Field Evaluation
Redspira

South Coast AQMD
AQ-SPEC
Air Quality Sensor Performance Evaluation Center
From 10/29/2020 to 12/25/2020, three Redspira 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:

- **Redspira (3 units tested):**
  - Particle sensor: optical; non-FEM (PMS5003, Plantower)
  - Each unit reports: PM$_{2.5}$ and PM$_{10}$ ($\mu$g/m$^3$), temperature (°C) and RH (%)
  - Unit cost: $180
  - Time resolution: 1-min
  - Units IDs: 0083, 0084, 0085

- **MetOne BAM (reference instrument):**
  - Beta-attenuation monitor (FEM PM$_{2.5}$ & PM$_{10}$)
  - Measures PM$_{2.5}$ & PM$_{10}$ ($\mu$g/m$^3$)
  - Unit cost: ~$20,000
  - Time resolution: 1-hr

- **Teledyne API T640 (reference instrument):**
  - Optical particle counter (FEM PM$_{2.5}$)
  - Measures PM$_{2.5}$ & PM$_{10}$ ($\mu$g/m$^3$)
  - Unit cost: ~$21,000
  - Time resolution: 1-min

- **Met station:**
  - Measures T, RH, P, WS and WD
  - Unit 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 all units was ~ 96% for all PM measurements

Redspira; intra-model variability

- Absolute intra-model variability was ~ 1.30 and 1.29 µg/m³ for PM$_{2.5}$ and PM$_{10}$, respectively (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 6.9% and 5.8% for PM$_{2.5}$ and PM$_{10}$, respectively (calculated as the absolute intra-model variability relative to the mean of the three sensor means)
Reference Instruments: PM$_{2.5}$ FEM BAM and FEM T640

- Data recovery for PM$_{2.5}$ from FEM BAM and FEM T640 was ~ 98% and ~ 100%, respectively.
- Very strong correlations between the reference instruments for PM$_{2.5}$ measurements ($R^2$ ~ 0.91) were observed.
Reference Instruments: PM$_{10}$
FEM BAM and T640

- Data recovery for PM$_{10}$ from FEM BAM and T640 was 99% and 100%, respectively.
- Strong correlations between the reference instruments for PM$_{10}$ measurements ($R^2 \approx 0.88$) were observed.
• The Redspira sensors showed strong correlations with the corresponding FEM T640 data (0.72 < $R^2$ < 0.88)
• Overall, the Redspira sensors overestimated the PM$_{2.5}$ mass concentrations as measured by FEM T640
• The Redspira sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM T640
The Redspira sensors showed weak correlations with the corresponding T640 data (0.30 < $R^2$ < 0.37).

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

The Redspira sensors did not seem to track the PM$_{10}$ diurnal variations as recorded by T640.
The Redspira sensors showed strong correlations with the corresponding FEM T640 data (0.81 < R² < 0.89).

Overall, the Redspira sensors overestimated the PM₂.₅ mass concentrations as measured by FEM T640.

The Redspira sensors seemed to track the PM₂.₅ diurnal variations as recorded by FEM T640.
Redspira vs T640 (PM$_{10}$; 1-hr mean)

- The Redspira sensors showed weak correlations with the corresponding T640 data ($0.36 < R^2 < 0.41$).
- Overall, the Redspira sensors underestimated the PM$_{10}$ mass concentrations as measured by T640.
- The Redspira sensors did not seem to track the PM$_{10}$ diurnal variations as recorded by T640.
The Redspira sensors showed very strong correlations with the corresponding FEM T640 data (0.91 < \( R^2 \) < 0.93).

Overall, the Redspira sensors overestimated the PM\(_{2.5}\) mass concentrations as measured by FEM T640.

The Redspira sensors seemed to track the PM\(_{2.5}\) diurnal variations as recorded by FEM T640.
The Redspira sensors showed weak to moderate correlations with the corresponding T640 data ($0.48 < R^2 < 0.52$).

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

- The Redspira sensors seemed to track the PM$_{10}$ diurnal variations as recorded by T640.
The Redspira sensors showed strong correlations with the corresponding FEM BAM data ($0.73 < R^2 < 0.82$).

Overall, the Redspira sensors overestimated the PM$_{2.5}$ mass concentrations as measured by FEM BAM.

The Redspira sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM BAM.
Redspira vs FEM BAM (PM$_{10}$; 1-hr mean)

- The Redspira sensors showed very weak correlations with the corresponding FEM BAM data (0.20 < $R^2$ < 0.23)
- Overall, the Redspira sensors underestimated the PM$_{10}$ mass concentrations measured by FEM BAM
- The Redspira sensors did not seem to track the PM$_{10}$ diurnal variations as recorded by FEM BAM
Redspira vs FEM BAM (PM$_{2.5}$; 24-hr mean)

- The Redspira sensors showed strong to very strong correlations with the corresponding FEM BAM data ($0.88 < R^2 < 0.92$)
- Overall, the Redspira sensors overestimated the PM$_{2.5}$ mass concentrations as measured by FEM BAM
- The Redspira sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM BAM
The Redspira sensors showed weak correlations with the corresponding FEM BAM data ($0.35 < R^2 < 0.37$).

Overall, the Redspira sensors underestimated the PM$_{10}$ mass concentrations measured by FEM BAM.

The Redspira sensors did not seem to track the PM$_{10}$ diurnal variations as recorded by FEM BAM.
**Summary: PM**

<table>
<thead>
<tr>
<th>Average of 3 Sensors, PM$_{2.5}$</th>
<th>Redspira vs FEM BAM &amp; FEM T640, PM$_{2.5}$</th>
<th>FEM BAM &amp; FEM T640 (PM$_{2.5}$, µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong> (µg/m$^3$)</td>
<td><strong>SD</strong> (µg/m$^3$)</td>
<td><strong>R$^2$</strong></td>
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<tr>
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<td>--------</td>
</tr>
<tr>
<td>5-min</td>
<td>19.0</td>
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<tr>
<td>1-hr</td>
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<td>16.2</td>
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<tr>
<td>24-hr</td>
<td>19.0</td>
<td>11.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average of 3 Sensors, PM$_{10}$</th>
<th>Redspira vs FEM BAM &amp; T640, PM$_{10}$</th>
<th>FEM BAM and T640 (PM$_{10}$, µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong> (µg/m$^3$)</td>
<td><strong>SD</strong> (µg/m$^3$)</td>
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<td>-----------------</td>
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<tr>
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<tr>
<td>24-hr</td>
<td>22.5</td>
<td>13.6</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.
Redspira vs South Coast AQMD Met Station (Temperature; 5-min mean)

- The Redspira sensors showed strong to very strong correlations with the corresponding South Coast Met Station data (0.86 < R^2 < 0.92)
- Overall, the Redspira sensors overestimated the temperature measurements as recorded by South Coast Met Station
- The Redspira sensors seemed to track the diurnal temperature variations as recorded by South Coast Met Station

\[
y = 0.7269x + 1.3494 \\
R^2 = 0.8609
\]

\[
y = 0.81x - 0.118 \\
R^2 = 0.8864
\]

\[
y = 0.8198x + 0.8469 \\
R^2 = 0.9167
\]
Redspira vs South Coast AQMD Met Station
(RH; 5-min mean)

- Redspira sensors showed very strong correlations with the corresponding South Coast Met Station data (0.93 < R² < 0.96)
- Overall, the Redspira sensors underestimated the RH measurements as recorded by South Coast Met Station
- The Redspira sensors seemed to track the diurnal RH variations as recorded by South Coast Met Station
Discussion

- The three Redspira sensors’ data recovery from all units was ~ 96% for all PM measurements.
- The absolute intra-model variability was ~ 1.30 and 1.29 µg/m³ for PM$_{2.5}$ and PM$_{10}$, respectively.
- Very strong correlations between FEM BAM and FEM T640 for PM$_{2.5}$ ($R^2$ ~ 0.91, 1-hr mean) and strong correlations between FEM BAM and T640 for PM$_{10}$ ($R^2$ ~ 0.88, 1-hr mean) mass concentration measurements.
- PM$_{2.5}$ mass concentrations measured by Redspira sensors showed strong correlations with the corresponding FEM T640 and FEM BAM data (0.73 < $R^2$ < 0.89, 1-hr mean). The sensors overestimated PM$_{2.5}$ mass concentrations as measured by FEM T640 and FEM BAM.
- PM$_{10}$ mass concentrations measured by Redspira sensors showed very weak to weak correlations with the corresponding T640 and FEM BAM data (0.20 < $R^2$ < 0.41; 1-hr mean). The sensors underestimated PM$_{10}$ mass concentrations measured by T640 and FEM BAM.
- 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.