Laboratory Evaluation:
MagnaSCI SRL uRADMonitor
SMOGGIE-PM v1.101
Background

Three MagnaSCI SRL uRADMonitor SMOGGIE-PM v1.101 (hereinafter uRADMonitor SMOGGIE) sensors (units IDs: 0032, 0033, 0034) were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (04/17/2020 to 6/27/2020) under ambient environmental conditions and have been evaluated in the South Coast AQMD Chemistry Laboratory under controlled artificial aerosol concentration/size range, temperature, and relative humidity. The same three uRADMonitor SMOGGIE units were tested both in the field (1st stage of testing) and in the laboratory (2nd stage of testing).

**uRADMonitor SMOGGIE (3 units tested):**
- PM Sensor – Optical Particle Counter (Plantower PMSA003, non-FEM)
- Each unit measures: PM$_{1.0}$, PM$_{2.5}$ and PM$_{10}$ (μg/m$^3$), T (°C), RH (%)
- Unit cost: $110
- Time resolution: 1-min
- Units IDs: 0032, 0033, 0034

**GRIMM (reference method):**
- Optical particle counter
- FEM PM$_{2.5}$
- Uses proprietary algorithms to calculate PM$_{1.0}$, PM$_{2.5}$, and PM$_{10}$ mass conc. from particle number measurements
- Cost: ~$25,000
- Time resolution: 1-min
Evaluation results for \( PM_{1.0} \) mass concentration

uRADMonitor SMOGGIE vs GRIMM
The uRADMonitor SMOGGIE sensors tracked well with the concentration variation as recorded by the GRIMM in the concentration range of 0 - ~200 μg/m³.

The uRADMonitor SMOGGIE sensors showed very strong correlations with the GRIMM PM\textsubscript{1.0} mass conc. (R\textsuperscript{2} > 0.99).
uRADMonitor SMOGGIE vs GRIMM PM\(_{1.0}\) Accuracy

- Accuracy (20°C and 40% RH)

<table>
<thead>
<tr>
<th>Steady state #</th>
<th>Sensor Mean (µg/m(^3))</th>
<th>GRIMM (µg/m(^3))</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.8</td>
<td>7.5</td>
<td>24.1</td>
</tr>
<tr>
<td>2</td>
<td>3.2</td>
<td>12.9</td>
<td>24.4</td>
</tr>
<tr>
<td>3</td>
<td>11.4</td>
<td>39.6</td>
<td>28.8</td>
</tr>
<tr>
<td>4</td>
<td>26.6</td>
<td>114.1</td>
<td>23.4</td>
</tr>
<tr>
<td>5</td>
<td>47.8</td>
<td>185.5</td>
<td>25.7</td>
</tr>
</tbody>
</table>

- The uRADMonitor SMOGGIE sensors underestimated GRIMM PM\(_{1.0}\) mass concentrations at 20 °C and 40% RH. The accuracy of the uRADMonitor SMOGGIE sensors was fairly constant (~ 23% to 29%) over the range of PM\(_{1.0}\) mass concentrations tested.

uRADMonitor SMOGGIE: Data Recovery and Intra-model Variability

- Data recovery for PM\(_{1.0}\) mass concentration from all units was 100%
- Low PM\(_{1.0}\) measurement variations were observed between the uRADMonitor SMOGGIE sensors
uRADMonitor SMOGGIE vs GRIMM (PM$_{1.0}$; 1-min mean)

- Precision (Effect of PM$_{1.0}$ conc., Temperature and Relative Humidity)

- Overall, the uRADMonitor SMOGGIE sensors showed high precision for all combinations of low, medium and high PM$_{1.0}$ conc., T, and RH.

- Precision was relatively higher at higher PM$_{1.0}$ mass concentrations.
uRADMonitor SMOGGIE PM$_{1.0}$: Climate Susceptibility

uRADMonitor SMOGGIE vs GRIMM
(5 °C RH ramping, med PM$_{1.0}$ mass conc.)

From 15% to 40% RH  65% RH

High Temp – RH ramping (medium conc.)

Low Temp – RH ramping (medium conc.)
Evaluation results for PM$_{2.5}$ mass concentration

uRADMonitor SMOGGIE vs FEM GRIMM
The uRADMonitor SMOGGIE sensors tracked well with the concentration variation as recorded by the FEM GRIMM in the concentration range of 0 - ~250 μg/m³.

The uRADMonitor SMOGGIE sensors showed very strong correlations with the FEM GRIMM PM$_{2.5}$ mass conc. (R$^2 > 0.99$)
uRADMonitor SMOGGIE vs FEM GRIMM PM$_{2.5}$ Accuracy

- Accuracy (20°C and 40% RH)

<table>
<thead>
<tr>
<th>Steady state #</th>
<th>Sensor Mean (µg/m$^3$)</th>
<th>FEM GRIMM (µg/m$^3$)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.1</td>
<td>8.7</td>
<td>95.2</td>
</tr>
<tr>
<td>2</td>
<td>12.9</td>
<td>14.8</td>
<td>87.3</td>
</tr>
<tr>
<td>3</td>
<td>24.3</td>
<td>48.1</td>
<td>50.6</td>
</tr>
<tr>
<td>4</td>
<td>63.5</td>
<td>149.4</td>
<td>42.5</td>
</tr>
<tr>
<td>5</td>
<td>106.8</td>
<td>250.3</td>
<td>42.7</td>
</tr>
</tbody>
</table>

- The uRADMonitor SMOGGIE sensors underestimated FEM GRIMM PM$_{2.5}$ mass concentrations at 20 °C and 40% RH. The accuracy of the uRADMonitor SMOGGIE sensors decreased (from ~95% to 43%) as PM$_{2.5}$ mass concentrations increased.

uRADMonitor SMOGGIE: Data Recovery and Intra-model Variability

- Data recovery for PM$_{2.5}$ mass concentration from all units was 100%
- Low PM$_{2.5}$ measurement variations were observed between the uRADMonitor SMOGGIE sensors
uRADMonitor SMOGGIE vs FEM GRIMM (PM$_{2.5}$; 1-min mean)

- Precision (Effect of PM$_{2.5}$ conc., Temperature and Relative Humidity)

- Overall, the uRADMonitor SMOGGIE sensors showed high precision for all combinations of low, medium and high PM$_{2.5}$ conc., T, and RH.

- Precision was relatively higher at higher PM$_{2.5}$ mass concentrations.
uRADMonitor SMOGGIE vs PM$_{2.5}$: Climate Susceptibility

Low Temp – RH ramping (medium conc.)

High Temp – RH ramping (medium conc.)
**Discussion**

- **Accuracy**: Overall, the accuracy of the uRADMonitor SMOGGIE sensors was fairly constant (~ 23% to 29%) over the range of PM$_{1.0}$ mass concentrations tested; the accuracy decreased (from ~95% to 43%) as PM$_{2.5}$ mass concentrations increased. The uRADMonitor SMOGGIE sensors underestimated the corresponding PM$_{1.0}$ and PM$_{2.5}$ measurements from GRIMM in the laboratory experiments at 20 °C and 40% RH.

- **Precision**: The uRADMonitor SMOGGIE sensors showed high precision for all test combinations (PM concentrations, T and RH) for PM$_{1.0}$ and PM$_{2.5}$ mass concentrations.

- **Intra-model variability**: Low intra-model variability was observed among the uRADMonitor SMOGGIE sensors for PM$_{1.0}$ and PM$_{2.5}$ mass concentrations.

- **Data Recovery**: Data recovery for PM$_{1.0}$ and PM$_{2.5}$ mass concentration was 100% from all uRADMonitor SMOGGIE units.

- **Coefficient of Determination**: The uRADMonitor SMOGGIE sensors showed very strong correlation/linear response with the corresponding GRIMM PM$_{1.0}$ and FEM GRIMM PM$_{2.5}$ measurement data ($R^2 > 0.99$).

- **Climate susceptibility**: For most of the temperature and relative humidity combination, the climate condition had minimal effect on the uRADMonitor SMOGGIE sensors’ precision; the sensors showed significant concentration variation at low PM levels.