Field Evaluation
Qingping - Air Monitor
From 11/07/2022 to 01/07/2023, three Qingping – Air Monitor 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.

**Qingping Air Monitor (3 units tested):**
- Particle sensor: optical; non-FEM (Grandway, Model P5500)
- Each unit reports: PM\(_{2.5}\) (\(\mu g/m^3\)), T (°C), RH (%)
- Unit cost: $135
- Also measures: CO\(_2\) (ppm) and tVOC (ppb)
- Time resolution: 1-min
- Units IDs: 39F5, 37DA, 3956

**GRIMM EDM180 (reference instrument):**
- Optical particle counter (FEM PM\(_{2.5}\))
- Measures PM\(_{1.0}\), PM\(_{2.5}\), and PM\(_{10}\) (\(\mu g/m^3\))
- Cost: ~$25,000 and up
- Time resolution: 1-min

**Teledyne API T640 (reference instrument):**
- Optical particle counter (FEM PM\(_{2.5}\))
- Measures PM\(_{1.0}\), PM\(_{2.5}\), and PM\(_{10}\) (\(\mu g/m^3\))
- 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 all units was ~100% for PM$_{2.5}$ mass concentration measurements.

Qingping Air Monitor; intra-model variability

- Absolute intra-model variability was ~0.43 µg/m$^3$ for PM$_{2.5}$ mass concentration measurements (calculated as the standard deviation of the three sensor means).
- Relative intra-model variability was ~3.4% for PM$_{2.5}$ mass concentration measurements (calculated as the absolute intra-model variability relative to the mean of the three sensor means).
Data recovery for PM$_{2.5}$ from FEM GRIMM and FEM T640 was ~96.7% and ~100%, respectively.

Very strong correlations between the reference instruments for PM$_{2.5}$ measurements ($R^2$ ~0.97) were observed.
The Qingping Air Monitor sensors showed strong correlations with the corresponding FEM GRIMM data ($0.86 < R^2 < 0.88$).

Overall, the Qingping Air Monitor sensors underestimated the PM$_{2.5}$ mass concentrations as measured by FEM GRIMM.

The Qingping Air Monitor sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM GRIMM.
The Qingping Air Monitor sensors showed strong correlations with the corresponding FEM GRIMM data ($0.89 < R^2 < 0.90$).

Overall, the Qingping Air Monitor sensors underestimated the PM$_{2.5}$ mass concentrations as measured by FEM GRIMM.

The Qingping Air Monitor sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM GRIMM.
Qingping Air Monitor vs FEM GRIMM (PM$_{2.5}$; 24-hr mean)

- The Qingping Air Monitor sensors showed very strong correlations with the corresponding FEM GRIMM data ($0.90 < R^2 < 0.92$)
- Overall, the Qingping Air Monitor sensors underestimated the PM$_{2.5}$ mass concentrations as measured by FEM GRIMM
- The Qingping Air Monitor sensors seemed to track the PM$_{2.5}$ daily variations as recorded by FEM GRIMM
The Qingping Air Monitor sensors showed strong to very strong correlations with the corresponding FEM T640 data ($0.88 < R^2 < 0.91$).

Overall, the Qingping Air Monitor sensors overestimated the PM$_{2.5}$ mass concentrations as measured by FEM T640.

The Qingping Air Monitor sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM T640.
The Qingping Air Monitor sensors showed very strong correlations with the corresponding FEM T640 data ($0.94 < R^2 < 0.95$).

Overall, the Qingping Air Monitor sensors overestimated the PM$_{2.5}$ mass concentrations as measured by FEM T640.

The Qingping Air Monitor sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM T640.
The Qingping Air Monitor sensors showed very strong correlations with the corresponding FEM T640 data ($0.95 < R^2 < 0.97$). Overall, the Qingping Air Monitor sensors overestimated the PM$_{2.5}$ mass concentrations as measured by FEM T640. The Qingping Air Monitor sensors seemed to track the PM$_{2.5}$ daily variations as recorded by FEM T640.
Qingping Air Monitor vs South Coast AQMD Met Station (Temp; 5-min mean)

- The Qingping Air Monitor sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.95$)
- Overall, the Qingping Air Monitor sensors underestimated the temperature measurement as recorded by South Coast AQMD Met Station
- The Qingping Air Monitor sensors seemed to track the diurnal temperature variations as recorded by South Coast AQMD Met Station

![Graphs showing temperature data comparison between Qingping Air Monitor and South Coast AQMD Met Station](image)

- $y = 0.9062x + 1.5142$, $R^2 = 0.951$
- $y = 0.9173x + 1.2455$, $R^2 = 0.9519$
- $y = 0.9321x + 0.8451$, $R^2 = 0.9457$
The Qingping Air Monitor sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.98$).

Overall, the Qingping Air Monitor sensors overestimated the RH measurement as recorded by South Coast AQMD Met Station.

The Qingping Air Monitor sensors seemed to track the diurnal RH variations as recorded by South Coast AQMD Met Station.
## Summary

### Summary of Measurement Errors

<table>
<thead>
<tr>
<th></th>
<th>Average of 3 Sensors, PM$_{2.5}$</th>
<th>Qingping Air Monitor vs FEM GRIMM &amp; FEM T640, PM$_{2.5}$</th>
<th>FEM GRIMM &amp; FEM T640 (PM$_{2.5}$, $\mu$g/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average ($\mu$g/m$^3$)</td>
<td>SD ($\mu$g/m$^3$)</td>
<td>$R^2$</td>
</tr>
<tr>
<td>5-min</td>
<td>12.4</td>
<td>9.1</td>
<td>0.86 to 0.90</td>
</tr>
<tr>
<td>1-hr</td>
<td>12.4</td>
<td>8.8</td>
<td>0.89 to 0.95</td>
</tr>
<tr>
<td>24-hr</td>
<td>12.4</td>
<td>6.0</td>
<td>0.91 to 0.96</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.

Average of 3 Sensors, PM$_{2.5}$

<table>
<thead>
<tr>
<th></th>
<th>PM$_{2.5}$ (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>12.4</td>
<td>11.5 to 12.8</td>
<td>0.3 to 102.7</td>
<td></td>
</tr>
<tr>
<td>1-hr</td>
<td>12.4</td>
<td>11.5 to 12.8</td>
<td>0.4 to 43.9</td>
<td></td>
</tr>
<tr>
<td>24-hr</td>
<td>12.4</td>
<td>11.5 to 12.9</td>
<td>2.7 to 27.9</td>
<td></td>
</tr>
</tbody>
</table>
Discussion

- The three **Qingping Air Monitor** sensors’ data recovery was ~100% for PM$_{2.5}$ mass concentration measurements
- The absolute intra-model variability was ~0.43 µg/m$^3$ for PM$_{2.5}$ mass concentration measurements
- Reference instruments: very strong correlations between FEM GRIMM and FEM T640 for PM$_{2.5}$ ($R^2$ ~0.97, 1-hr mean) mass concentration measurements
- PM$_{2.5}$ mass concentrations measured by the Qingping Air Monitor sensors showed strong to very strong correlations with the corresponding FEM GRIMM and FEM T640 data ($0.89 < R^2 < 0.95$, 1-hr mean). The sensors underestimated PM$_{2.5}$ mass concentrations as measured by FEM GRIMM and overestimated PM$_{2.5}$ mass concentrations as measured by FEM T640
- No sensor calibration was performed by South Coast AQMD Staff for this evaluation
- 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**