Indoor and Outdoor VOC Measurements in Schools Near Busy Roadways in Las Vegas, NV

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Presentation Outline

• Background on Las Vegas Schools Study
• Black carbon filtration results
• VOC measurements and design issues
• VOC results
• Implications for classroom VOC monitoring and removal
Introduction to US 95 MSAT Study

MSAT study objectives

• Characterize outdoor and indoor concentrations at schools (student exposure)
• Determine US 95 vehicle contributions (before and after new lanes opened)
• Determine MSAT removal efficiencies of new filtration systems

Focus on priority MSATs: diesel particulate matter; and VOC species benzene, 1,3-butadiene, acrolein, formaldehyde, and acetaldehyde
Three Schools Next to US 95 and Background School

Air inlets for classrooms at schools were 36, 317, and 76 meters from the sound wall of US 95.
Filtration Systems for Fyfe and Adcock

Note that

- Filtration systems were installed after the summer IOP
- Classrooms were occupied during the winter IOP, but not always during the summer IOP
- Western High School did not have a gas-phase filter installed
Typical HVAC Flow and Fan Additions for VOC and PM Filters

Inlet sampling line at fan inlet (opposite side of fan at right).
Typical Classroom Sampling Location

Note carpet on floor and fabric on walls; potential absorption surfaces for VOCs.
Diurnal Pattern of Pollution Is an Important Consideration for Exposure and Mitigation

Median concentrations by hour of BC (µg/m³), CO (ppm), NO (ppb), and NO2 (ppb) at Fyfe on weekdays in winter (December 2007 to February 2008).
Effective filter efficiency: original system about 74%; improved system about 97%.

Effective filter efficiency: original system about 61%; improved system about 78%.

Teacher often left door open to outside!
Air Inlet Concentration Ranges and MDLs

(9-11 and 13-15 LST samples on 15 days)
Adcock Seasonal Concentration Ratios: Classroom/Outdoor

- Ratios > 1 indicate classroom concentrations are greater than outdoor concentrations.
- Summer concentrations of all pollutants except \( \text{CCl}_4 \) were higher in the classroom.
- Winter concentrations (with filtration) were about the same indoors as outdoors.

(9-11 and 13-15 LST samples on 15 days)
Fyfe Seasonal Concentration Ratios: Classroom/Outdoor

- Summer and winter classroom concentrations of most VOCs are higher than outdoor concentrations.
- Ratio of VOCs is as much as 100% higher in the classroom compared to outdoor air, but is not elevated for benzene or 1,3-butadiene.
- Note that CCl$_4$ is same indoors and outdoors.

(9-11 and 13-15 LST samples on 15 days)
Key Findings for Gas-Phase MSATs

• VOC concentrations were mostly higher in classrooms than in outdoor air sampled at the same time
• Adcock Elementary filtration system was the most effective at reducing indoor concentrations
• Individual VOCs showed different patterns in concentrations
Penetration Lag Could Explain Higher Classroom/Outdoor Ratios

From McCarthy et al., *Atmospheric Environment*, 2007
What About Indoor Sources?

Pollutants show differences in elevated indoor concentrations

- Carbonyls are highest and have known indoor sources
- Aromatics, hexane, isopentane are also high. Cleaning supplies, whiteboards, printers?
- Low indoor concentrations include benzene, 224-trimethylpentane (gasoline) and CCl₄.
Implications for Classroom VOC Monitoring and Removal (1 of 2)

- Temporal variability in concentrations matters for exposure
- Indoor sources may dominate exposure
- Characterize indoor sources
- Comparison with outdoor concentrations can be complicated if outdoor concentrations are changing
- Materials in classroom may absorb VOCs and release them later
Implications for Classroom VOC Monitoring and Removal (2 of 2)

• HVAC operations can influence indoor concentrations (start time was during morning rush hour): fill classroom with the dirtiest air; place large burden on system.

• If classroom doors open to outside, an open door can defeat VOC removal
Acknowledgments

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• John Terry was the NDOT Project Manager.
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• Clark County School District (Paul Gerber and Steve Dellosritto) provided access and support at the schools.
• Joey Landreneau (STI) and David Vaughn (STI) performed monitoring and sampling. Alison Ray, Jennifer DeWinter, Theresa O’Brien, and Steve Brown performed data validation and data analyses.
# Filter Details for Adcock and Fyfe

<table>
<thead>
<tr>
<th>Filter</th>
<th>Name</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>MERV 8 pre-filter</td>
<td>Camfil Aeropleat 2”</td>
<td></td>
</tr>
<tr>
<td>MERV 15 PM filter</td>
<td>Camfil Farr Durafil 4V</td>
<td>DU4V-1511-11-MV15</td>
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<tr>
<td>Gas-phase filter</td>
<td>Camfil Farr Camsorb Riga-Carb</td>
<td>CSRC-205-242412-PH carbon impregnated with oxidation coating</td>
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</tbody>
</table>
VOC Replicates Comparison
Outdoor Concentration Ranges - National

(9-11 and 13-15 LST samples on 15 days)
Western Seasonal Concentration Ratios: Classroom/Outdoor

Note that Western High School had no gas-phase filtration (control) and no summer VOC measurements.

- Ratio of VOCs is 30% to 200% higher in classrooms than in outdoor air. Carbonyls are higher.
- Note CCl₄ is same indoors and outdoors.

(9-11 and 13-15 LST samples on 15 days)
## Statistics for Classroom: Outdoor Ratios

<table>
<thead>
<tr>
<th></th>
<th>Adcock Elem. Summer</th>
<th>Adcock Elem. Winter</th>
<th>Western High Winter</th>
<th>Fyfe Elem. Summer</th>
<th>Fyfe Elem. Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>2.7</td>
<td>1.1</td>
<td>2.5</td>
<td>1.7</td>
<td>1.8</td>
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<tr>
<td>Mean</td>
<td>2.7</td>
<td>1.1</td>
<td>2.4</td>
<td>1.7</td>
<td>1.7</td>
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<tr>
<td>95% CI</td>
<td>0.6</td>
<td>0.1</td>
<td>0.4</td>
<td>0.3</td>
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<tr>
<td>25th</td>
<td>2.1</td>
<td>1.0</td>
<td>1.9</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>75th</td>
<td>3.1</td>
<td>1.2</td>
<td>2.9</td>
<td>2.1</td>
<td>1.9</td>
</tr>
</tbody>
</table>

(9-11 and 13-15 LST samples on 15 days)
# Measurements

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Parameters</th>
<th>Fyfe Elementary</th>
<th>Adcock Elementary</th>
<th>Western High</th>
<th>Hancock Elementary</th>
</tr>
</thead>
</table>

- IOPs lasted three weeks; VOC and carbonyl samples were collected twice daily on weekdays.
- VOCs and carbonyls samples were 2-hr duration, typically starting at 9 AM and 1 PM