SA-Spruce Avenue
ST-Strathearn

East
GB-Gold Bar
Median alkane levels in Edmonton neighborhoods
Central vs East

Winter 2010

Indoor

Outdoor

Alkane
Median BTEX levels in Edmonton neighborhoods
Central vs East

Winter 2010

BTEX

Indoor

μg/m³

0  5  10  15  20

Central (PD+SA+ST, N = 10)
East (GB, N = 5)

Benzene

Toluene
Ethylbenzene

m,p-Xylene
o-Xylene

1.0  1.4
7.1  7.7
1.4  1.6
4.2  5.1
1.2  1.8
Summary

- Indoor BTEX levels 2- to 6-fold higher than outdoors for both seasons.

- A significant variation in BTEX levels was found in different strata with higher levels in newer homes.

- Alkanes were dominant in Edmonton homes indoors.

- More work needed to better understand levels and sources of population exposure to VOCs.
Acknowledgment

Health Canada
Marie-Ève Héroux
Dr. Amanda J. Wheeler
Keith Van Ryswyk
Morgan MacNeill
Ryan Kulka
Thank you very much for your attention!
Median levels in Edmonton neighborhoods
Central vs East

Winter 2010

Benzene
1,3-Butadiene

μg/m³

Central (PD+SA+ST, N = 10)
East (GB, N = 5)
Median BTEX levels in Edmonton neighborhoods
Central vs East

Winter 2010

Indoor

Outdoor

BTEX