PM$_{2.5}$ Air Quality Sensor Performance Evaluation in Taiwan: Technical System Design and Setup

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In order to get the public know the ambient air quality for reference when doing outdoor activities, the Environmental Protection Administration in Taiwan (Taiwan EPA) has applied low-cost PM$_{2.5}$ sensors to monitor pollution at local levels. The reliability and validity of collected data causes lots of attention and discussion in related communities. While comparing sensor readings with PM$_{2.5}$ monitors installed in monitoring stations, it is common to see biases between them. However, the public, even researchers do not have a clue to define the deviation is acceptable or not.

To address the issue of data quality from deployed sensors, ITRI received funding from Taiwan EPA to cooperated a 4-year project of testing systems design and setup for air quality sensors. The main goal in the first year, 2017, is to test and certify the performance of targeted PM$_{2.5}$ Sensors. The design includes both field and laboratory testing. Testing parameters include correlation coefficient, detection limit, and precision between modules.

For field-testing, eight stations are now equipped individually with sensor shelters, automated continued monitors as reference method, manual sampler, and data collecting devices. Two of these stations, Lin-Yuan and Chien-Chin are located nearby industrial area in the southern Taiwan and characterized with wider hourly concentration range, possibly varied from 2 to 80 µg/m$^3$ from September to December. In laboratory, we design a wind tunnel system with the capability to control the temperature, humidity, and wind speed to do the climate interference testing.

**Keywords:** PM$_{2.5}$, field testing, wind tunnel, air quality sensor.

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### Field Testing Platform

- **Lin-Yuan testing site** is in the southern of Taiwan and situated in downwind direction of petroleum industrial area. It is also the site for collocated equivalent comparison of monitors and manual samplers. The hourly value of PM$_{2.5}$ in fall and winter time has the possibility to reach over 100 µg/m$^3$.

- **Hsinchu testing site** is in the northern of Taiwan and situated in ITRI campus. We installed three different types of monitors to compare their performance for ensuring data quality of reference method. Meanwhile, we also setup more than three shelters for PM$_{2.5}$ sensors. So far, more than six type of sensors are under evaluation since June, 2017.

### Laboratory Evaluation Platform

*(located in ITRI campus in Hsinchu, Taiwan)*

The testing system was featured of having capabilities to adjust key parameters including:
- Particle mass concentration
- Wind speed
- Temperature and humidity

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**Metrological Traceability Chain for Sensor Performance Evaluation**

- **SI unit**
  - mass
  - flow

- **Manual Sampler, $x_i$**
  - Daily average
  - Hourly average
  - Minute-reading

- **Continued Monitor, $y_i$**
  - Minute-reading

- **Sensor, $z_i$**

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**Preliminary results using reading of TSI DustTrak II as the reference value for linear regression, sensor type: Edimax / AI-1001W and Met One 831**

<table>
<thead>
<tr>
<th>Testing period</th>
<th>Edimax / AI-1001W</th>
<th>Met One 831</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th August 2017 to 10th August 2017 (7-day)</td>
<td>$Y = 1.46 X + 1.40$</td>
<td>$Y = 2.14 X + 3.30$</td>
</tr>
<tr>
<td>Linear Regression Results</td>
<td>$R^2 = 0.95$</td>
<td>$R^2 = 0.86$</td>
</tr>
<tr>
<td>Resolution: 5 min</td>
<td>$Y = 1.51 X + 1.01$</td>
<td>$Y = 2.15 X – 3.30$</td>
</tr>
<tr>
<td>Resolution: 1 hr</td>
<td>$R^2 = 0.98$</td>
<td>$R^2 = 0.86$</td>
</tr>
</tbody>
</table>

**SUMMARY and FUTURE WORK**

A. Field testing platforms located in eight areas in Taiwan are going to serve for performance testing of newly developed or commercial PM$_{2.5}$ sensors.

B. Laboratory evaluation system are designed and expected to provide service by the end of 2017. Climate interferences on the sensor performance including temperature, humidity, and wind speed, are expected to be investigated quantitatively.

C. Over six different type of optical sensors and portable monitors are now under field testing in the industrial, coast side area of Taiwan. Testing over 3-month are expected to estimate and compare their durability and drift.

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