2019 Advanced Institute on Health Investigation
and Air Sensing for Asian Pollution (AI on Hi-ASAP)
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Community Source Identification

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Objectives of Community Monitoring in Hi-ASAP

- (1) applying low-cost sensing devices to assess ambient $PM_{2.5}$ levels for comparison with exposure levels
- (2) applying low-cost sensing devices in communities to quantify community/local source contribution

Background for Hi-ASAP

- Taking advantages of high spatiotemporal resolutions of new low-cost $PM_{2.5}$ sensors to answer the following questions:

- Prerequisites: sensors providing research-grade data
- Community sources (restaurants, temples, traffic within communities, home factories, biomass burning, garbage burning, etc)
  - $PM_{2.5}$ increments due to community sources? Unknown sources?

Required Tasks in Community Monitoring in Hi-ASAP

- at least one environmental sensor should be set-up to assess $PM_{2.5}$ levels in the ambient environment close to (within 10km radius) the subjects' community. It is crucial for later data analysis for exposure and health evaluation for the above objective (1)
- Measurements from a sensor set-up at a 10-meter height location or at a ground location without obvious $PM_{2.5}$ source can be used as reference sites for comparison

Community Culture-related Air-Pollutant Sources in Asian Cities

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

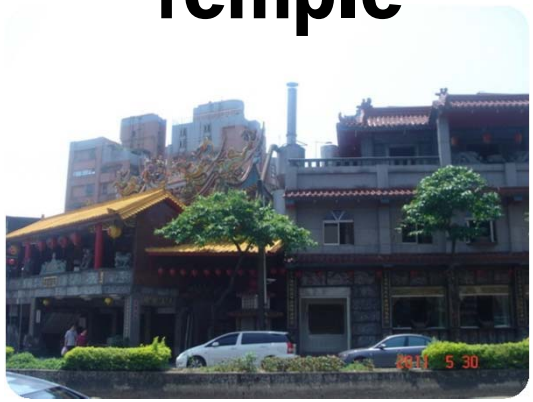
VOCs PAHs

NO_2 SO_2 many others

Asian style restaurant

Traffic

Temple



Night market

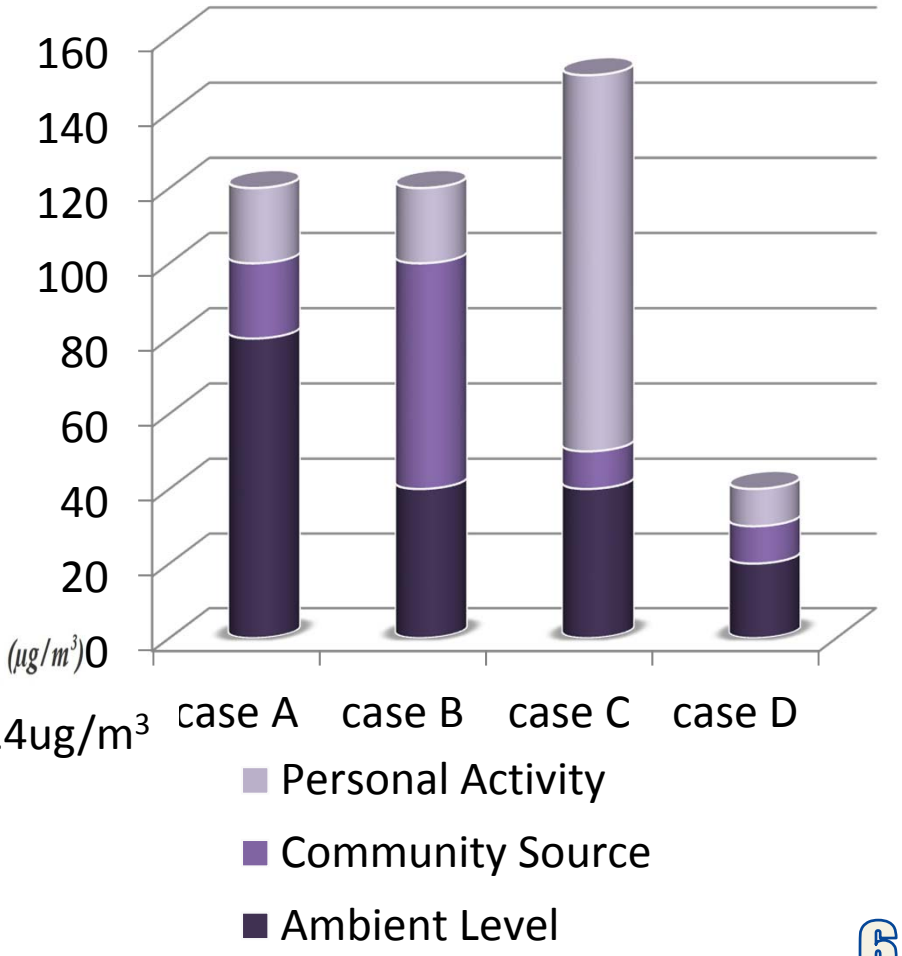
Hair salon

Car salon

Spatial Variability of $PM_{2.5}$ levels within a Taiwanese community

With GRIMM instrument

Exposure Level =**Ambient** level
+ **Community source** contribution
+ **Personal activity** contribution



[Candice LUNG, 2014]

Community Culture-related $PM_{2.5}$ Sources in Asia

Different Vehicles in Asia

(Cambodia, Sri Lanka, the Philippines)

Street Vendors in Asia

(China, Sri Lanka, Thailand)

Other sources:

rice-straw burning, garbage open-burning, etc.

Variability of intra-urban exposure
to particulate matter and CO
from Asian-type community pollution sources

[Lung et al., Atmospheric Environment, 83:6-13, 2014]

- Study aims:
  - assess the actual PM and CO levels and variability within Taiwanese communities
  - evaluate the contribution of various community pollution sources to community PM and CO levels

Fig.1: Local store

Fig.2: Background

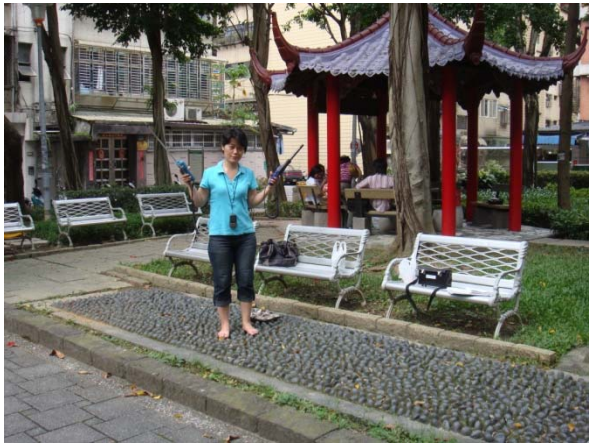


Fig.3: Traffic

Fig.4: Restaurant

Fig.5: Temple

Fig.6: Construction site

Table 3 Coefficient estimates of PM and CO in final multiple regression models

	PM_1 (μg/m^3)	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)	CO (ppm)
Intercept	5.10 (2.67)$^+$	4.81 (3.14)	6.46 (5.86)	3.11 (0.34)***
Background	0.99 (0.061)***	1.06 (0.066)***	1.22 (0.10)***	0.29 (0.057)***
Restaurant	6.18 (2.17)*	6.33 (2.46)*	7.27 (3.90)$^+$	1.64 (0.29)***
Temple	13.2 (3.09)***	15.1 (3.50)***	17.2 (5.54)*	-0.17 (0.40)
Construction	0.93 (3.10)	1.69 (3.52)	14.2 (5.59)*	0.48 (0.45)
Factory	2.45 (3.43)	2.82 (3.89)	5.90 (6.17)	-0.030 (0.45)
Store	1.39 (2.08)	1.74 (2.35)	3.10 (3.72)	-0.66 (0.28)*
Traffic	4.93 (2.78)$^+$	5.26 (3.15)$^+$	7.41 (5.00)	0.31 (0.37)
Vehicle/min	-0.10 (0.062)	-0.12 (0.071)$^+$	-0.20 (0.11)$^+$	0.026 (0.0079)*
Wind Speed	-6.63 (2.34)*	-7.27 (2.65)*	-16.8 (4.18)***	-1.26***
Adjusted R^2	0.60	0.60	0.47	0.26
N	237	237	237	288

$^+$: 0.05<p<0.1, *: 0.001<p<0.05, **: 0.0001<p<0.001, ***: p<0.0001

Summary of a series of community campaigns in Taiwan with GRIMM instrument

Table: $PM_{2.5}$ difference between ground and high levels in communities

Characteristics of communities	**Ground level-high level $\mu g/m^3$**	**Correlation coefficient of $PM_{2.5}$ in ground level and high level**	**Main exposure source to humans**
Very Few pollution sources	-2.3~ -5.7	r = 0.75~0.98	Ambient environment (long-range transport or far-away factories)
Only traffic source	3.7 ~ 4.3	r = 0.78~0.8	Ambient environment + traffic
Complicated and mixed sources (traffic, restaurants, temples and construction sites)	8.8 ~ 9.5	r = 0.24~0.43	Ambient environment + community sources

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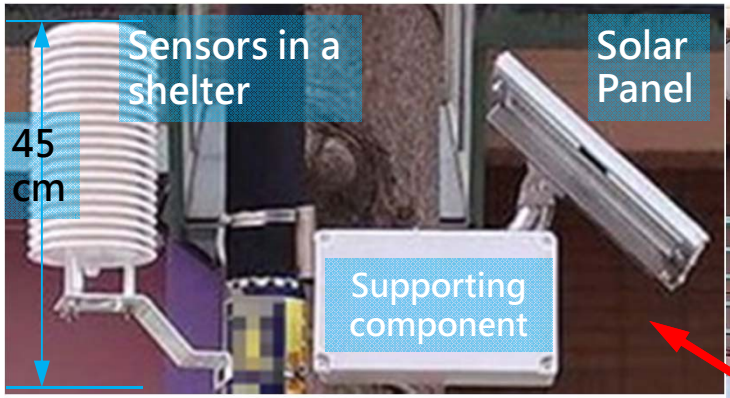
Application of PM sensors in assessing ambient and community levels

■High-level monitoring system
■Central site (sensors and other instruments)

■Street-level monitoring system (AS-LUNG-O)



- Research-grade
- Water-proof
- Wireless transmission
- High time resolution
- $PM_{2.5}$, Temperature, RH% and CO_2
- Less than US$700 per set
- In the future, other chemical sensors can be deployed

Monitoring Strategy for Hi-ASAP (1)

- Select one central site at a location higher than 10 meters above ground (high level) and another location at street level without any near-by sources (street-level background site) for ambient $PM_{2.5}$ levels (not near any sources)
  - locations have to be within 10km radius of the subjects' community
  - definition of a "community"
  - data will be compared with those from monitoring sites near the sources
- Select monitoring sites near the targeted community sources
  - the availability of the sensors and your monitoring strategy determine the number of the monitoring sites
- Set-up sensing devices about 3-5 meters from the sources in light poles or any fixed structures
  - Apply for permits
- If you set up sensing devices close to two sources, you need to collect more information about the source activities to differentiate their contributions

Monitoring Strategy for Hi-ASAP (2)

- Prepare for long-term monitoring (one month, one year or longer)
  - Power supply: solar panels (enough sunlight), batteries, or sockets
  - Advantages: (1) quantify source emission on $PM_{2.5}$ for the overall emission with diurnal, weekly, monthly, and seasonal variations; (2) be able to catch the irregular source emissions; (3) collect large sample size
  - Disadvantages: require manpower and resources for routine checking and maintenance
- Prepare for short-term monitoring (ex. 3 days or one week)
  - Record the activities of those targeted sources
    - Traffic counts for different types of vehicles for traffic emission
    - Active burning activities for cooking, temple, biomass burning, garbage burning, and other emission sources
  - Advantages: (1) detailed activity records (on, off, or different types of emissions) to quantify the contribution of source emissions on $PM_{2.5}$; (2) intensive manpower needed for a short time
  - Disadvantages: (1) need good luck to catch the irregular emission; (2) small sample sizes

Monitoring Strategy for Hi-ASAP (3)

- Need to check on data regularly
  - Check every day (wireless) or download data every week or every month (SD cards)
  - Zeros? Numbers too high? Ghost peaks?
- Convert observations to research-grade data based on side-by-side comparison with research instruments such as GRIMM or nearby EPA monitoring stations
- Average observations (1-min resolution) to 5-min means for data analysis
- Maintain sensing devices with regular cleaning and annual evaluation

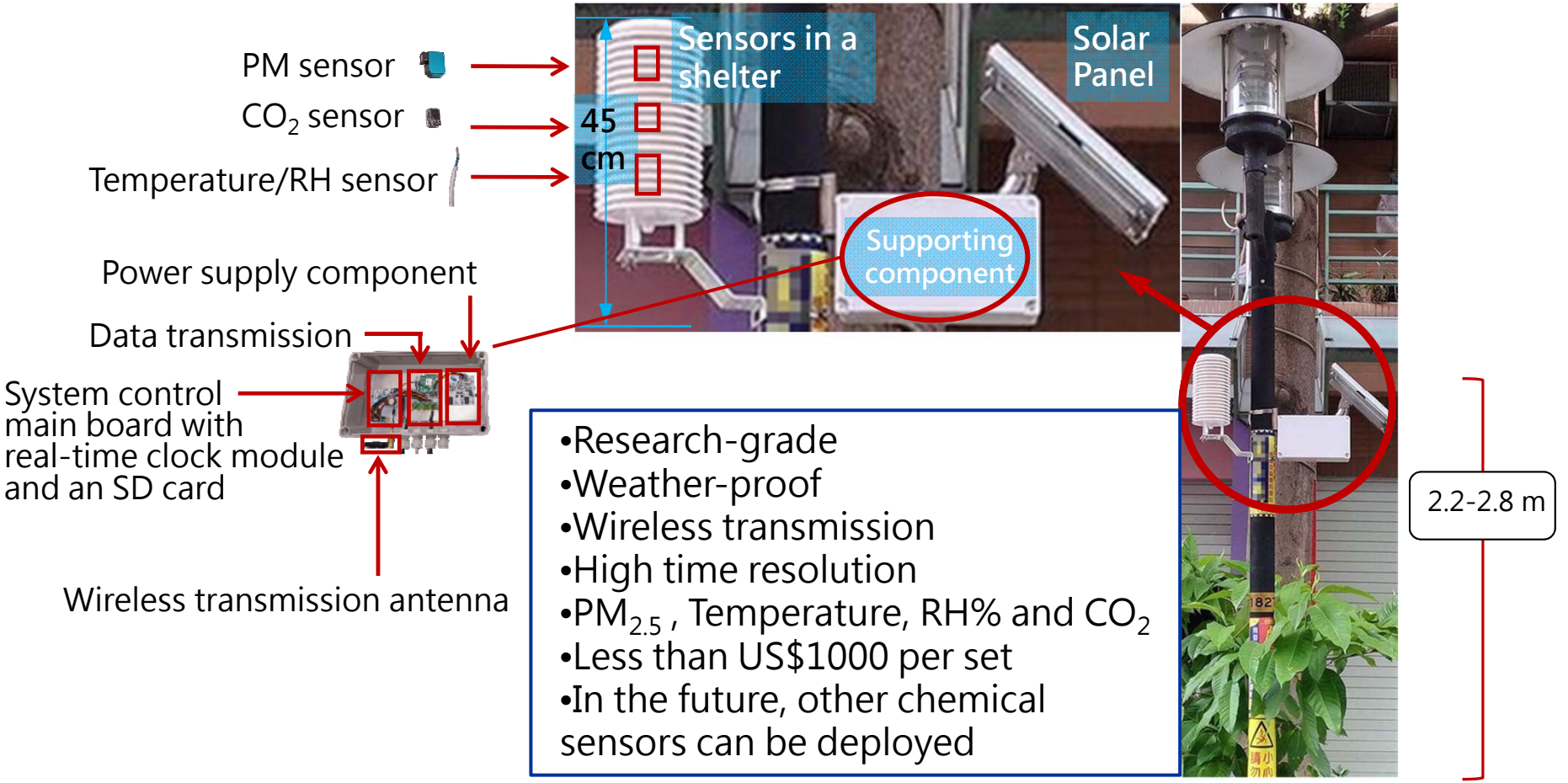
Case Study with AS-LUNG-O
(manuscript under review)

- Motivation: (1) Higher intra-urban variability in Asian residential communities than those in western countries
  - various $PM_{2.5}$ sources, such as restaurants and home factories
- (2) High exposure levels to residents due to community sources

- Objectives:
  - to quantify $PM_{2.5}$ contributions from the community sources

Set-up of AS-LUNG-O for $PM_{2.5}$ Community Source Quantification

■Street-level monitoring system (solar panel facing the south)

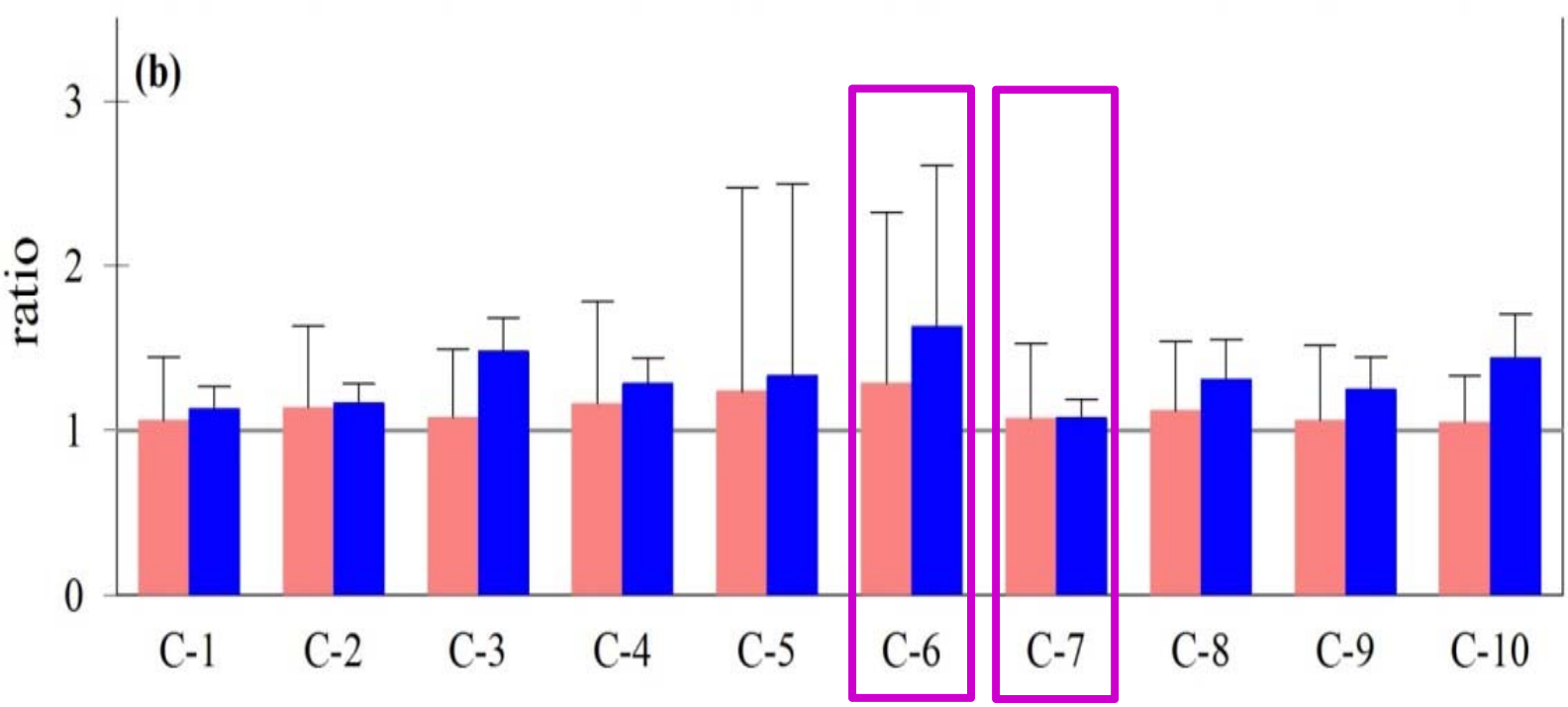


- Research-grade
- Weather-proof
- Wireless transmission
- High time resolution
- $PM_{2.5}$, Temperature, RH% and CO_2
- Less than US$1000 per set
- In the future, other chemical sensors can be deployed

Monitoring Strategy

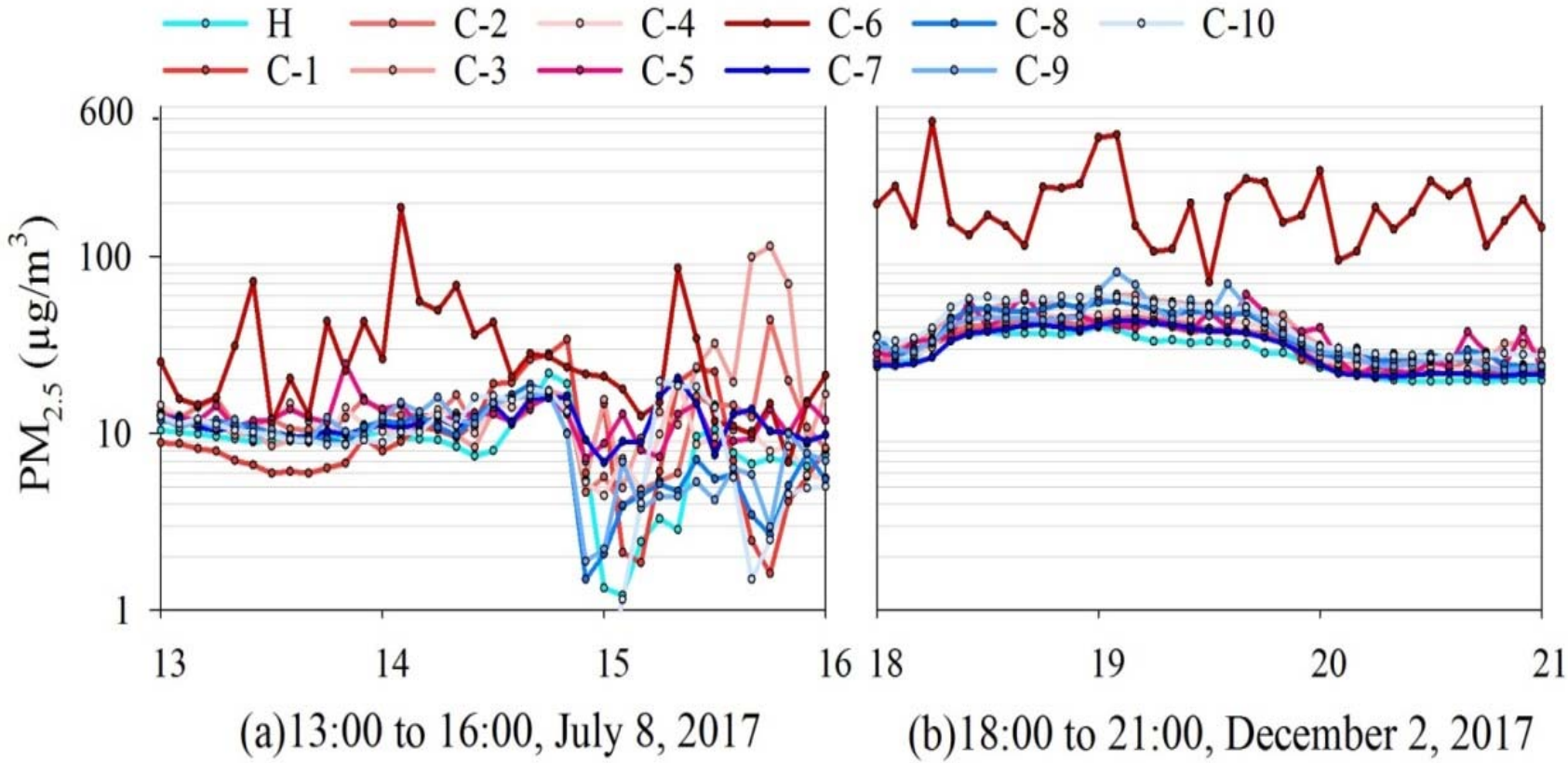
- 10 AS-LUNG-O devices were placed at 2.5 meters above ground near certain community sources
  - PM_1, $PM_{2.5}$, CO_2, temperature, and relative humidity with 1-min resolution
  - Wireless transmission plus SD-card to avoid data loss
- One AS-LUNG(O) at 10 meters above ground to assess ambient levels (high-level site)
- July 1-28 and December 1-31, 2017
- Data were converted to GRIMM comparable measurements with 1-min resolution
- 5-min averages used for data analysis

Date	High-level	C1 – C10
July	**17.5±8.6**	**18.0±9.3**
December	**29.3±10.8**	**37.4±17.3**



Note: ratio: 5-min community levels/ 5-min high levels;
Summer: 1.05-1.29 (max: 35.5); Winter: 1.08-1.63 (max: 21.6)
C7: street-level background site

Tempo-spatial variation of $PM_{2.5}$ at community sites (5-min averages)



$PM_{2.5}$ Increments from Community Sources with Multiple Regression

Variable	Coefficient Estimate[a] ($\mu g/m^3$)	Std. Error	Partial R^2
Intercept (street-background)[b]	-1.718	1.161	0.543
High-level site	1.205	0.005	
Season	5.377	0.280	0.016
Temple	2.724	0.156	0.006
Market	3.904	0.173	0.004
Traffic with passing-by vehicles	3.307	0.168	0.001
Stop-and-go traffic	4.384	0.191	0.002
Wind speed	-1.001	0.084	0.001
School	1.566	0.188	0.0003
Vendor (fried chicken)	1.796	0.249	0.0002
Gas station	0.739	0.172	0.0001
Relative humidity	-0.027	0.007	0.00002
Temperature	-0.090	0.025	0.00006

a: most of estimates with significant level $p<0.0001$, except b: insignificant

Summary and Recommendations

- Applications of sensors in environmental health researches
  - complementary to the regular samplers and expensive monitors
  - combined with chemical analysis: EC/OC, sulfate, nitrate, PAHs, organic acids, etc.
- Issues using low-cost sensors
  - Side-by-side comparison with research-grade instruments to obtain correction equations (accuracy adjustment)
  - Data Transmission
  - Stability
  - Maintenance (power supply, cleaning)

Other Consideration for Hi-ASAP

- Take photos for the targeted sources (ex. different types of activities), the sensing devices, and the surrounding environments for result explanation and presentations
- Write down any suspicious activities and environmental conditions in order to explain your data afterwards
- Better to have access to meteorological measurements (ex. T, RH%, wind speed, wind direction, and rain) from the nearby weather agencies; if not available, record any raining days which may need to be excluded from the datasets
- Access to EPA data for comparison (ex. convert EPA data to GRIMM-comparable data)
- Insurance for the sensing devices
  - depends on the decisions of individual research groups
  - in case the devices harm people (ex. under Typhoon)
- Do not offend the neighbors

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Thank you very much for your attention!

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