SEA Stakeholder Advisory Round Table (StART)

December 2021

Elena Austin, Timothy Gould, Nancy Carmona, Tim Larson, Edmund Seto
Healthy Schools, Healthy Air

- Inform schools, districts and state legislators on the current ability of building ventilation systems to effectively remove outdoor sources of particles.
- Quantify the current ability of ventilation solutions to remove indoor generated particles.
- Identify any additional benefit and cost of in-room filtration and air handling interventions.
- Based on the experimental measures in an unoccupied classroom, describe the size fractioned infiltration rates of 1) ultrafine particles of aircraft origin 2) ultrafine particles of traffic origin and 3) wildfire smoke.
- Communicate study results to partners.

* Funded (50k) by cities of the cities of SeaTac, Burien, Federal Way, Normandy Park and Des Moines
Project Timeline and Activities

• Developed communication plan with school districts around study goals (January 2021)
• Identified 5 schools of interest based on age, proximity to flights and ventilation characteristics February 2021)

• Measurement Period (March – August 2021)
  • Measured outdoor air exchange rate
  • Measured indoor and outdoor pollutants
  • Evaluated a portable air cleaning unit (HEPA)

• Analysis and report back Period
  • Synthesize Results
  • Report back

• Final Report (December 2021)
• Timothy Gould
• Edmund Seto
• Elena Austin
• Timothy Larson
• Nancy Carmona
• Jeff Shirai
Goal

- Understand the impact of outdoor air pollution on the air quality indoors
  - Are outdoor air pollutants significantly removed by current air filtration approaches?
  - Can indoor air quality be improved through the use of a portable HEPA filter unit?
Particle Infiltration into Indoor Spaces
Study Methods
STEP 1: Outdoor Air Exchange Rate Determination

GOAL: Determine the exchange of air from outdoor into the indoor spaces.

Used measurement method developed by the Harvard T.H. Chang School of Public Health – Harvard Healthy Buildings Program
STEP 1: Outdoor Air Exchange Rate Determination

• Begin with CO₂ at least 4x above typical in building concentration (source: dry ice).
• Rate of decay with no further CO₂ sources in room based on air exchange from
  • outside infiltration
  • active ventilation system
STEP 2: Air Quality Measurements in Classroom

- CO2 analyzer
- NanoScan for size distribution of U-F particles
- CPC and P-Trak - total U-F particle counts (>10, >20 nm, respectively)
- MA200 and AE51 black carbon analyzers
- Timer & valves to switch In/Out inlets
STEP 3: BlueAir HEPA filter on 2nd sampling day

Continue ultra-fine particle and CO2 measurements inside and outdoors to assess reduction of particle concentration in classroom on account of HEPA filter
STEP 4: Analysis Plan

• Calculate Outdoor Air Exchange Rate
• Describe size-fractioned relationship between indoor/outdoor measurements
• Develop a particle size dependent infiltration model for each school. This model is based on the relationship between change in indoor concentration as explained by indoor and outdoor conditions
• Identify sources of air pollution indoors using multivariate methods

![Ultrafine Particle Concentration (#/cc)](image)
STEP 6: Return Results

- Develop overall project summary documents as well as school specific report back
- Evaluate report back elicit feedback from stakeholders
Results
## Monitoring Schedule at Schools

<table>
<thead>
<tr>
<th>School and room</th>
<th>First Visit</th>
<th>Sea-Tac flight operations overhead</th>
<th>second visit</th>
<th>Sea-Tac flight operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>School A 1&lt;sup&gt;st&lt;/sup&gt; flr.</td>
<td>June 9-11</td>
<td>Landing</td>
<td>July 26-28</td>
<td>Takeoff</td>
</tr>
<tr>
<td>School A 2&lt;sup&gt;nd&lt;/sup&gt; flr.</td>
<td>June 14-16</td>
<td>Landing 14&lt;sup&gt;th&lt;/sup&gt; &amp; 15&lt;sup&gt;th&lt;/sup&gt; Takeoff 16h</td>
<td>July 28-30</td>
<td>Take off</td>
</tr>
<tr>
<td>School B</td>
<td>April 14-16</td>
<td>Takeoff</td>
<td>July 20-22</td>
<td>Landing 20&lt;sup&gt;th&lt;/sup&gt; &amp; 21&lt;sup&gt;st&lt;/sup&gt; Takeoff 22&lt;sup&gt;nd&lt;/sup&gt;</td>
</tr>
<tr>
<td>School C</td>
<td>April 7-9</td>
<td>Takeoff</td>
<td>July 13-15</td>
<td>Takeoff</td>
</tr>
<tr>
<td>School D</td>
<td>June 22-24</td>
<td>Takeoff</td>
<td>August 10-12</td>
<td>Landing</td>
</tr>
<tr>
<td>School E</td>
<td>March 24-26</td>
<td>Takeoff 24&lt;sup&gt;th&lt;/sup&gt; &amp; 26&lt;sup&gt;th&lt;/sup&gt; Landing 20&lt;sup&gt;th&lt;/sup&gt;</td>
<td>July 7-9</td>
<td>Takeoff</td>
</tr>
</tbody>
</table>

Summary: 44 datafiles collected per classroom sampled -> 264 files -> 500 MB of data
Air Exchange Calculation

- Measurements based on CO₂ release in the room
- Decay is measured as outdoor air is exchanged with indoor air
- Modeled as:

\[
[\text{CO}_2]_{\text{classroom}} = [\text{CO}_2]_{\text{outdoor}} + [\text{CO}_2]_{\text{peak}} * e^{-AER \cdot t}
\]
# Outdoor Air Exchange Rate

## Table 1 - Outdoor Air Exchange Rate (AER Outdoor)

<table>
<thead>
<tr>
<th>School</th>
<th>Room # 1</th>
<th>Room # 2</th>
<th>Room # 3</th>
<th>Room # 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>School A</td>
<td>2.1/h</td>
<td>4.4/h</td>
<td>1.3/h</td>
<td>1.1/h</td>
</tr>
<tr>
<td>School B</td>
<td>0.6/h</td>
<td></td>
<td>0.9/h</td>
<td></td>
</tr>
<tr>
<td>School C</td>
<td>2.2/h</td>
<td></td>
<td>2.6/h</td>
<td></td>
</tr>
<tr>
<td>School D</td>
<td>2.9/h</td>
<td></td>
<td>0.4/h</td>
<td></td>
</tr>
<tr>
<td>School E</td>
<td>1.1/h</td>
<td>1.1/h</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Black carbon

What happens to black carbon concentrations with the introduction of a PAC with a HEPA filter?
Ultrafine Particle Concentration
Ratio of Indoor to Outdoor Concentration
HEPA Filter Performance – Modeled Infiltration Fraction

- Total Particle Number (#/cc)
- Aircraft Particles

Box plots showing the ratio of indoor to outdoor particles with the HEPA filter off and on.
## Infiltration and Removal Efficiency

<table>
<thead>
<tr>
<th>Pollutant Type</th>
<th>Infiltration before HEPA</th>
<th>Confidence Range (%)</th>
<th>Infiltration After HEPA</th>
<th>Confidence Range</th>
<th>Removal by HEPA (%)</th>
<th>Confidence Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Particles</td>
<td>54%</td>
<td>[47, 59]</td>
<td>9%</td>
<td>[8, 9]</td>
<td>83%</td>
<td>[82, 84]</td>
</tr>
<tr>
<td>Aircraft Particles</td>
<td>41%</td>
<td>[38, 56]</td>
<td>14%</td>
<td>[12, 15]</td>
<td>67%</td>
<td>[68, 73]</td>
</tr>
<tr>
<td>Traffic Particles</td>
<td>74%</td>
<td>[71, 79]</td>
<td>20%</td>
<td>[18,21]</td>
<td>73%</td>
<td>[73, 74]</td>
</tr>
</tbody>
</table>

*Table 1 - Infiltration (%) with and without the portable HEPA filter unit installed in classrooms*
Modeled Impact

Indoor Air Concentration, assuming average Outdoor UFP of 5000 #/cc
Predicted through Regression Model

Ultrafine Particle Concentration

HEPA Status

- School A
- School B
- School C
- School D
Reporting back monitoring results

• Engaging a wide audience
  • Parents
  • School district administrators
  • Teachers
  • Community members

• Report back challenges
  • Knowledge of air environment health literacy
    • Potential for overwhelming quantity of information or complicated language
  • Awareness of how the exposure affects their communities
  • Attitude towards research
  • Knowing how to find out if air quality is bad
  • Willingness to modify behavior and follow suggestions
  • Tailoring messaging to reach each target audience
School Resilience to Air Pollution
Evaluating impact of air quality interventions in school environments

PROJECT GOALS:
• Do current ventilation solutions effectively control indoor air quality in schools?
• Are there school based interventions that significantly improve indoor air quality?
• What are the long-term average exposures across the spatial area?

School-aged children represent a vulnerable population with respect to air pollution exposure.
Ventilation systems are not evaluated for the efficiency in removing ultrafine particles from outdoor sources including roadway traffic, aircraft traffic and wildfire smoke.

Funding Received From WA State
Mobile Monitoring Goals – Long term averages

• Developing and refining mobile monitoring to estimate annual exposure concentrations to traffic and aviation air pollutants including NO$_x$, Black Carbon and size-resolved particles.

• Engage with State and local agencies to develop plans for long-term monitoring

• Identify emissions factors and spatial variations across the area of interest
ACT Mobile Monitoring Campaign

- 309 stop locations representative of ACT cohort (large, geographically diverse area)
- 9 fixed driving routes
- 2-min samples per stop
- Measured UFPs, BC, PM2.5, CO, CO2, NO2
- A driving schedule ensured temporally balanced sampling

Top: Jittered ACT locations and monitoring stops. Bottom: Mobile monitoring routes and stops
Annual Averages

- Collected ~27 samples per site
  - 5 AM - 12 AM
  - March 2019 - March 2020
  - >270 drive days

- Calculated site annual averages from the ~27 visits

Annual average UFP estimates from mobile monitoring observations.
School Resilience to Wildland Smoke and Outdoor sources of Fine & Ultrafine Particles

PROJECT GOALS:
• **Implement** a classroom-based Portable Air Cleaner (PAC) intervention to reduce exposure to wildland fire smoke across 10 Washington State schools.
• **Observe** impact of the PAC intervention on respiratory health of students using a randomized-controlled study design within school.
• **Engage** with participating schools to adapt an existing hands-on air quality curriculum aimed at increasing environmental health literacy on the topic of ambient smoke, air quality and health.

The aim of this partnership is to develop a classroom-based intervention to improve indoor air quality PAC removal of fine and ultrafine particles as well as education of students and teachers to increase understanding of wildland smoke impacts and smoke readiness principles.

Rural and urban locations are being recruited.
Discussion and Next Steps
THANK YOU!
ASHRAE COVID flush-out calculations