Application of PM$_{2.5}$ Low-cost-sensors to Assess Community Sources

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- AS-LUNG (Academia Sinica- LUNG)
  - Outdoor version (AS-LUNG (O))
  - Portable version (AS-LUNG(P))
Set-up of AS-LUNG(O) in the community

- Solar panel
- PM sensor
- CO₂ sensor
- Temperature/RH sensor
- Water-proof housing
- System control main board with RTC (Time) module & SD card
- Data transmission element
- Power supply element
- Wireless transmission antenna

2.2-2.8m
Community Culture-related Air-Pollutant Sources in Asian Cities

Asian style restaurant

Night market

Traffic

Temple

Hair salon

Car salon

PM$_{2.5}$ (WHO classified as a human carcinogen)

VOCs

PAHs

NO$_2$

SO$_2$

many others

Candice Lung
Motivation

• Higher *intra-urban variability* in Asian residential communities than those in western countries
  – various PM$_{2.5}$ sources, such as *restaurants and home factories*

• High *exposure* levels to residents due to *community sources*

• Objectives:
  – to evaluate the *applicability of AS-LUNG(O)*
  – to *quantify PM$_{2.5}$ contributions from those community sources*
## Comparison with GRIMM

### Table 1  PM$_{2.5}$ comparison in the laboratory and in the field

$\text{AS-LUNG(O)} = \text{slope*GRIMM} + \text{intercept}$

<table>
<thead>
<tr>
<th></th>
<th>PM$_{2.5}$-Slope</th>
<th>PM$_{2.5}$-Intercept</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In lab (Sensor=40)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (STD)</td>
<td>2.33 (0.22)</td>
<td>-1.23 (1.65)</td>
<td>0.95 (0.04)</td>
</tr>
<tr>
<td>Max, Min</td>
<td>2.73, 1.86</td>
<td>2.92, -3.91</td>
<td>0.98, 0.80</td>
</tr>
<tr>
<td><strong>In field (Sensor=11 for 3 days)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (STD)</td>
<td>2.01 (0.26)</td>
<td>3.66 (5.27)</td>
<td>0.88 (0.10)</td>
</tr>
<tr>
<td>Max, Min</td>
<td>2.39, 1.66</td>
<td>9.49, -2.01</td>
<td>0.97, 0.68</td>
</tr>
</tbody>
</table>

- Lab: T: 18.1-34.9C, RH: 56.3-97.4%, PM$_{2.5}$: 3-150ug/m$^3$
- Field: T:25.9-40.9C, RH: 43.4-93.8%, PM$_{2.5}$: 3.9-30.1ug/m$^3$
Monitoring Strategy

• **AS-LUNG-outdoor (AS-LUNG(O))**, a PM$_{2.5}$ sensor device with a solar panel and water-proof housing, was used for this work.
  – PM$_1$, PM$_{2.5}$, CO$_2$, temperature, and relative humidity with 1-min resolution
  – Wireless transmission plus SD-card to avoid data loss

• **10 AS-LUNG(O) devices** were placed at 2.5 meters above ground in Taiwanese communities to assess source contribution

• **one AS-LUNG(O) at 10 meters** above ground to assess ambient levels (high-level site)

• **July 1-28 and December 1-31, 2017**

• **evaluated against GRIMM in the laboratory and fields**; the measurements were converted accordingly
■ This community is in the center of Taiwan island. *Within 1 km²*
■ Site C-1 to C-10 (street side) and H (high-level) are community sites where AS-LUNG(O) sensors set-up
■ AS-LUNG(O) usually *3-5 meters* from one or two community sources (traffic, vendor, temple, store, etc)
Temporal variation of PM$_{2.5}$ in one community site (5-min averages)
<table>
<thead>
<tr>
<th>Date</th>
<th>High-level</th>
<th>C1 – C10</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>17.5±8.6</td>
<td>18.0±9.3</td>
</tr>
<tr>
<td>December</td>
<td>29.3±10.8</td>
<td>37.4±17.3</td>
</tr>
</tbody>
</table>

Note: data were 5-min means
hourly PM$_{2.5}$ levels at street sites compared to those at high-level site

- **Summer:** ratio means among different sites were 1.04-1.27
- **Winter:** ratio means among different sites were 1.07-1.62
5-min PM$_{2.5}$ at street sites compared to the 5-min at high-level site

Summer: ratio means among different sites were 1.05-1.29, with a 5-min maximum of 35.5

Winter: ratio means among different sites were 1.08-1.63 with a 5-min maximum of 21.6

Moreover, the highest 1-min level at a site near vendors and traffic was 100 times of that at the high-level site
5-min PM$_{2.5}$ at street sites compared to those at background street site

- **Summer:** ratio means among different sites were 1.10-1.38 with a 5-min maximum of 44.6
- **Winter:** ratio means among different sites were 1.06-1.51 with a 5-min maximum of 19.5
### PM$_{2.5}$ Increments from Community Sources
(regression with dummy variables, adj. $R^2=0.75$)

| Variable                        | Estimate (ug/m$^3$) | Std. Error | Pr(|t|)   |
|---------------------------------|---------------------|------------|----------|
| Intercept                       | 12.8                | 0.333      | <2e-16   |
| H_PM$_{2.5}$ (high-level)       | 1.22                | 0.003      | <2e-16   |
| Wind Speed                      | 0.13                | 0.073      | 0.0757   |
| temperature                     | -0.41               | 0.006      | <2e-16   |
| RH                              | -0.09               | 0.003      | <2e-16   |
| School                          | 1.83                | 0.132      | <2e-16   |
| Vehicle (wide street)           | 1.72                | 0.119      | <2e-16   |
| **Vehicle (narrow street)**     | **3.98**            | **0.135**  | **<2e-16** |
| **Store**                       | **4.49**            | **0.124**  | **<2e-16** |
| Gas Station                     | 2.12                | 0.121      | <2e-16   |
| **Temple**                      | **2.67**            | **0.111**  | **<2e-16** |
| Vendor (Fried Chicken)          | 1.64                | 0.175      | <2e-16   |
Take Home Messages

• Our results showed the applicability of AS-LUNG (O) in the field and significant contribution from community PM$_{2.5}$ sources

• Potential applications of low-cost PM sensors:
  – For residents to take actions to prevent exposure and health risks
  – For government agencies to formulate control strategies to reduce personal exposure levels