2019 Advanced Institute on Health Investigation
and Air Sensing for Asian Pollution (AI on Hi-ASAP)
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Exposure Assessment

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Exposure Assessment

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Definition of Exposure

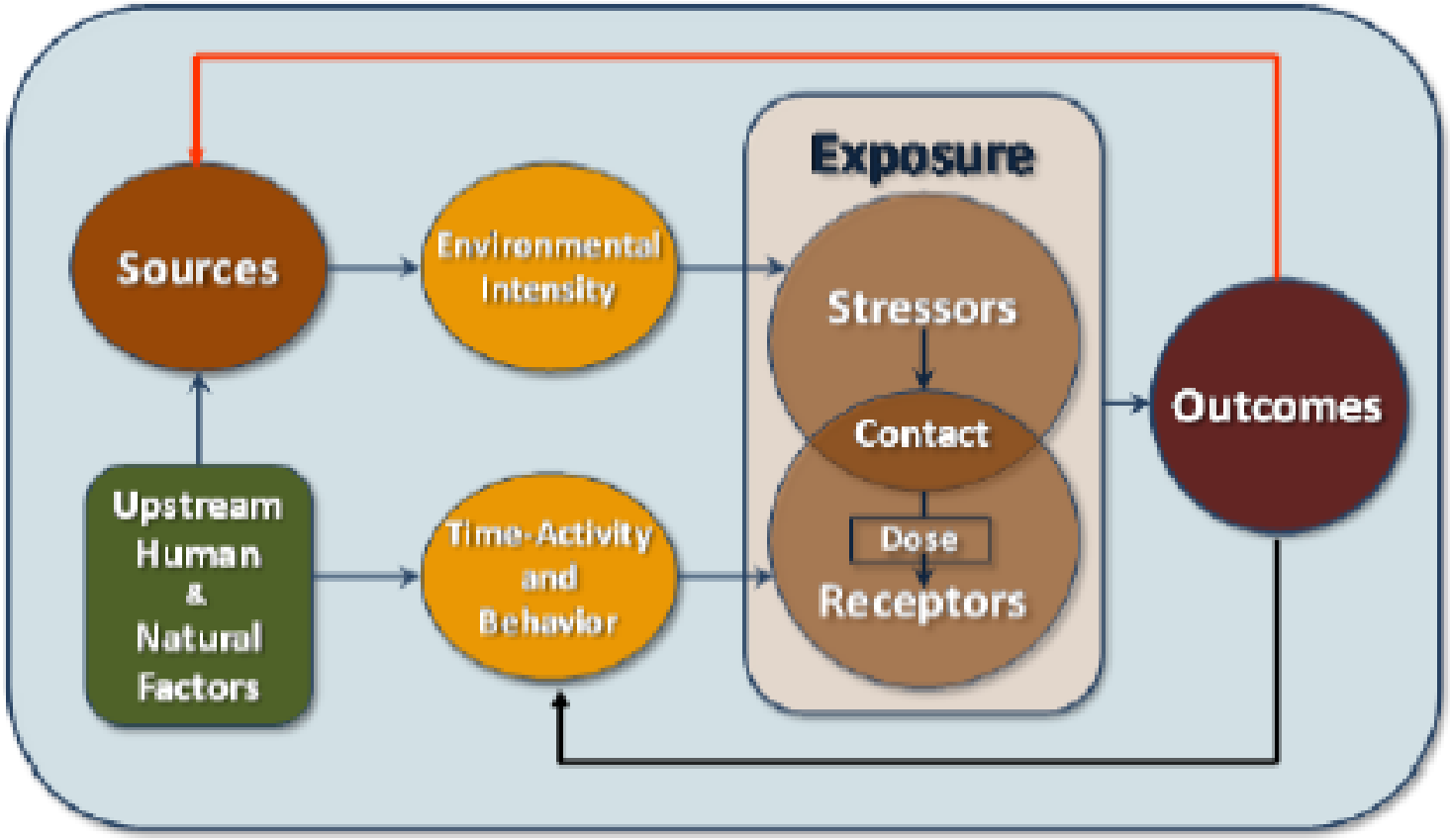
- Contact of a biological receptor with chemical/physical agent (including biologically generated agent)

- Exposure assessment: Determining how an environmental pollutant comes into contact with the human body
  - Route (inhalation for air pollutants)
  - Magnitude (exposure concentrations)
  - Frequency (contact frequency)
  - Duration (exposure duration)

Exposure Assessment

Assessment and Control

New Framework of Exposure Science



Exposure Science in the 21st Century, 2012

왜 공간과 시간이 중요할까?

VOCs

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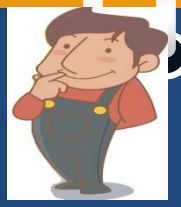
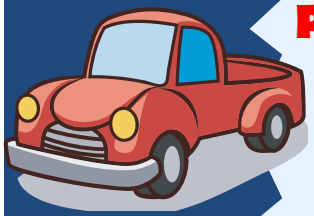
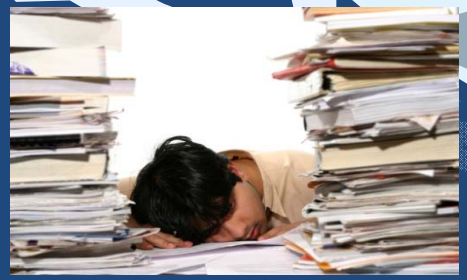


NO_2

VOCs

PM

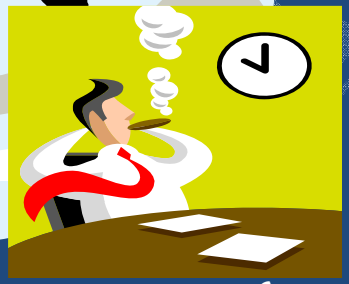




HCHO

PM

PM



Purpose of Exposure Assessment

- **Protect population from risk to certain pollution**
- Examine long-term effects of emission control strategies on the exposure to a contaminant in the general population
- Provide information on exposure magnitude and variance in order to plan and design additional studies
- Compare exposure levels between various groups of a population
- Identify high-risk groups
- And more..

Exposure equation

$$E = C \cdot T$$

- E = Exposure
- C = Concentration
- T = Exposure time

Exposure is associated with **concentration** in exposure media and the **time** subject spay in the media

In Hi-ASAP, "exposure concentration" is C in the above equation, T can be obtained from time-activity diary (TADs). If you want to calculate total exposure (E), both C and T is needed

In the current exposure-health evaluation, exposure concentration (C) is used rather than E because 5-min exposure concentration is matched with 5-min HRV indicators

Objectives of Exposure Assessment in Hi-ASAP

- To apply $PM_{2.5}$ LCS devices to assess close-to-reality $PM_{2.5}$ exposure levels of defined groups, to characterize activity patterns, behaviors, and sources associated with short-term or peak $PM_{2.5}$ exposures, and to determine the damage coefficients of exposure-health relationship

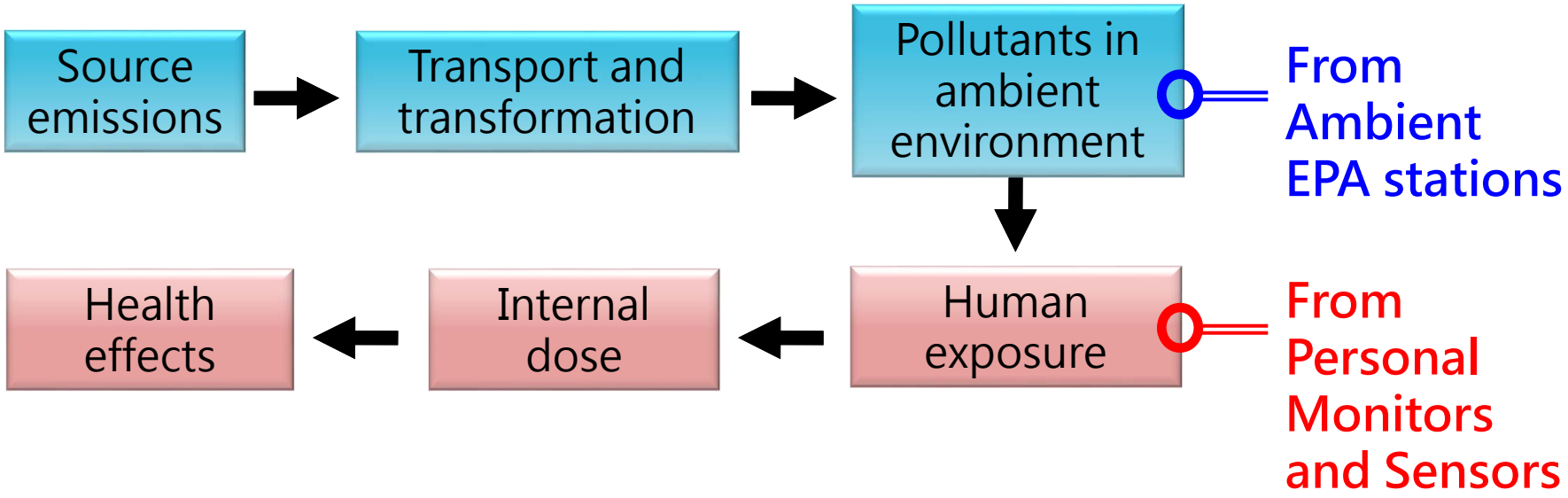
Background for Hi-ASAP (1)

- Newly developed light-weight LCS devices can be applied to understand the temporal and spatial variations of $PM_{2.5}$ exposure levels in the breathing zones in fine resolution and to assess contribution of various exposure sources (and/or behaviors) (such as traffic emission, cooking, and others). In addition, these LCS devices can be used in household indoor/outdoor monitoring and to characterize important indoor sources
- assess controllable factors is important so that useful recommendations can be provided to policy makers to formulate effective strategies for source reduction or behavior changes in order to take proactive actions to reduce health risks
  - "Behavior change to reduce health risks" is a powerful way of communication to the general public for health risk reduction of $PM_{2.5}$ and further air quality improvement. In order to do so, time-activity diary and questionnaires filled by the recruited subjects are required in this activity

Background for Hi-ASAP (2)

- Personal LCS $PM_{2.5}$ devices will be used
- The type of $PM_{2.5}$ sensor used is not limited to AS-LUNG; any type with good quality could be applied
- Sensor evaluation shall be conducted prior to application
- QA/QC data needs to be transparent and shared among participating team members
  - QA/QC results of AS-LUNG-portable (AS-LUNG-P) and other potential sensors for personal exposure assessment should be presented before the end of 2019 for the Hi-ASAP team

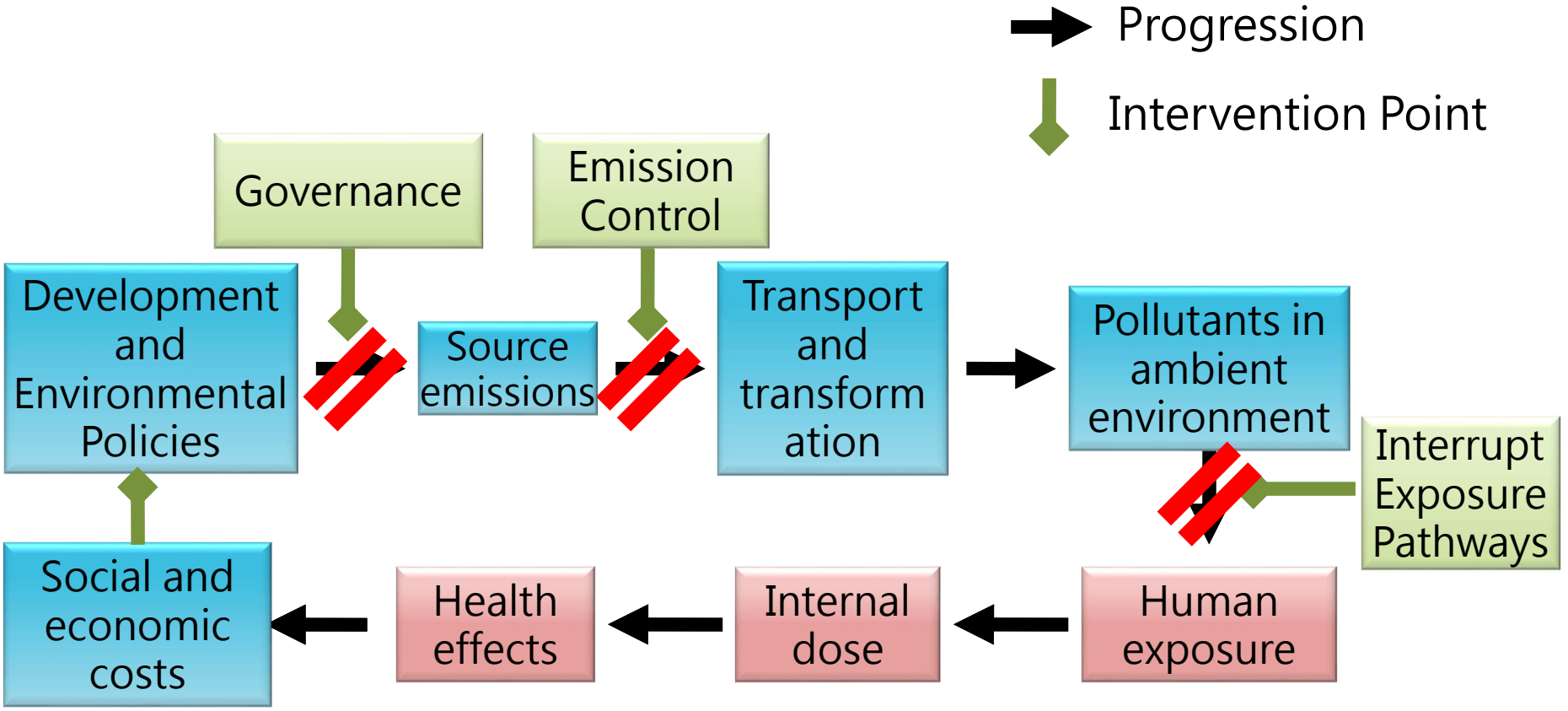
Progression of Pollutants from Emissions to Health Effects



Why is " $PM_{2.5}$ exposure concentration" important?

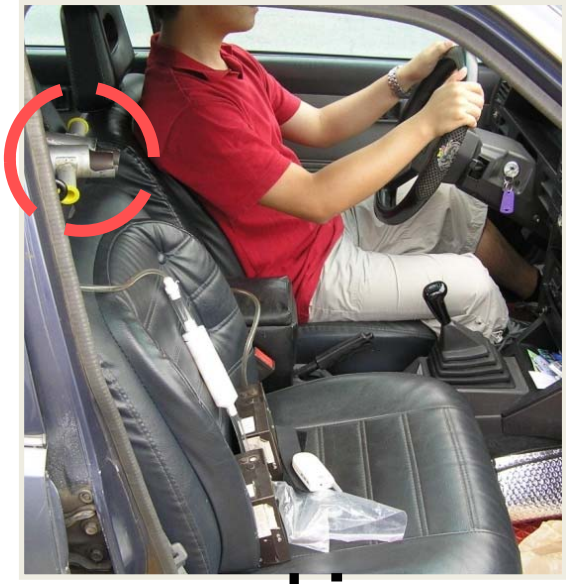
- More accurate estimates for exposure, more accurate estimates for damage coefficients of exposure-health relationships
  - 17% increase in all-cause mortality when more spatially resolved exposure estimates were used for a LA subgroup of the American Cancer Society population (Jerrett et al., 2005) compared with 4% increase in an earlier study for 10ug/m^3 increase in $PM_{2.5}$ for ACS population (Pope III et al., 2002)
- People are directly exposed to freshly emitted aerosols with different physio-chemical properties compared to ambient aerosols
- Peak exposures, which may induce asthmatic attacks and other health effects, are much higher than ambient levels

Solution-oriented Research:
Identify potential intervention points to reduce health impacts of air pollution



worshipper in temple

worshipper in parade

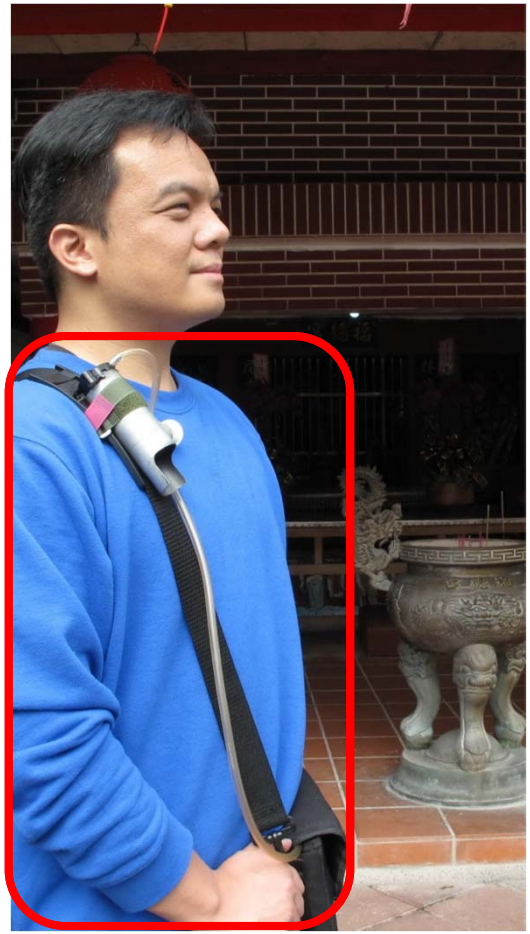


car driver

motorcyclist

subway rider

Light-weight Sampling, Monitoring, and Sensing Devices for $PM_{2.5}$ Exposure and Health Research



Before year 2000
Personal PM sampler (PEM) with a pump weight 2kg

After year 2000
GRIMM real-time PM monitor

Year of 2017 Wearable PM sensor. Less than 200g with GPS and wifi

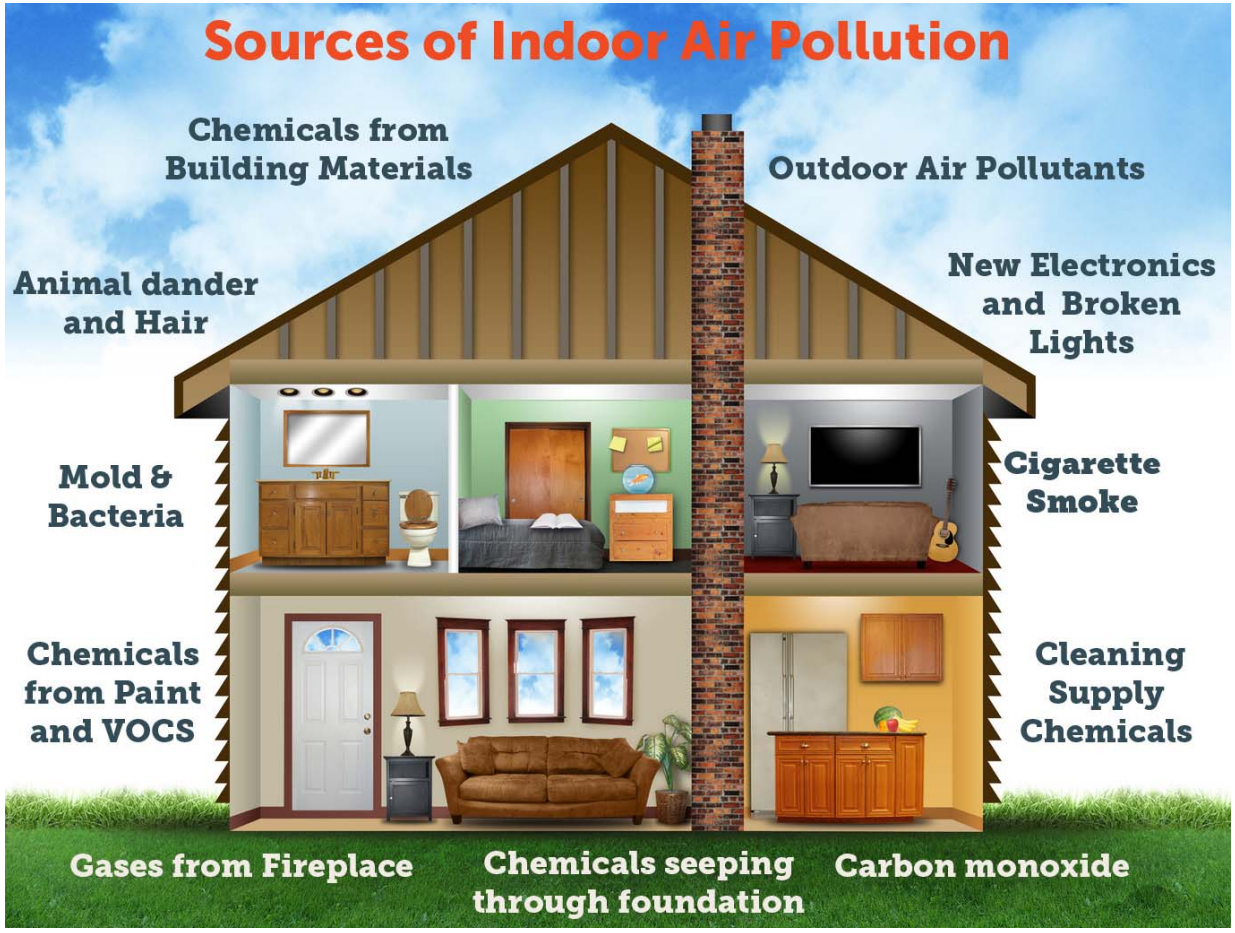
Sources of daily Air Pollution exposure

Indoor Sources

- People stay indoors 80-90% of times

PM Indoor Source

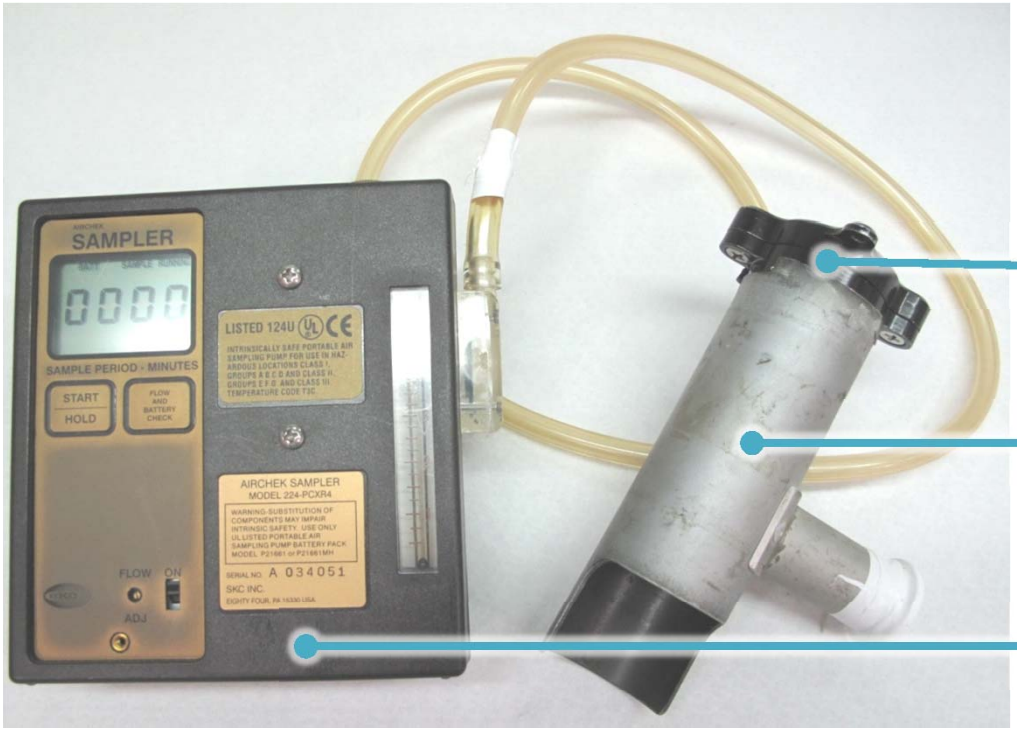
- Smoking
- Cooking
- Incense-burning
- Burning activities
- Humans
- others



PM from outdoors

http://www.aee-inc.com/indoor-air-quality-testing.php

light-weight personal **PM2.5 Sampler**



PEM
- Personal Environmental Monitors
- SKC 761-203
- 37 mm Teflon filter

Elutriator
- Avoid wind interfering
- Carbon-filled Teflon surface to prevent static effect

Pump
- Portable with battery
- Flow rate: 4 L/min

- Subjects wear this sampling package for 24-hour to assess daily exposure
- 2-kg weight with low-level noise and vibration
- Need micro-balance with readability of 1 ug
- Filters can be analyzed for chemical compositions

Residents' Particle Exposures in Six Different Communities in Taiwan

[**Lung** et al., Science of the Total Environment, 2007]

- Objectives: PM exposure levels and exposure factors
- Sampling strategy: 55 subjects in Six communities with personal, home indoor, home outdoor sampling and time-activity diaries (TAD) for 24 hours from Taipei, Taichung, and Kaohsiung
- Findings: roughly 20ug/m^3 higher PM exposure if the subjects spent more time outdoors, rode motorcycles, burned incenses, stayed in kitchen, or passed community factories

Studied Communities

- two communities were selected from Taipei (northern Taiwan, N), Taichung (central Taiwan, C), and Kaohsiung (southern Taiwan, S)
  - NM and NR in Taipei
  - CC and CM in Taichung
  - SM and SI in Kaohsiung

- these six communities represented residential (R), commercial (C), mixed (M), and industrial (I) types
- six to ten non-smokers in each community, totally 55 subjects

Personal sampling

- Wore personal sampler for 24-hr
- Questionnaire: basic info
- Time-activity diaries (TAD)
  - locations, main activities, pollution sources, and ventilation conditions
- Indoor sampling: each subject's living room
- Outdoor sampling: outside the window or on the outdoor balcony

Questionnaire B – Time-Activity Diary

Date: [continental time]:20 / / (yyyy/mm/dd)

Name:

Weather: □Sunny □Cloudy □Rainy □Windy

Items / Time (hhmin)	A. Location	B. Ventilation status	C. Activity type		D. Air quality		
			Activity 1	Activity 2	Source 1	Source 2	Weather
1800-1830	18	9	8	6	3	sticky tofu	S, W
Please set your watch first and then write down your time-activity information below !							

【Part A:selection card】

[Vehicles]

9. Bike, electric scooter
10. Motorcycle, electric locomotive
11. Car, truck, taxi
12. Bus
13. Underground; tube; subway
14. Train
15. Farm, livestock oriented machine car
16. Walking, wheelchair
62. Other vehicles, please write down

[Outdoor] hall, road, outdoors, open ground

16. On the road(walking on the road, waiting for bus or traffic light)
17. Traditional market
18. Night market, fairgrounds, school carnival
19. Small market under ten vendors
20. Sports field (playgrounds, golf course, etc.)
21. Parks, Scenery spot, farm and other outdoor places
22. Home exteriors (balcony or loft)
23. Outdoor workplace
63. None of the above, please write down other outdoor locatio

PM_{10} levels from PEMs(ug/m^3)

		NM	NR	CC	CM	SM	SI	overall
personal	**N**	**8**	**8**	**8**	**9**	**8**	**6**	**47**
	mean	**48.5**	**91.1**	**68.7**	**129.7**	**85.8**	**98.2**	**87.4**
	SD	**26.2**	**28.9**	**21.6**	**51.8**	**33.0**	**37.0**	**42.2**
indoor	**N**	**8**	**8**	**6**	**9**	**8**	**6**	**45**
	mean	**53.6**	**67.0**	**88.9**	**86.3**	**83.6**	**107.9**	**79.8**
	SD	**18.7**	**25.1**	**63.5**	**24.5**	**24.0**	**26.9**	**34.4**
outdoor	**N**	**7**	**8**	**6**	**7**	**7**	**6**	**41**
	mean	**57.8**	**69.4**	**90.8**	**103.0**	**132.3**	**127.3**	**95.5**
	SD	**24.7**	**23.4**	**34.8**	**21.8**	**51.6**	**29.4**	**41.3**

The ambient PM_{10} from Taiwan EPA stations were from 37-98ug/m^3.

Current 24-hr PM10 standard is 125ug/m^3.

$PM_{2.5}$ Exposure levels in comparison

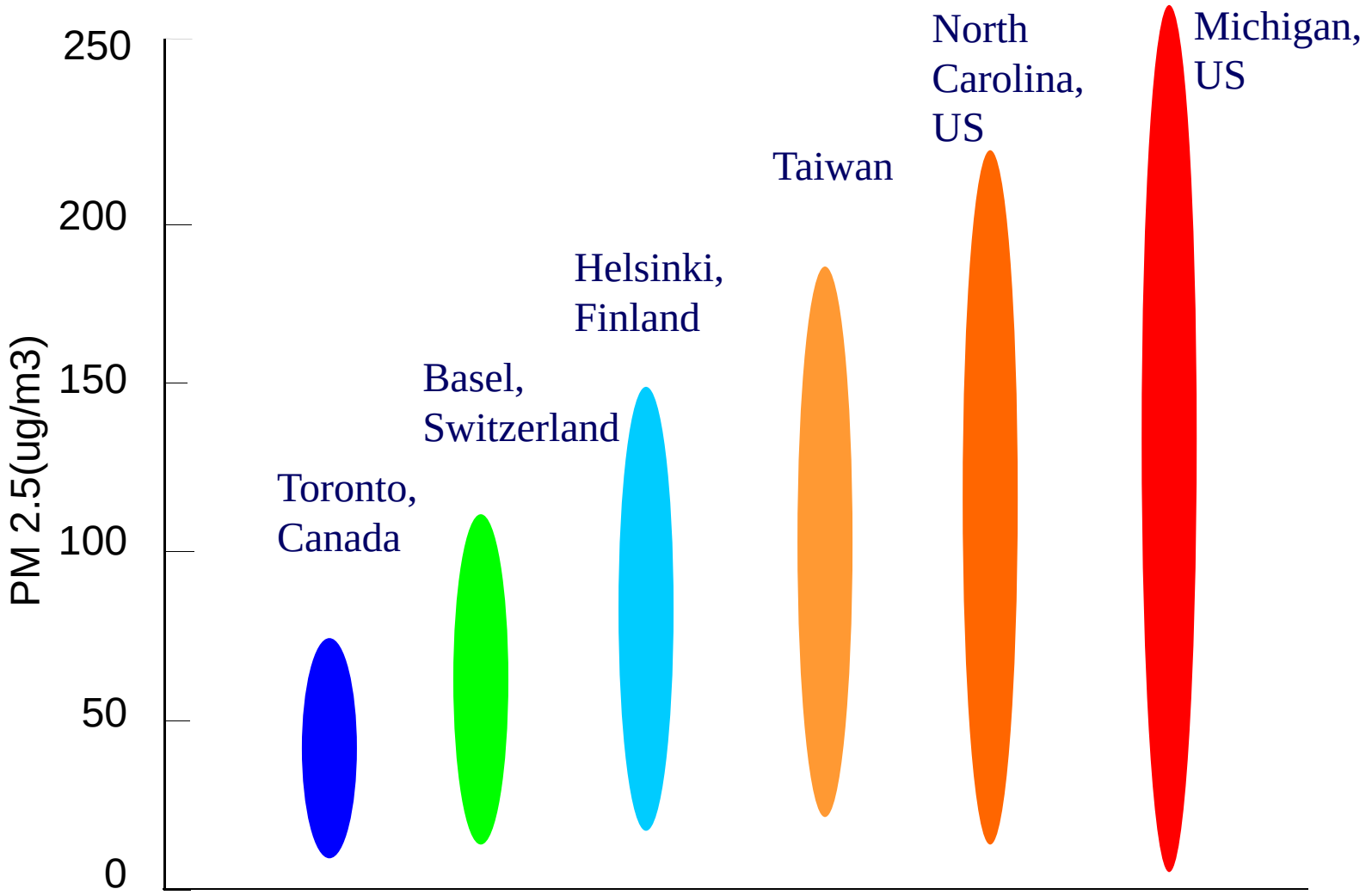
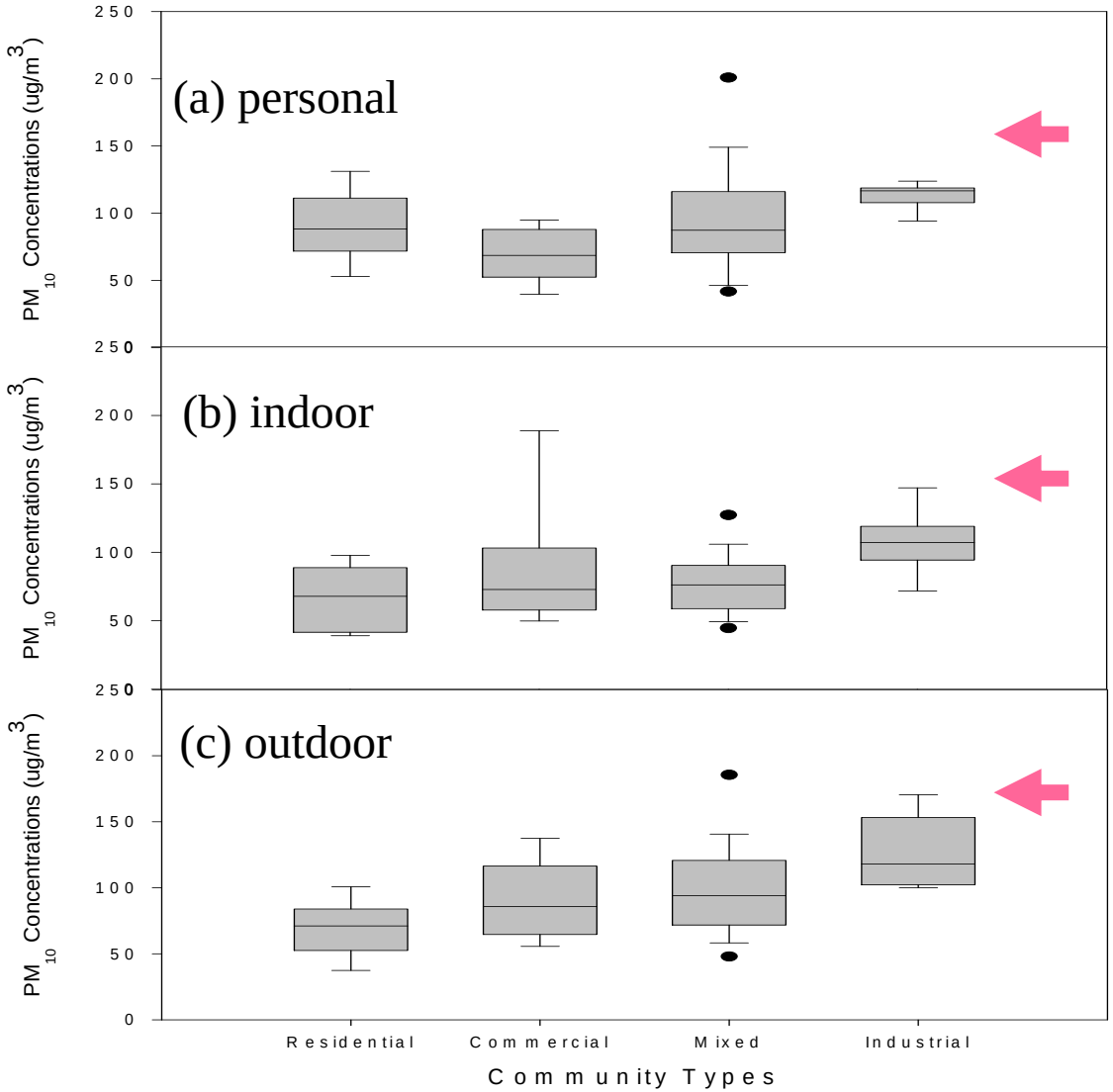


Figure 1: (a) personal, (b) indoor, and (c) outdoor PM_{10} levels ($\mu g/m^3$) among different community types



middle lines represent median values; dots represent the 5% and 95% percentiles

Table 6 Personal PM_{10} levels ($\mu g/m^3$) classified by different (a) locations (b) traffic-related activities and (c) pollution sources during the sampling day

(a) Locations		N	mean	SD
% time spent outdoors[1]*	<16%	24	72.7	48.9
	>16%	23	101.5	27.9
kitchen[2]*	no	22	73.1	36.4
	yes	25	100.1	43.5

(b) Traffic-related activity		N	mean	SD
time spent on transportation[1]†	<4 hour	24	75.9	28.0
	>4 hour	23	99.5	51.0
rode a motorcycle*	no	30	77.4	37.7
	yes	17	105.1	44.9

***: $p<0.05$, †: $0.05<p<0.1$, Wilcoxon rank sum test was used**

1: these variables were classified by the median values

2: two subjects reported cooking but did not select kitchen in the "location" since they did not have a separated kitchen

Table 6 (continued)

(c) Pollution source		N	mean	SD
cooking or in the kitchen[2†]	no	20	74.3	34.6
	yes	27	97.2	45.2
burning incense[†]	no	37	83.0	41.0
	yes	10	103.8	44.6
Passing by factories*	no	34	76.8	34.0
	yes	13	115.2	49.8
ETS exposure duration[1]	<0.5 hr	23	79.1	30.6
(Environmental Tobacco Smoke)	>0.5 hr	24	95.4	50.2

Table 8 Best-fit stepwise regression (R^2 = 0.54) for personal PM_{10} exposures ($\mu g/m^3$)

Variable	Parameter Estimate	Standard Error	*p* value
Intercept	**50.7**	**8.49**	**<.0001**
time spent on transportation (hr)	**3.15**	**1.05**	**0.0048**
passing by factories	**24.2**	**10.4**	**0.0255**
in the kitchen	**23.3**	**9.02**	**0.0142**
environmental tobacco exposure (hr)	**1.89**	**0.89**	**0.0412**

Note: the variables are ranked in the order of entering the regression model, passing by factories and being in the kitchen were dichotomous variables while the time spent on transportation and ETS exposure duration were continuous ones

Findings from Residents' Personal Exposure

- PM_{10} levels in home outdoors were 30-100% higher than EPA stations)
- 70% of household had higher outdoor levels than indoors, with 2-58% higher
- major personal exposure sources: commuting/cooking/second hand smoke/small factory/incense burning
- special culture habits and community settings deserve more investigation
- community sources affect spatial distribution of PM within communities

[龍世俊]

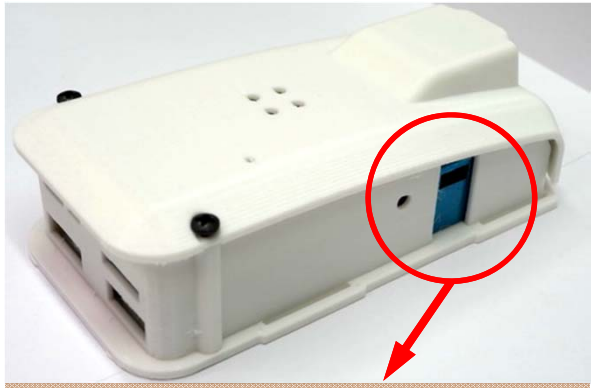
Summary and Recommendations

- **Personal**
indoor
outdoor PM levels $\geqq$ PM levels of **EPA monitoring stations**

- The major exposure factors were due to personal activities
- Exposure factors of culture-related activities and special living conditions in Taiwan need to be investigated

Customized research-grade $PM_{2.5}$ sensors ($PM_{2.5}$, CO_2, Temperature, and RH%)

■Personal version
(palm size, 4cm depth)



•PM2.5 inlet
•GPS, motion sensor, Wireless transmission, SD card

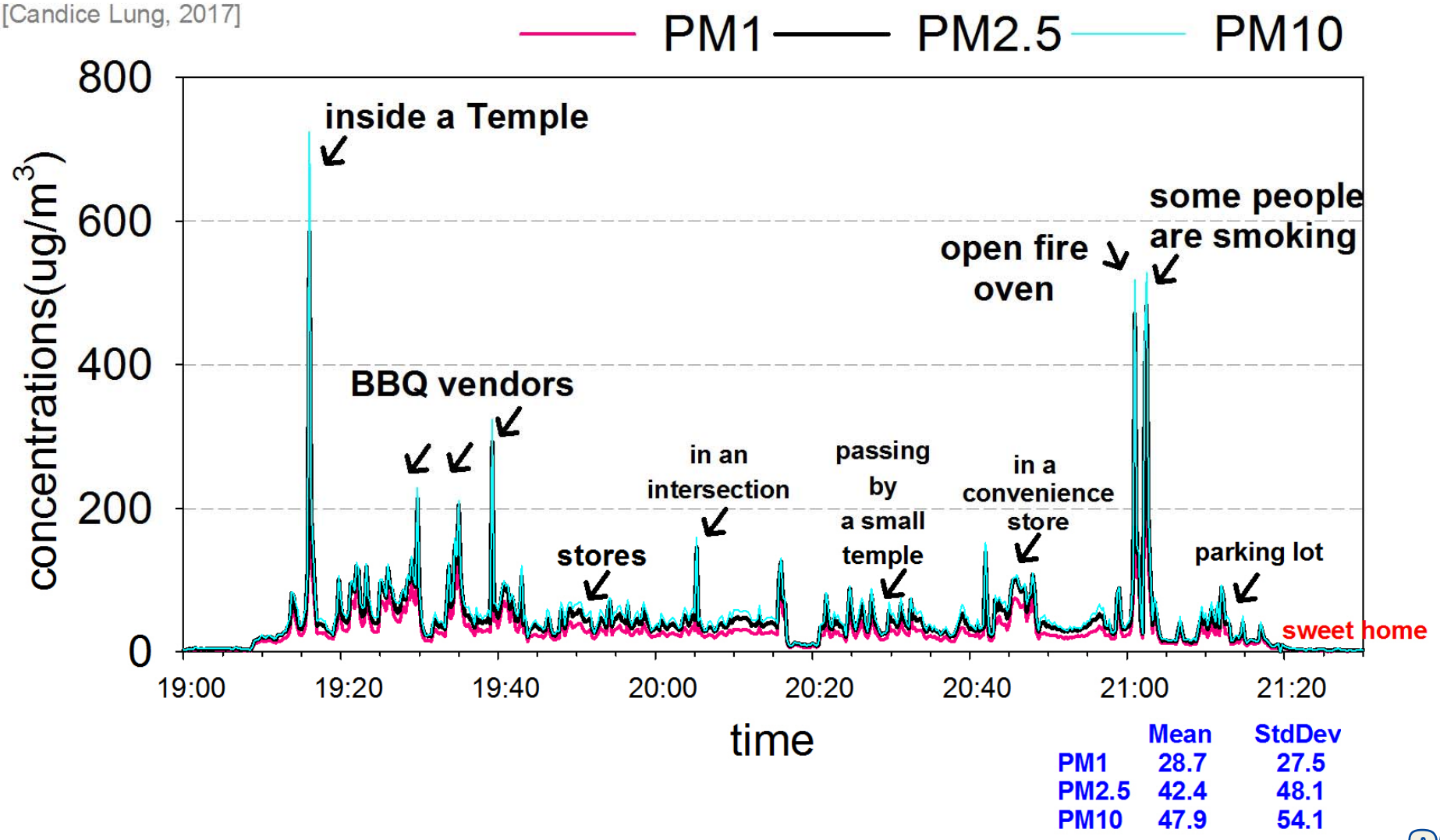
■Indoor version (LASS4U)
(palm size, 5cm depth)

•Wireless transmission

AS-LUNG
Academia Sinica.TAIWAN

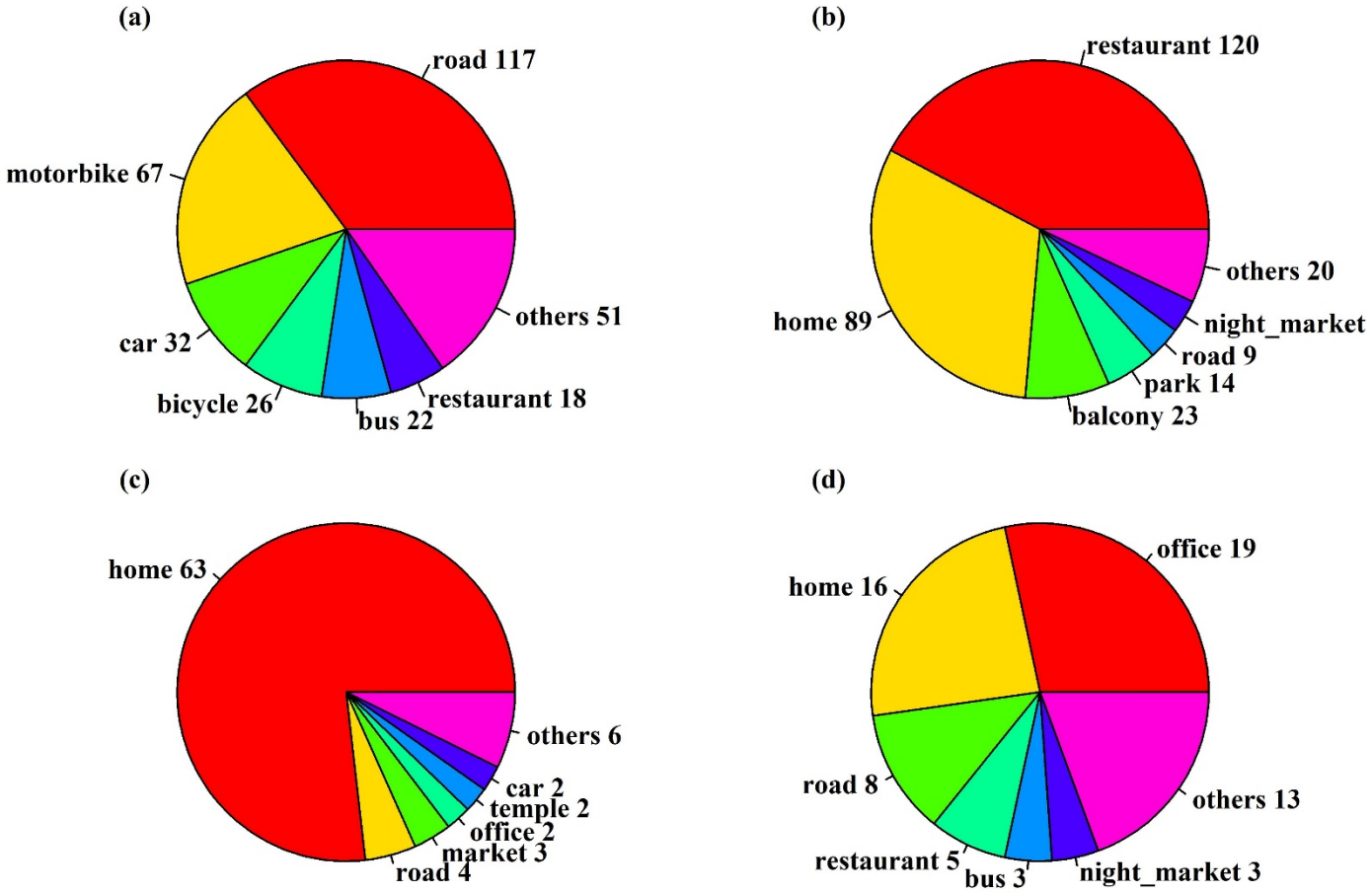
[Candice Lung, 2017]

July 4, 2017, Taipei night market
AS-LUNG sampling rate: every 15 seconds



	Mean	StdDev
PM1	28.7	27.5
PM2.5	42.4	48.1
PM10	47.9	54.1

The counted numbers of the exposure micro-environments based on the responses at 30-min intervals of time-activity diaries of 33 subjects indicating (a) vehicle emission (n=333), (b) cooking (n=284), (c) incense-burning (n=82), and (d) Environmental Tobacco Smoke (n=67)



Required Tasks in Exposure Assessment in Hi-ASAP

- to conduct personal $PM_{2.5}$ exposure assessment for 2-7 days (minimum 48 hours or working hours of two working days) on the same days when subjects undergo health investigation
- to ask subjects to fill out a time-activity diary (TADs) at 30-min intervals on the days of exposure-health investigation
- to provide indoor/outdoor and/or indoor/ambient ratios in each studied season
- Evaluations on exposure sources or indoor air quality are optional

Exposure Monitoring Strategy for Hi-ASAP (1)

- (a) Subject recruitment:
  - subjects are the same as those recruited for exposure-health relationship evaluation. The proposed subjects are non-smoking subjects in communities or from certain occupational groups without pre-existing heart diseases and asthma who will at least go out 1-2 hours (expected outdoor exposure sources: traffic, home factories, or opening fire) and perform cooking, incense-burning, mosquito-coil-burning or any type of combustion activity every day
- (b) Sensor wearing for exposure assessment
  - subjects will wear portable $PM_{2.5}$ LCS devices for 2-7 days (minimum requirement: 48-hour or working hours of two working days)
  - sensor measurements for heart-rate assessment and/or tests for lung condition evaluation should be conducted at the same days
  - subjects will be asked to fill out a questionnaire for personal characteristics as indicated in exposure-health evaluation

Exposure Monitoring Strategy for Hi-ASAP (2)

- (c) Fill out time-activity diary (TADs):
  - subjects will be asked to fill out time-activity diary at 30-min intervals for the places stayed, activities performed, and pollution sources encountered at the same days of wearing $PM_{2.5}$ LCS devices
- (d) Household indoor/outdoor monitoring:
  - Indoor/outdoor ratio is an important factor to explain exposure patterns, explore potential high-exposure activity, and provide policy-relevant recommendations
  - There are several options to conduct indoor/outdoor monitoring, please select one of them after considering resources and manpower required in each research group.
  - The ratio of indoor over outdoor levels (indoor/outdoor ratio) and/or indoor over environment/community sensor levels (indoor/ambient ratio) in each season are required inputs to the databases for international comparison

Exposure Monitoring Strategy for Hi-ASAP (3) Indoor/outdoor or indoor/ambient ratios

- Option 1:
  - $PM_{2.5}$ LCS devices will be set-up in the households of the subjects in their living rooms and outdoor microenvironments (ex. backyard, balcony, patio, etc) at the same days of exposure assessment (48-hour)
- Option 2:
  - Indoor/outdoor monitoring will be conducted when the questionnaire is conducted. When the research assistants ask questions to subjects at their homes, the research assistants can monitor indoor/outdoor environments by wearing $PM_{2.5}$ LCS devices
  - staying outdoors for 10-min before entering their homes, and measuring indoor when they stay inside, and staying outdoors for another 10-min when leaving their homes.
  - The time of staying outdoors and indoors need to be recorded (optional: the research assistants can conduct 5-min monitoring at kitchen, bedroom, worshipping room, and other microenvironments with potential sources. Interested research groups can team up for joint publications)
- Option 3 (basic requirement):
  - Several periods of personal exposure levels during 48-hour of the monitoring period are selected when the subjects are staying at their homes without doing any $PM_{2.5}$-generation activities nor exposing themselves to any known $PM_{2.5}$ sources. Then $PM_{2.5}$ levels from the environment/community sensor during the same periods of time are selected for calculating indoor/ambient ratio

Exposure Monitoring Strategy for Hi-ASAP (4)

- Data analysis
  - $PM_{2.5}$ exposure will be used in exposure-health evaluation
  - $PM_{2.5}$ exposure of these subjects will be analyzed along with their indoor/outdoor levels and TADs to explore high-exposure sources, places, activities, and factors (with two-sample t test, ANOVA analysis, multiple regression, and graphic presentation)
  - Exposure levels can be compared between different seasons, among different types of communities, and among different areas of this international team

Important Notes for Exposure Assessment and Exposure-Health Relationship Evaluation (1)

- Ask subjects follow their typical daily routines
  - This is an observational-type of study, not an experimental study. Please don't ask your subject change their daily activities
- Ask subjects take good care of your sensing devices
  - tell them it is worthy of nothing (money) to sell them but these devices are precious in conducting research
- Answer subjects' questions professionally
  - do not make jokes about what we do
  - good attitude will earn respect and trust
- Pay attention to your subjects' responses, ask them whether they have any concerns
- Do not think you are their boss just because you give them compensation; you are not. Be a nice person to them

Important Notes for Exposure Assessment and Exposure-Health Relationship Evaluation (2)

- Do not just taking measurements without evaluating any controllable factors
  - Concentration levels change significantly temporally and spatially
  - My exposure is not equal to your exposure
  - Without evaluating factors, it is just a student's homework, not research
- The important thing is to identify and quantify contribution of exposure factors, sources, and behaviors

Exposure Assessment

Any questions?

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