Field Evaluation
Oizom - Polludrone Smart
From 07/31/2021 to 09/29/2021, three Oizom Polludrone Smart (hereinafter Polludrone Smart) sensors were deployed at the South Coast AQMD stationary ambient monitoring site in Rubidoux and were run side-by-side with Federal Equivalent Method (FEM) instruments measuring the same pollutants.

**Polludrone Smart (3 units tested):**
- Sensors: CO – Electrochemical (Alphasense B4, non-FEM)
- O₃ – Electrochemical (Alphasense B4, non-FEM)
- NO – Electrochemical (Alphasense B4, non-FEM)
- NO₂ – Electrochemical (Alphasense B4, non-FEM)
- PM Sensors – Optical Particle Counter (Wuhan Cubic PM3006S)
- Each unit measures: CO (ppm), O₃ (ppb), NO and NO₂ (ppb), PM₁₀, PM₂.₅ and PM₁₀ (μg/m³), T (°C), RH (%)
- Unit cost: $8,000 (PM + Gas sensors)
- Time resolution: 1-min
- Units IDs: 0001, 0002, 0003

**Teledyne API T640 (reference instrument):**
- Optical particle counter (FEM PM₂.₅)
- Measures PM₁₀, PM₂.₅ and PM₁₀ (μg/m³)
- Cost: ~$21,000
- Time resolution: 1-min

**Met Station (T, RH, P, WS, WD):**
- Cost: ~$5,000
- Time resolution: 1-min
Data validation & recovery

- Basic QA/QC procedures were used to validate the collected data (i.e. obvious outliers, negative values and invalid data-points were eliminated from the data-set)
- Data recovery from Unit 0001, Unit 0002 and Unit 0003 was ~ 99%, 95% and 99% for all PM measurements, respectively

Polludrone Smart; intra-model variability

- Absolute intra-model variability was ~ 0.13, 0.20 and 0.48 µg/m³ for PM$_{1.0}$, PM$_{2.5}$ and PM$_{10}$, respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 0.78%, 0.96% and 1.11% for PM$_{1.0}$, PM$_{2.5}$ and PM$_{10}$, respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)
Polludrone Smart vs T640 (PM\textsubscript{1.0}; 5-min mean)

- The Polludrone Smart sensors showed strong correlations with the corresponding T640 data (0.81 < R\textsuperscript{2} < 0.87)
- Overall, the Polludrone Smart sensors overestimated the PM\textsubscript{1.0} mass concentrations as measured by T640
- The Polludrone Smart sensors seemed to track the PM\textsubscript{1.0} diurnal variations as recorded by T640
The Polludrone Smart sensors showed strong correlations with the corresponding FEM T640 data ($0.75 < R^2 < 0.82$).

Overall, the Polludrone Smart sensors overestimated the PM$_{2.5}$ mass concentrations as measured by FEM T640.

The Polludrone Smart sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM T640.
Polludrone Smart vs T640 (PM$_{10}$; 5-min mean)

- Polludrone Smart sensors showed weak correlations with the corresponding T640 data ($0.32 < R^2 < 0.35$)
- Overall, the Polludrone Smart sensors underestimated the PM$_{10}$ mass concentrations as measured by T640
- The Polludrone Smart sensors did not seem to track the PM$_{10}$ diurnal variations as recorded by T640
The Polludrone Smart sensors showed strong correlations with the corresponding T640 data ($0.82 < R^2 < 0.87$).

Overall, the Polludrone Smart sensors overestimated the PM$_{1.0}$ mass concentrations as measured by T640.

The Polludrone Smart sensors seemed to track the PM$_{1.0}$ diurnal variations as recorded by T640.
The Polludrone Smart sensors showed strong correlations with the corresponding FEM T640 data (0.76 < $R^2$ < 0.82).

Overall, the Polludrone Smart sensors overestimated the PM$_{2.5}$ mass concentrations as measured by FEM T640.

The Polludrone Smart sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM T640.
The Polludrone Smart sensors showed weak correlations with the corresponding T640 data ($0.33 < R^2 < 0.35$).

Overall, the Polludrone Smart sensors underestimated the PM$_{10}$ mass concentrations as measured by T640.

The Polludrone Smart sensors did not seem to track the PM$_{10}$ diurnal variations as recorded by T640.
The Polludrone Smart sensors showed strong to very strong correlations with the corresponding T640 data ($0.88 < R^2 < 0.92$).

Overall, the Polludrone Smart sensors overestimated the PM$_{1.0}$ mass concentrations as measured by T640.

The Polludrone Smart sensors seemed to track the PM$_{1.0}$ diurnal variations as recorded by T640.
Polludrone Smart vs FEM T640 (PM$_{2.5}$; 24-hr mean)

- The Polludrone Smart sensors showed strong correlations with the corresponding FEM T640 data ($0.82 < R^2 < 0.87$)
- Overall, the Polludrone Smart sensors overestimated the PM$_{2.5}$ mass concentrations as measured by FEM T640
- The Polludrone Smart sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM T640

y = 0.507x + 5.4333
$R^2 = 0.8318$

y = 0.489x + 5.7139
$R^2 = 0.8662$

y = 0.4845x + 5.813
$R^2 = 0.8222$
Polludrone Smart vs T640 (PM\textsubscript{10}; 24-hr mean)

- The Polludrone Smart sensors showed very weak to weak correlations with the corresponding T640 data (0.26 < R\textsuperscript{2} < 0.31)
- Overall, the Polludrone Smart sensors underestimated the PM\textsubscript{10} mass concentrations as measured by T640
- The Polludrone Smart sensors did not seem to track the PM\textsubscript{10} diurnal variations as recorded by T640
### Summary

#### Polludrone Smart vs T640, PM$_{1.0}$

<table>
<thead>
<tr>
<th>Duration</th>
<th>Average (µg/m$^3$)</th>
<th>SD (µg/m$^3$)</th>
<th>$R^2$</th>
<th>Slope</th>
<th>Intercept</th>
<th>MBE$^1$ (µg/m$^3$)</th>
<th>MAE$^2$ (µg/m$^3$)</th>
<th>RMSE$^3$ (µg/m$^3$)</th>
<th>Ref. Average</th>
<th>Ref. SD</th>
<th>Range during the field evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-min</td>
<td>16.8</td>
<td>9.7</td>
<td>0.82</td>
<td>0.50</td>
<td>3.6</td>
<td>4.1</td>
<td>4.5</td>
<td>6.5</td>
<td>12.6</td>
<td>5.7</td>
<td>2.3 to 62.5</td>
</tr>
<tr>
<td>1-hr</td>
<td>16.8</td>
<td>9.6</td>
<td>0.82</td>
<td>0.50</td>
<td>3.7</td>
<td>4.1</td>
<td>4.4</td>
<td>6.4</td>
<td>12.6</td>
<td>5.6</td>
<td>2.7 to 54.8</td>
</tr>
<tr>
<td>24-hr</td>
<td>16.8</td>
<td>7.7</td>
<td>0.88</td>
<td>0.51</td>
<td>3.7</td>
<td>4.1</td>
<td>4.3</td>
<td>5.6</td>
<td>12.6</td>
<td>4.3</td>
<td>6.0 to 23.6</td>
</tr>
</tbody>
</table>

#### Polludrone Smart vs FEM T640, PM$_{2.5}$

<table>
<thead>
<tr>
<th>Duration</th>
<th>Average (µg/m$^3$)</th>
<th>SD (µg/m$^3$)</th>
<th>$R^2$</th>
<th>Slope</th>
<th>Intercept</th>
<th>MBE$^1$ (µg/m$^3$)</th>
<th>MAE$^2$ (µg/m$^3$)</th>
<th>RMSE$^3$ (µg/m$^3$)</th>
<th>Ref. Average</th>
<th>Ref. SD</th>
<th>Range during the field evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-min</td>
<td>21.5</td>
<td>11.7</td>
<td>0.76</td>
<td>0.49</td>
<td>5.3</td>
<td>4.9</td>
<td>5.4</td>
<td>8.0</td>
<td>16.4</td>
<td>6.9</td>
<td>3.4 to 78.1</td>
</tr>
<tr>
<td>1-hr</td>
<td>21.4</td>
<td>11.6</td>
<td>0.76</td>
<td>0.49</td>
<td>5.3</td>
<td>4.9</td>
<td>5.4</td>
<td>7.9</td>
<td>16.4</td>
<td>6.8</td>
<td>4.2 to 68.8</td>
</tr>
<tr>
<td>24-hr</td>
<td>21.4</td>
<td>9.0</td>
<td>0.82</td>
<td>0.48</td>
<td>5.4</td>
<td>4.9</td>
<td>5.3</td>
<td>6.8</td>
<td>16.4</td>
<td>5.0</td>
<td>8.4 to 28.1</td>
</tr>
</tbody>
</table>

#### Polludrone Smart vs T640, PM$_{10}$

<table>
<thead>
<tr>
<th>Duration</th>
<th>Average (µg/m$^3$)</th>
<th>SD (µg/m$^3$)</th>
<th>$R^2$</th>
<th>Slope</th>
<th>Intercept</th>
<th>MBE$^1$ (µg/m$^3$)</th>
<th>MAE$^2$ (µg/m$^3$)</th>
<th>RMSE$^3$ (µg/m$^3$)</th>
<th>Ref. Average</th>
<th>Ref. SD</th>
<th>Range during the field evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-min</td>
<td>44.5</td>
<td>21.8</td>
<td>0.33</td>
<td>0.48</td>
<td>23.7</td>
<td>-2.6 to -1.5</td>
<td>14.3 to 15.5</td>
<td>17.9 to 19.8</td>
<td>46.8</td>
<td>19.3</td>
<td>10.8 to 240.6</td>
</tr>
<tr>
<td>1-hr</td>
<td>44.5</td>
<td>21.5</td>
<td>0.34</td>
<td>0.46</td>
<td>24.7</td>
<td>-2.6 to -1.5</td>
<td>14.1 to 15.3</td>
<td>17.3 to 19.1</td>
<td>46.8</td>
<td>18.1</td>
<td>13.3 to 194.7</td>
</tr>
<tr>
<td>24-hr</td>
<td>44.5</td>
<td>15.8</td>
<td>0.27</td>
<td>0.35</td>
<td>29.2</td>
<td>-2.5 to -1.5</td>
<td>11.3 to 12.3</td>
<td>13.1 to 14.2</td>
<td>46.8</td>
<td>11.3</td>
<td>23.7 to 81.3</td>
</tr>
</tbody>
</table>

1 Mean Bias Error (MBE): the difference between the sensors and the reference instruments. MBE indicates the tendency of the sensors to underestimate (negative MBE values) or overestimate (positive MBE values).

2 Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.

3 Root Mean Square Error (RMSE): another metric to calculate measurement errors.
The Polludrone Smart sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.97$).

Overall, the Polludrone Smart temperature measurements overestimated the corresponding South Coast AQMD Met Station data.

The Polludrone Smart sensors seemed to track the temperature diurnal variations as recorded by South Coast AQMD Met Station.
The Polludrone Smart sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.98$).

Overall, the Polludrone Smart RH measurements overestimated the corresponding South Coast AQMD Met Station data.

The Polludrone Smart sensors seemed to track the RH diurnal variations as recorded by South Coast AQMD Met Station.
Discussion

• The three Polludrone Smart sensors’ data recovery from Unit 0001, Unit 0002 and Unit 0003 was ~ 99%, 95% and 99% for all PM measurements, respectively

• The absolute intra-model variability was ~ 0.13, 0.20 and 0.48 µg/m³ for PM$_{1.0}$, PM$_{2.5}$ and PM$_{10}$, respectively

• PM$_{1.0}$ mass concentrations measured by the Polludrone Smart sensors showed strong correlations with the corresponding T640 data ($0.82 < R^2 < 0.87$, 1-hr mean). The sensors overestimated PM$_{1.0}$ mass concentrations as measured by T640

• PM$_{2.5}$ mass concentrations measured by the Polludrone Smart sensors showed strong correlations with the corresponding FEM T640 data ($0.76 < R^2 < 0.82$, 1-hr mean). The sensors overestimated PM$_{2.5}$ mass concentrations as measured by FEM T640

• PM$_{10}$ mass concentrations measured by the Polludrone Smart sensors showed weak correlations with the corresponding T640 data ($0.33 < R^2 < 0.35$; 1-hr mean). The sensors underestimated PM$_{10}$ mass concentrations as measured by T640

• No sensor calibration was performed by South Coast AQMD Staff prior to the beginning of this test

• Laboratory chamber testing is necessary to fully evaluate the performance of these sensors under known aerosol concentrations and controlled temperature and relative humidity conditions

• All results are still preliminary