Innovate UK MiGHT Malaysian Industry-Government Group for High Technology Newton-Ungku Omar Fund SCIENCE to ACTION

Air Quality in Kuala Lumpur Urban Environment

Mohd Talib Latif, Liew Juneng, Murnira Othman, Nor Hafizah Baharudin, Azliyana Azhari, Diana Abdul Halim, Jenny Stocker, Kate Johnson, Nor Azura Sulong, Fatimah Ahamad, Mohd Shahrul Mohd Nadzir, Kemal Maulana Alhasa, Haris Hafizal, Ahmad Fariz Mohamad

UNIVERSITY OF CAMBRIDGE British Geological Survey NATURAL ENVIRONMENT RESEARCH COUNCIL seadpri UNIVERSITY OF MALAYA KUALA LUMPUR MET Malaysia UCL CERC UKM PAKARUNDING CORE Expert Systems GMT Geomapping Technology Sdn Bhd (593061-U) JBA risk management Cuesta GEOLOGICAL SOCIETY OF MALAYSIA Asian Network on Climate Science and Technology (ANCST)

Presentation Outline

- Continuous Air Quality Monitoring System (CAQMS)
- Atmospheric Dispersion Modelling System (ADMS)
- Low Cost Air Quality Sensor
- $PM_{2.5}$ and Its Composition
- Haze Episode
- Study on VOCs (BTEX) in ambient air
- Conclusion

New Air Quality Monitoring Station (2017-

Continuous Air Quality Monitoring

65 Continuous Stations

Manual Air Quality Monitoring

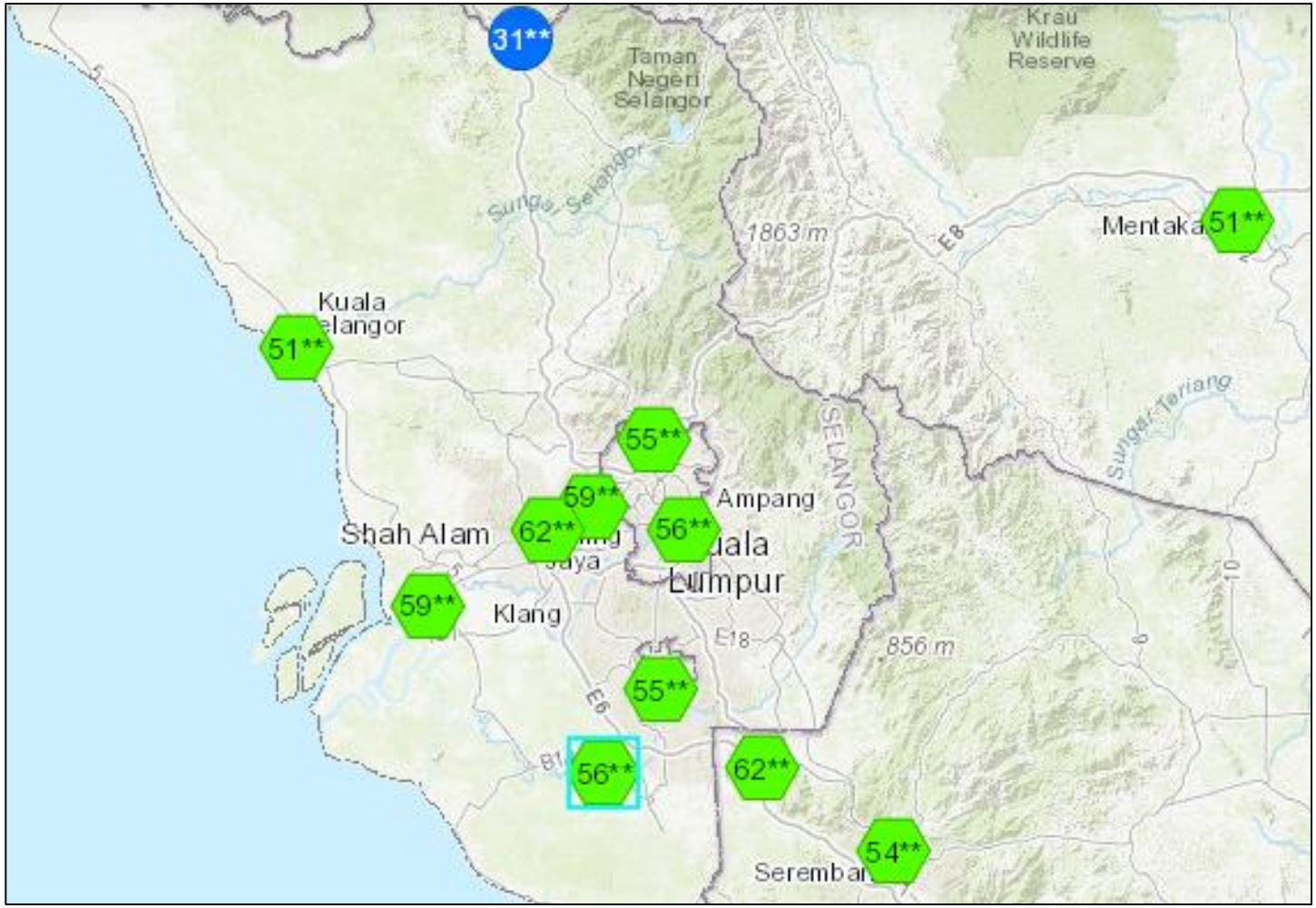
14 Manual Stations

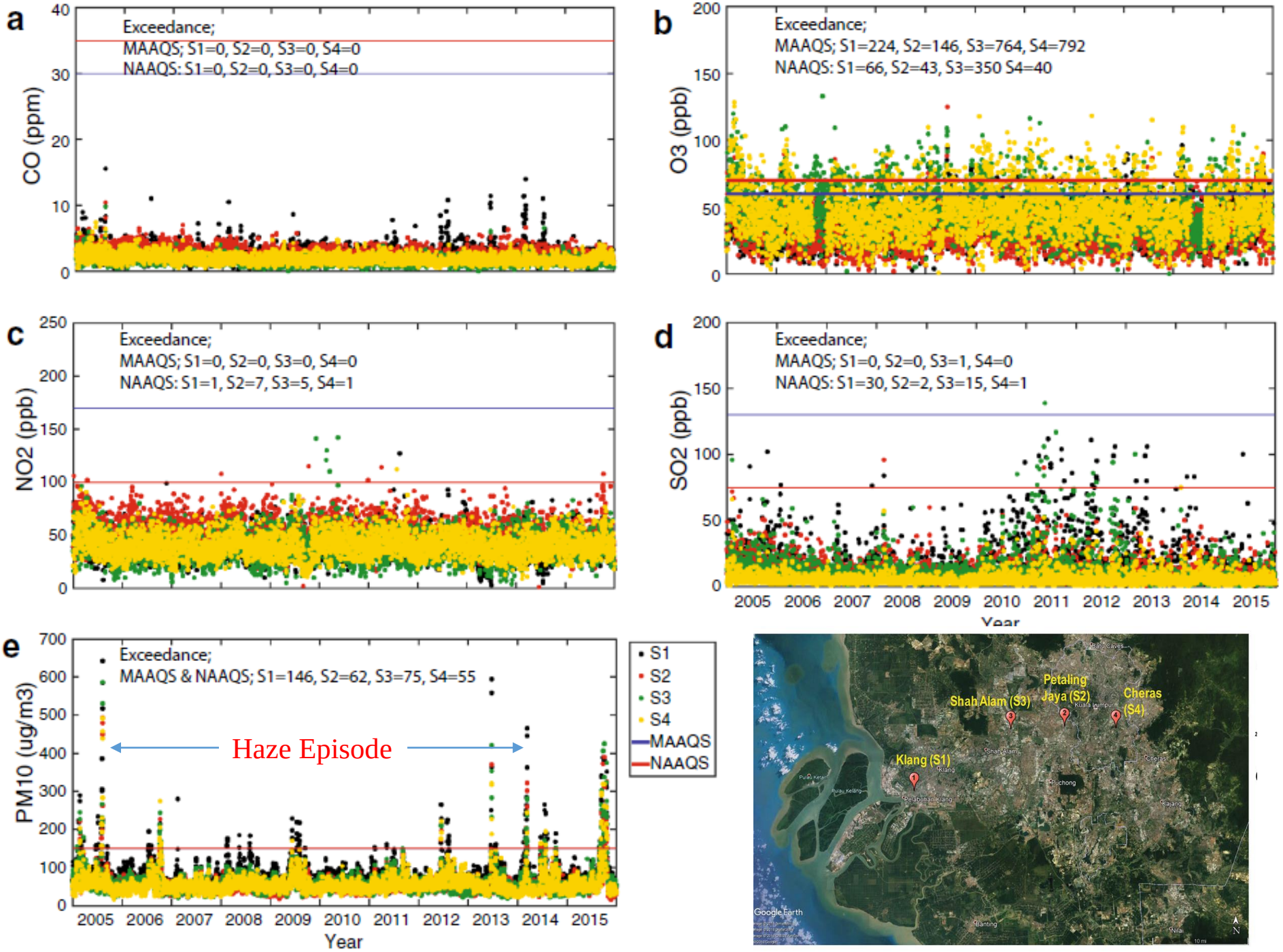
Mobile Continuous Air Quality Monitoring

3 Mobile Stations

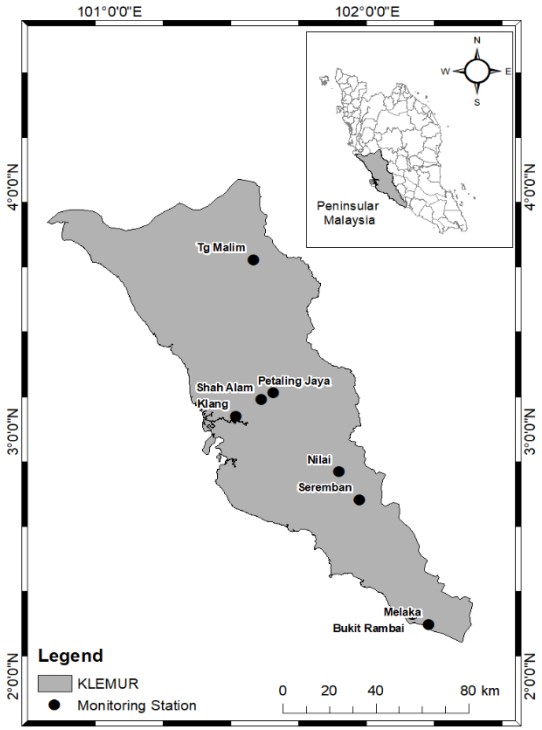
Pakar Scieno TW Sdn Bhd
(2017 – Present)

Continuous Air Quality Monitoring System, CQMS in the Klang Valley (2017-)

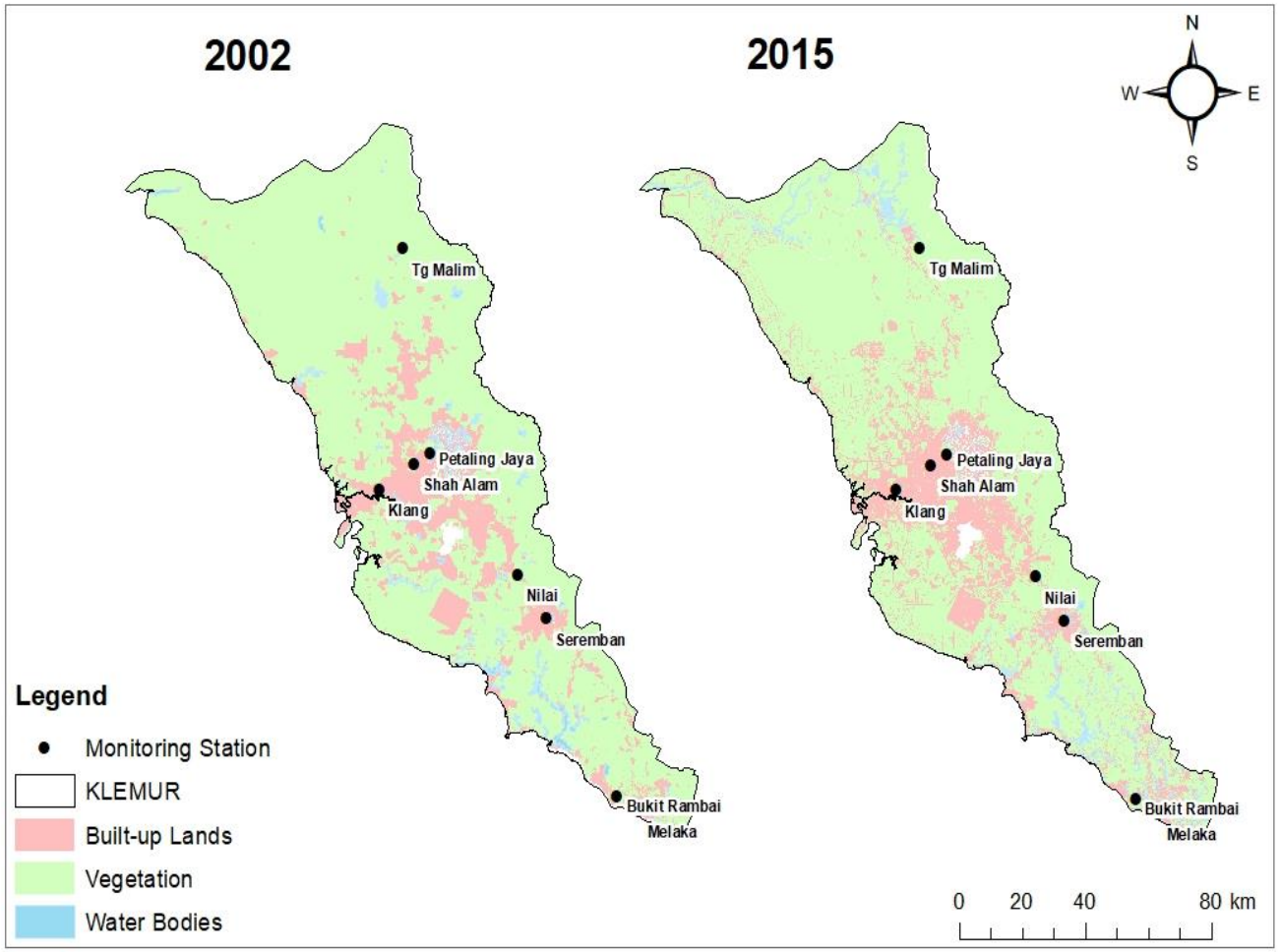



a
Exceedance;
MAAQS; S1=0, S2=0, S3=0, S4=0
NAAQS: S1=0, S2=0, S3=0, S4=0
CO (ppm)
b
Exceedance;
MAAQS; S1=224, S2=146, S3=764, S4=792
NAAQS: S1=66, S2=43, S3=350 S4=40
O3 (ppb)
c
Exceedance;
MAAQS; S1=0, S2=0, S3=0, S4=0
NAAQS: S1=1, S2=7, S3=5, S4=1
NO2 (ppb)
d
Exceedance;
MAAQS; S1=0, S2=0, S3=1, S4=0
NAAQS: S1=30, S2=2, S3=15, S4=1
SO2 (ppb)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Year
e
Exceedance;
MAAQS & NAAQS; S1=146, S2=62, S3=75, S4=55
Haze Episode
S1
S2
S3
S4
MAAQS
NAAQS
PM10 (ug/m3)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Year
Shah Alam (S3)
Petaling Jaya (S2)
Cheras (S4)
Klang (S1)
Google Earth

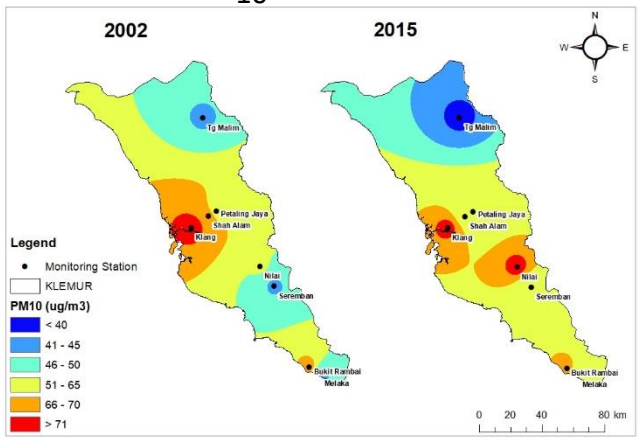
Land use changes for Kuala Lumpur Extended Mega Urban Regions (KLEMUR)



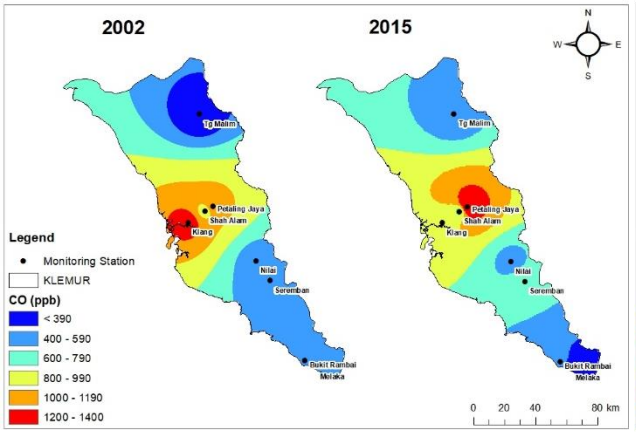
Land use Activity	Area (KM^2) 2002	2015
Water bodies	177	94
Vegetation	9721	9334
Built-up Lands	2075	2554



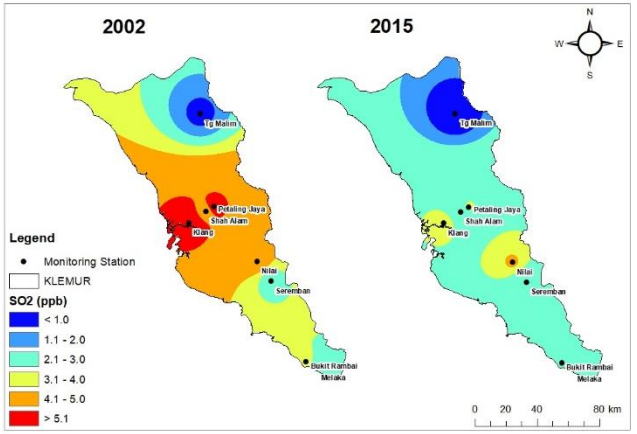
PM_{10} (µg/m³)



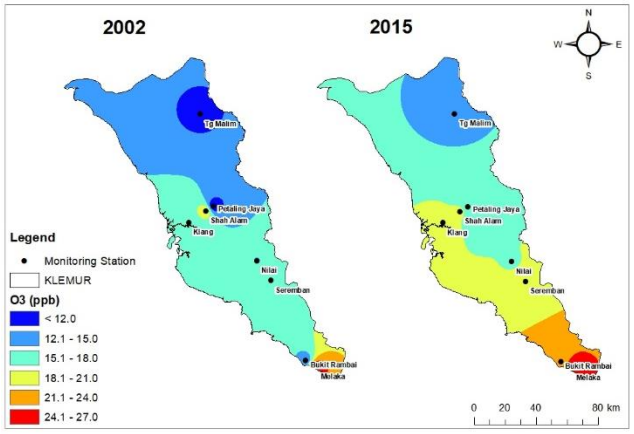
CO (ppb)



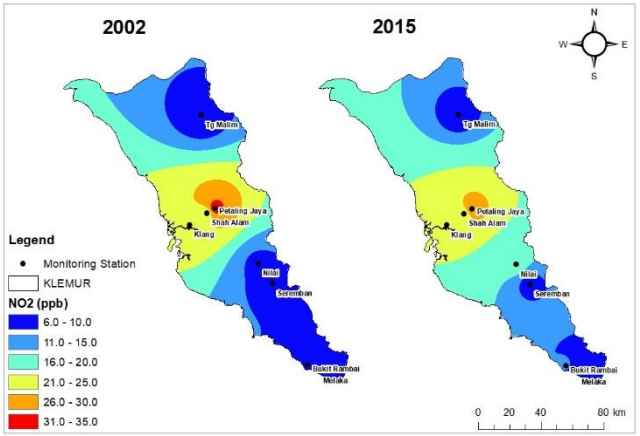
SO_2 (ppb)



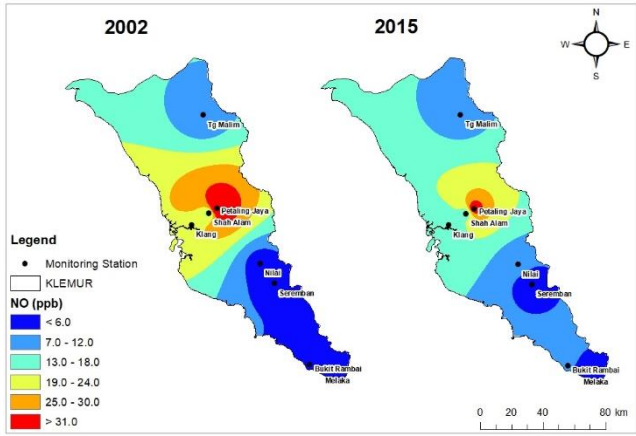
O_3 (ppb)



NO_2 (ppb)

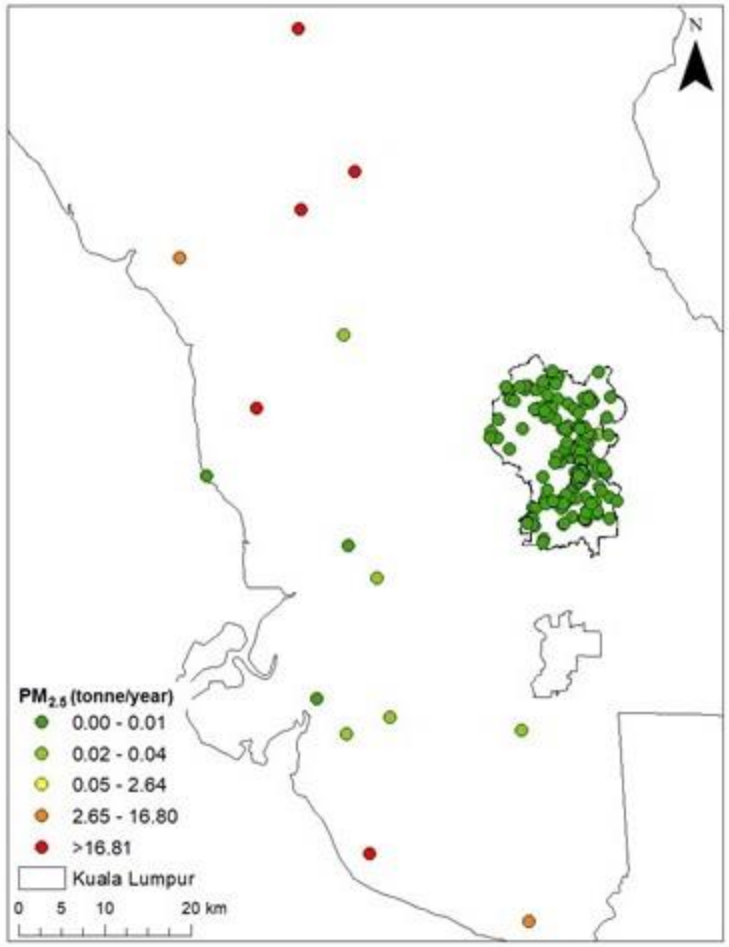


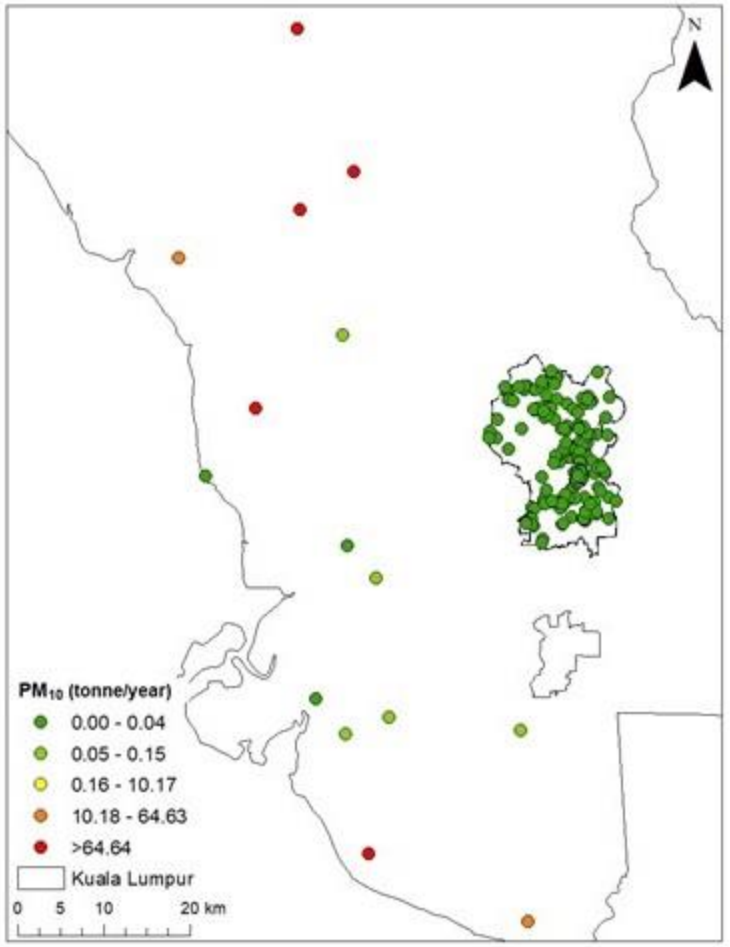
NO (ppb)

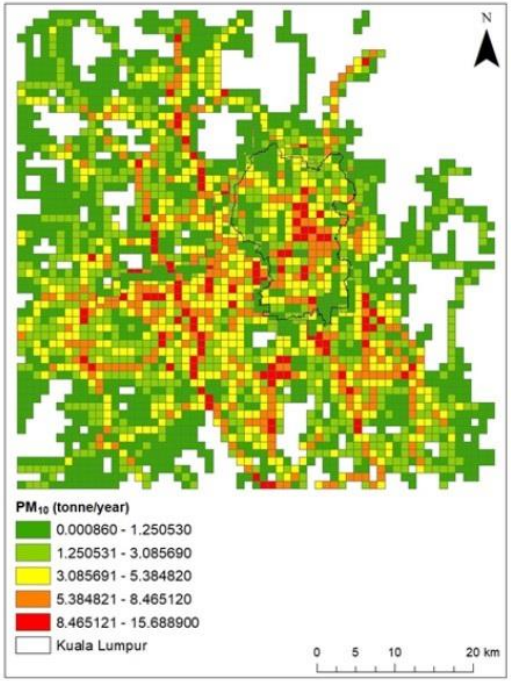


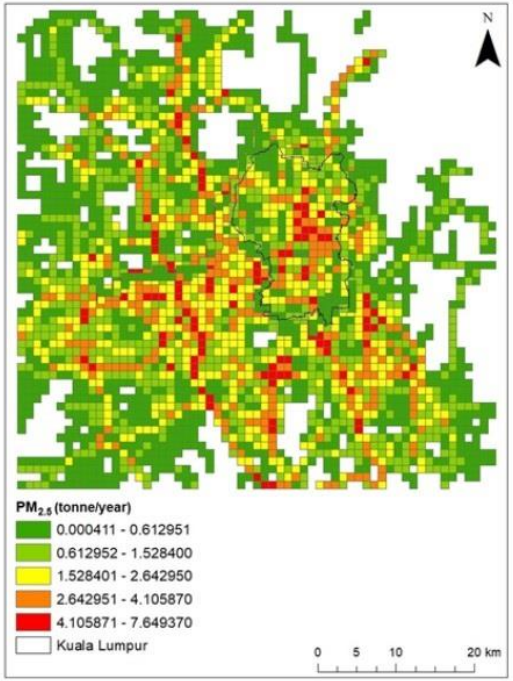
Atmospheric Dispersion Modelling System (ADMS)

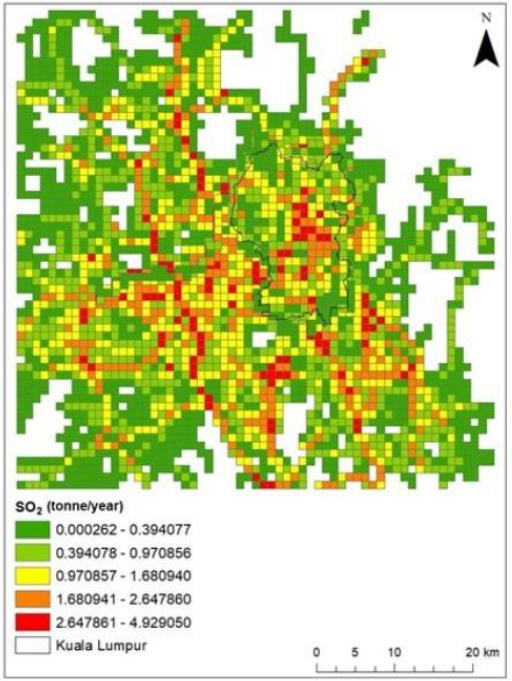
Emission rate for point source pollution for Kuala Lumpur Urban Environment

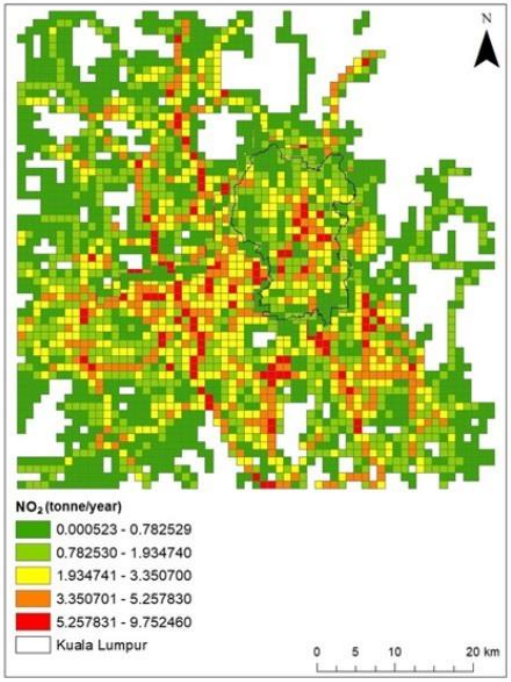


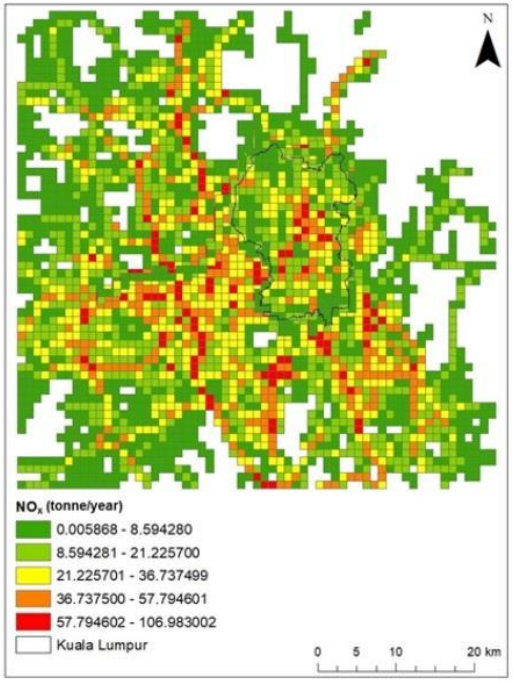






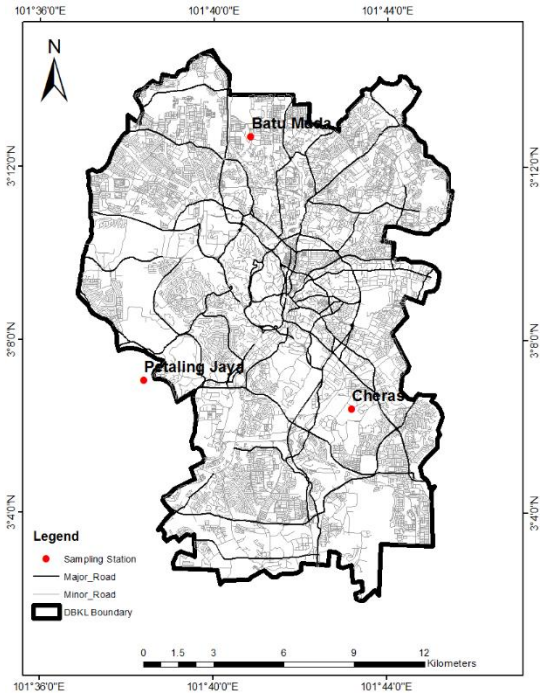






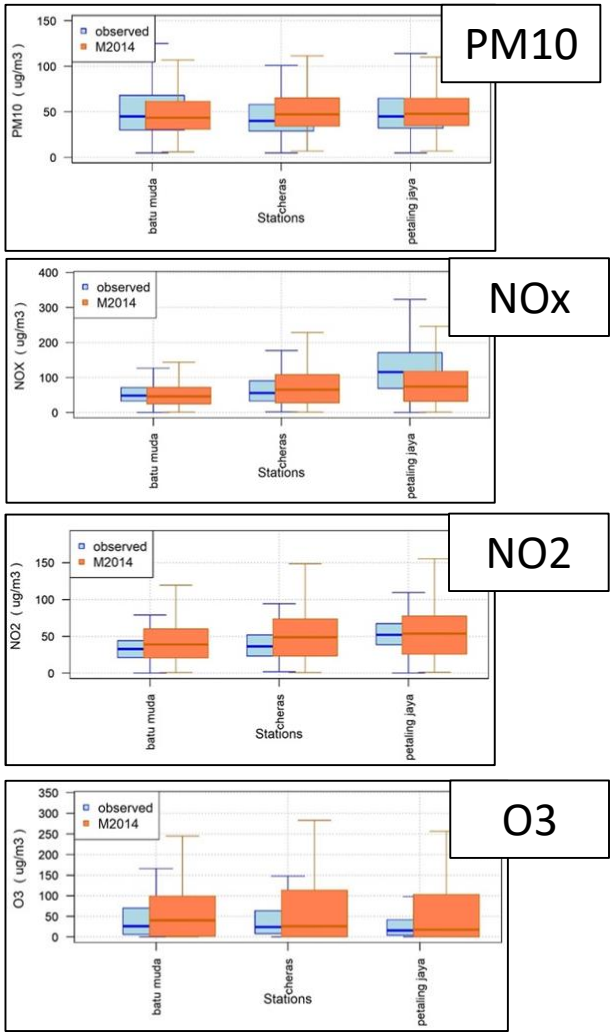
Emission rate for road source pollution in grid for Kuala Lumpur Urban Environment

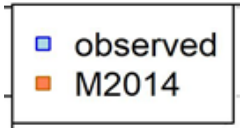
Model Verification



2 Stations in Kuala Lumpur:
- **Cheras**
- **Batu Muda**

1 Station in near to KL:
- **Petaling Jaya**

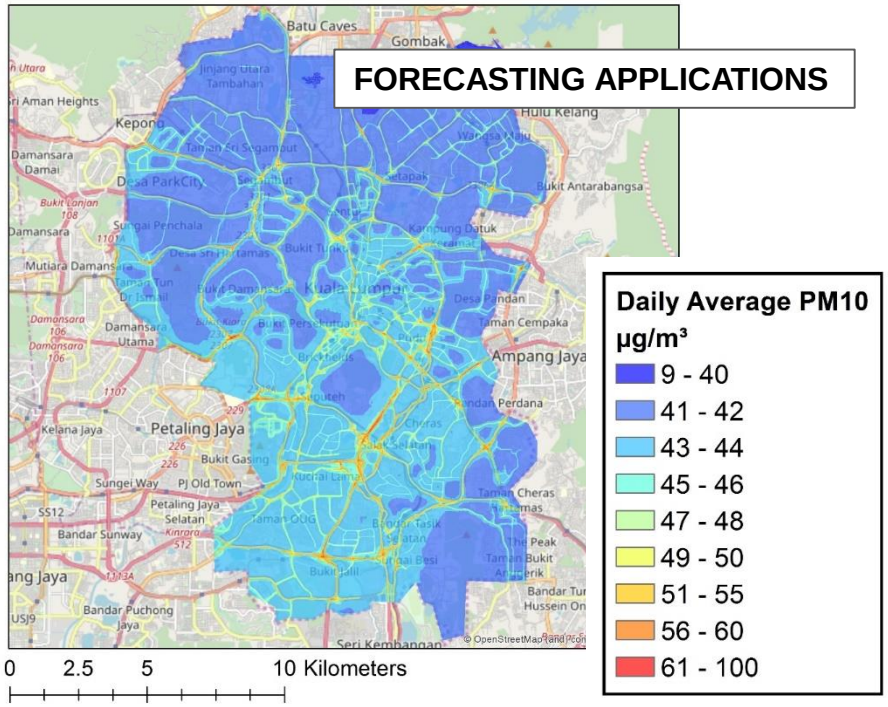




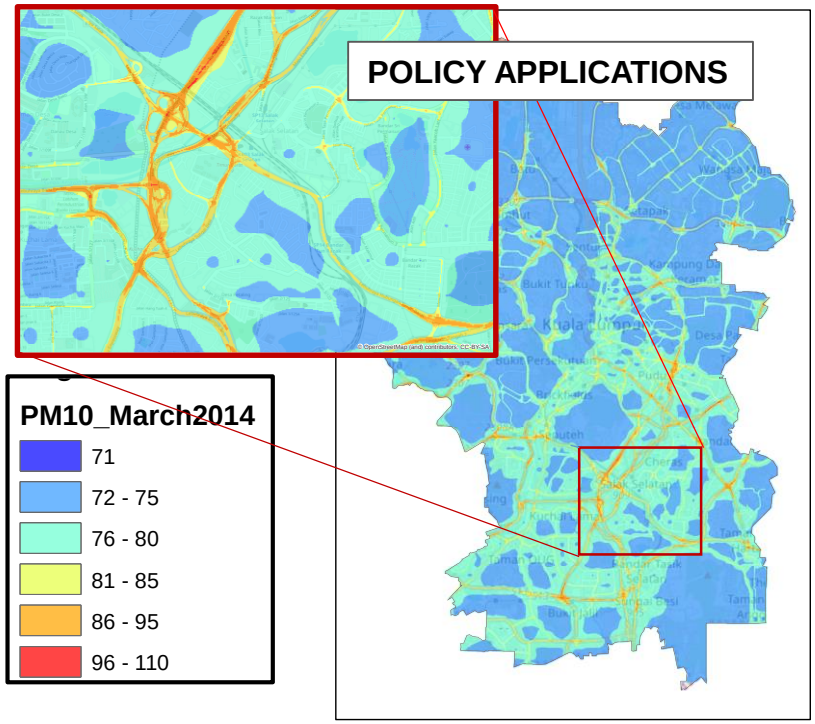
- **Comparisons between modelled and observed concentrations of air pollutants**
- **Model perform good agreement**

Air Quality Maps

- Daily PM10 concentrations

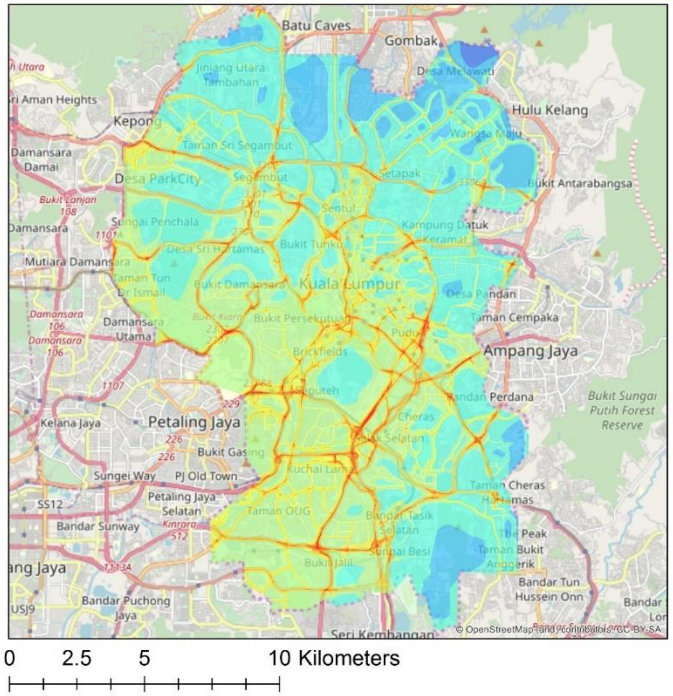


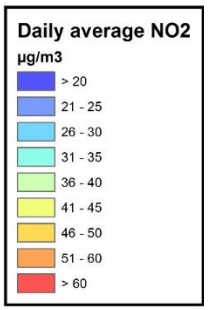
- March 2014 PM10 concentrations



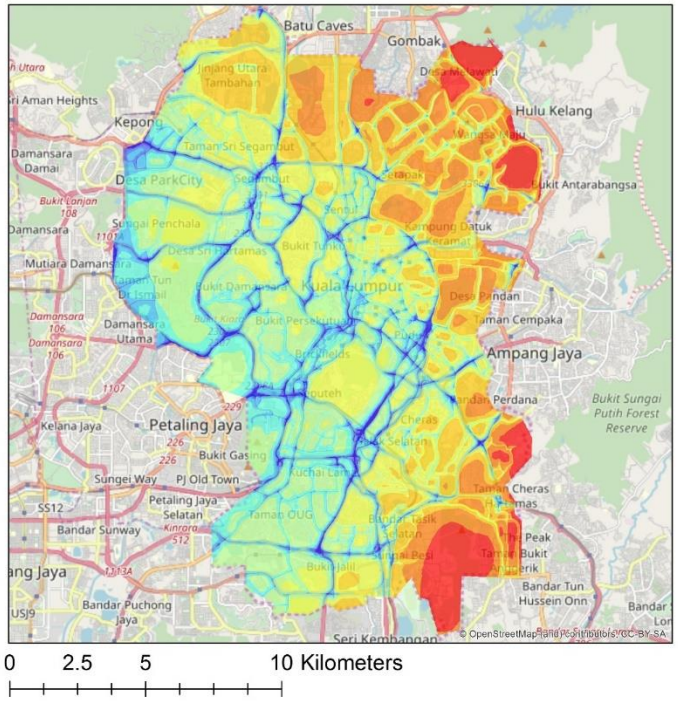
Air Quality Maps

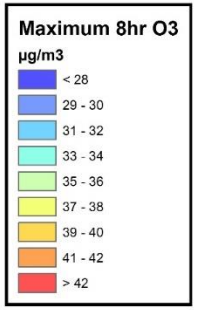
- Daily NO_2 concentrations





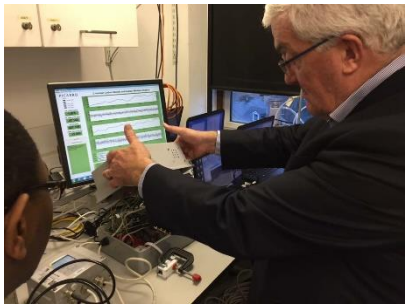
- Daily O_3 concentrations





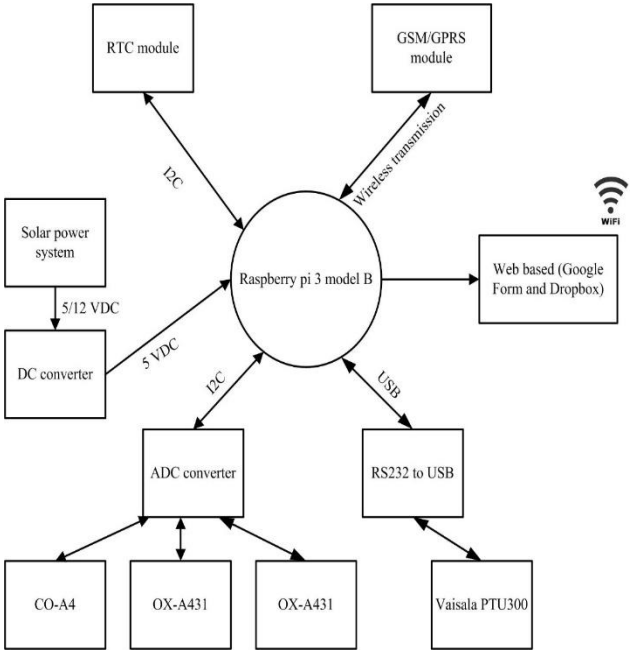
Low Cost Sensor

Low Cost Air Quality Sensor



Newton Fund

Hardware Development

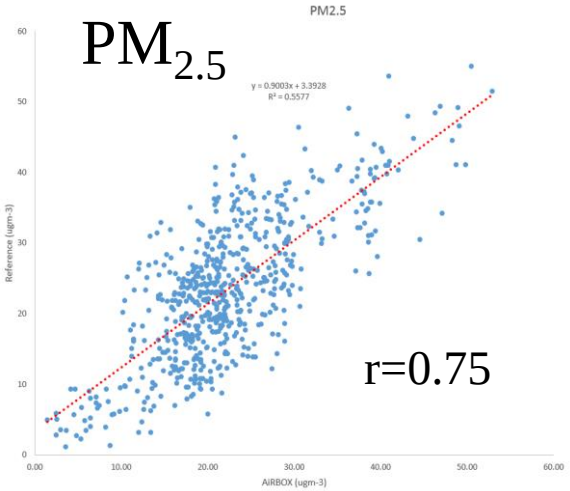


Technical specification

Parameters	Sensors	Range	Detection limit	correlation	Resolution	Accuracy
PM_1, $PM_{2.5}$ & PM_{10}	Alphasense OPC	0-1200 μgm^{-3}	1 μgm^{-3}	r=0.75	1 μgm^{-3}	~<± 5 μgm^{-3}
Nitrogen Dioxide	Alphasense EC	0- 5 ppb	2 ppb	r=0.82	1 ppb	~<± 5 ppb
Carbon Monoxide	Alphasense EC	0-30 ppm	0.02 ppm	r=0.88	0.02 ppm	~± 5 ppb
Sulphur Dioxide	Alphasense EC	0-200 ppb	0.2 ppb	r=0.88	1 ppb	~<± 5 ppb
Ozone	Alphasense EC	0-200 ppb	2 ppb	r=0.82	1 ppb	~<± 5 ppb

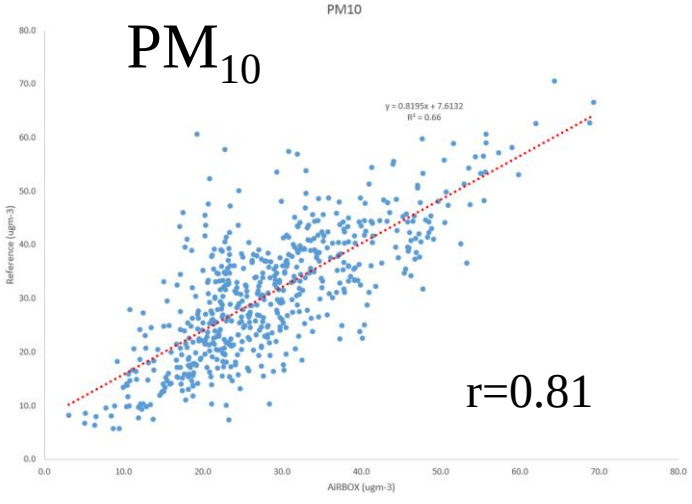
Sensor Calibration – Comparison with PSTW-DOE Instrument

$PM_{2.5}$



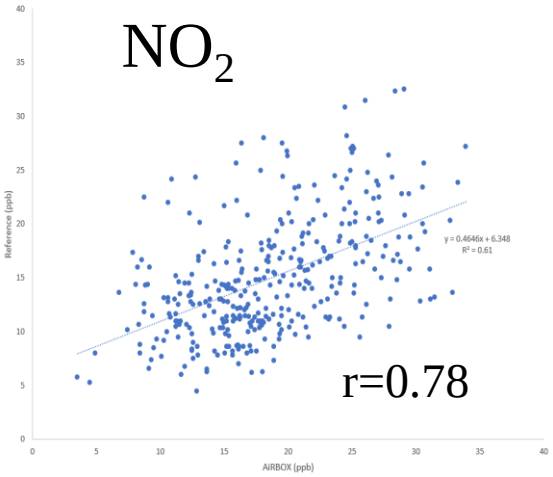
r=0.75

PM_{10}



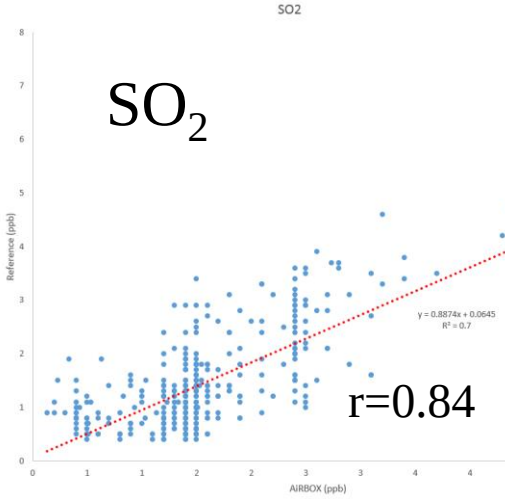
r=0.81

NO_2



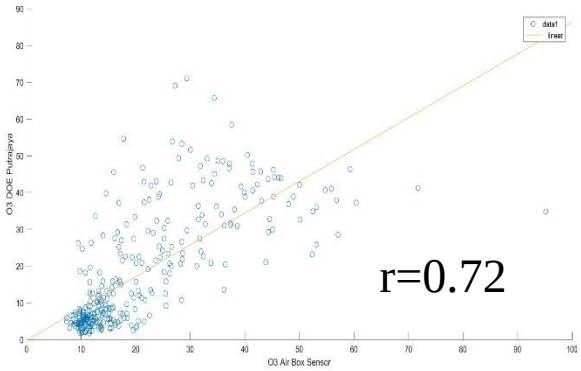
r=0.78

SO_2



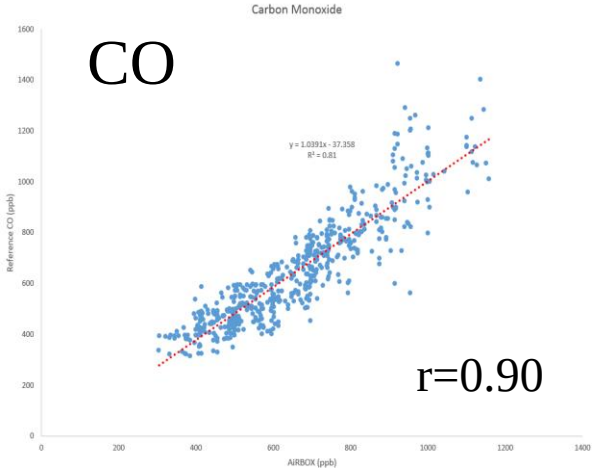
r=0.84

O_3



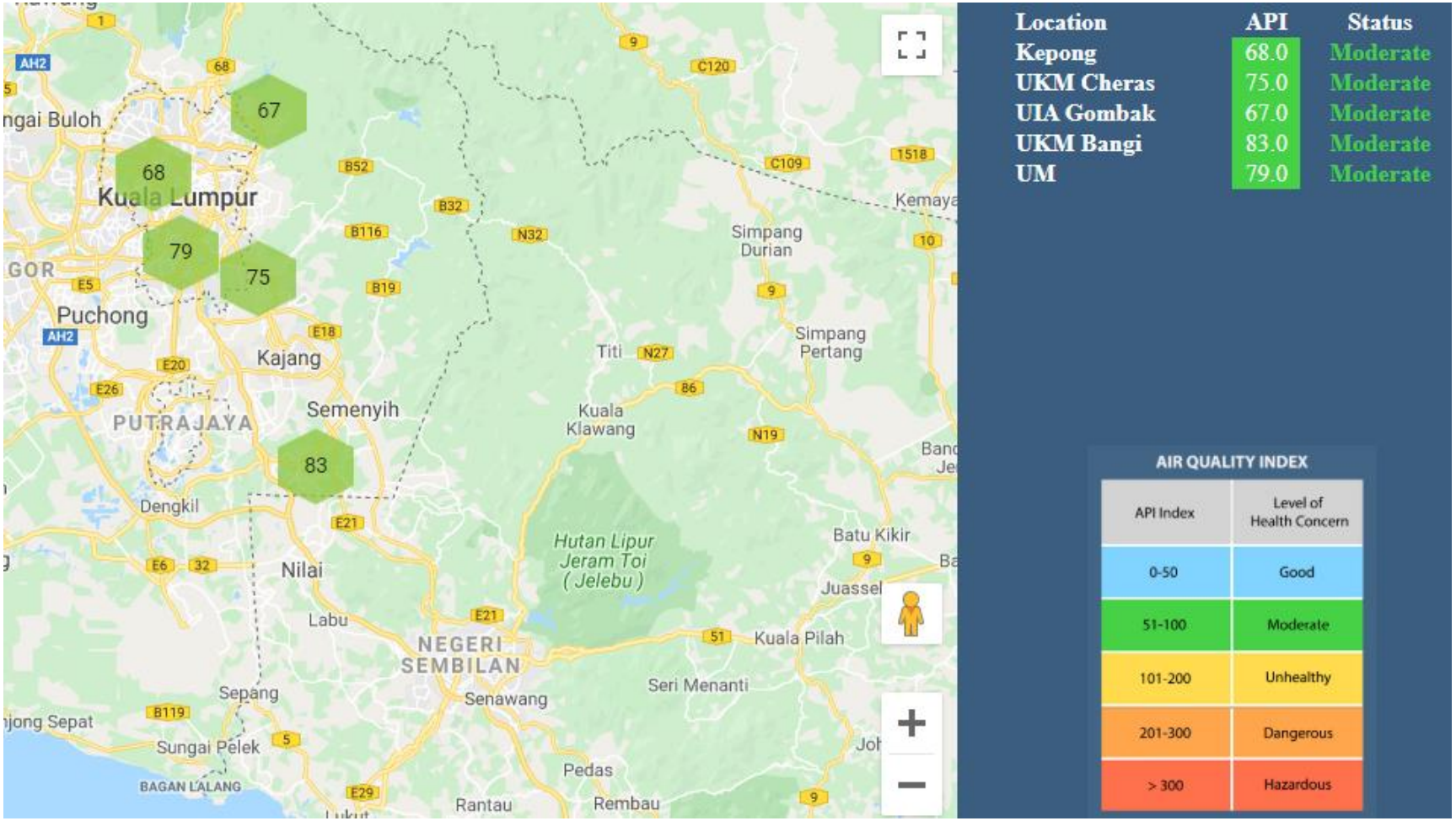
r=0.72

CO



r=0.90

Air Quality Dashboard

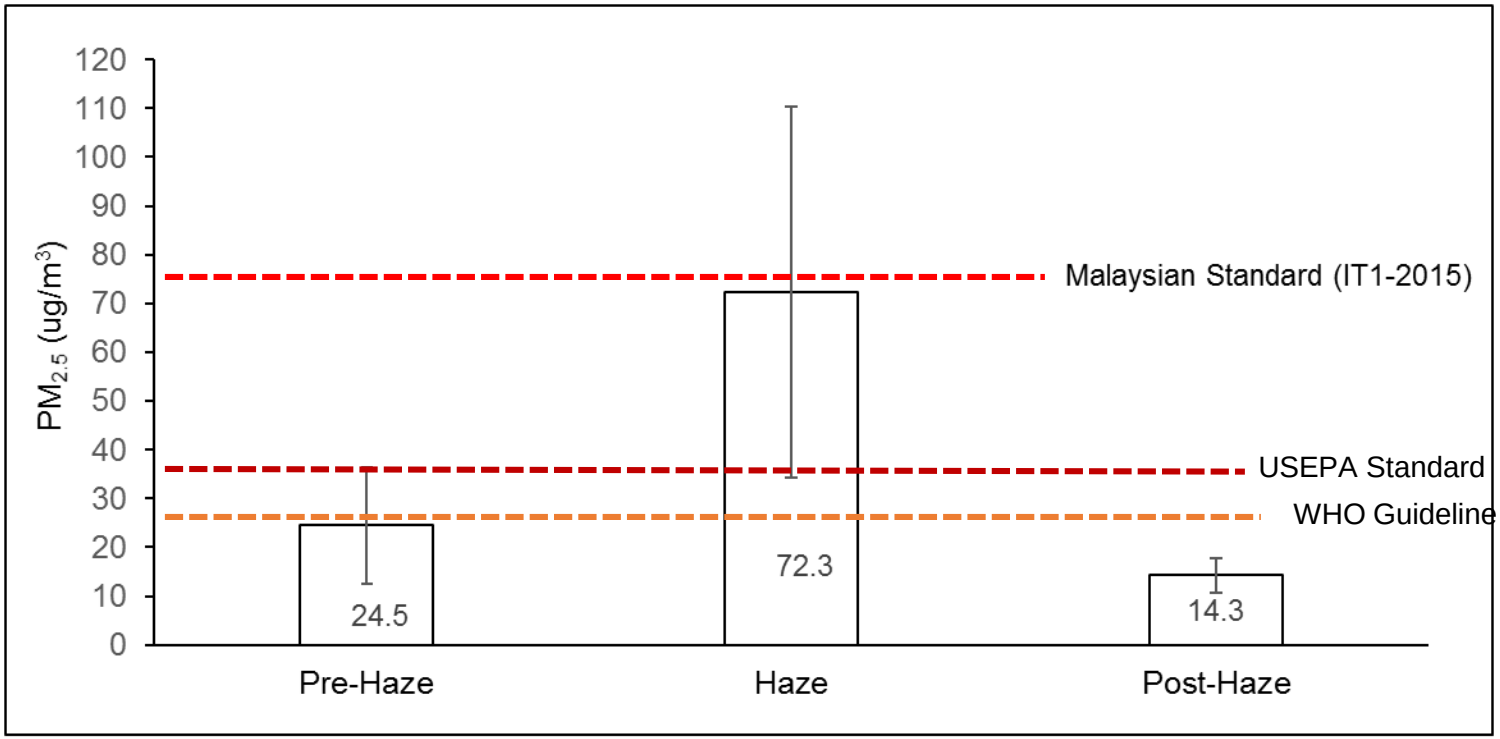


https://www.innosens.com.my/dashboard/main.php

13th October, 2019

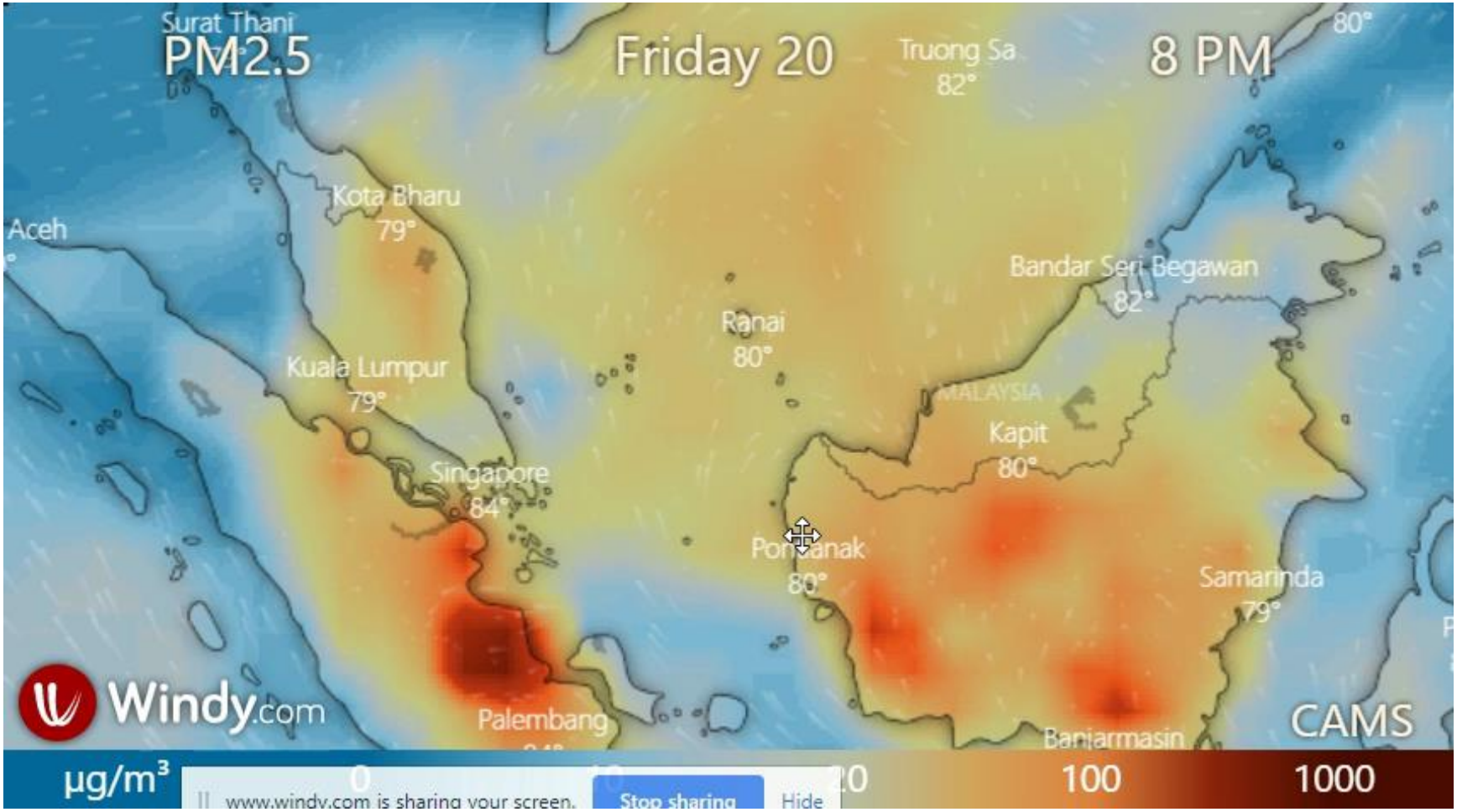
$PM_{2.5}$ Monitoring

Average $PM_{2.5}$ Concentration

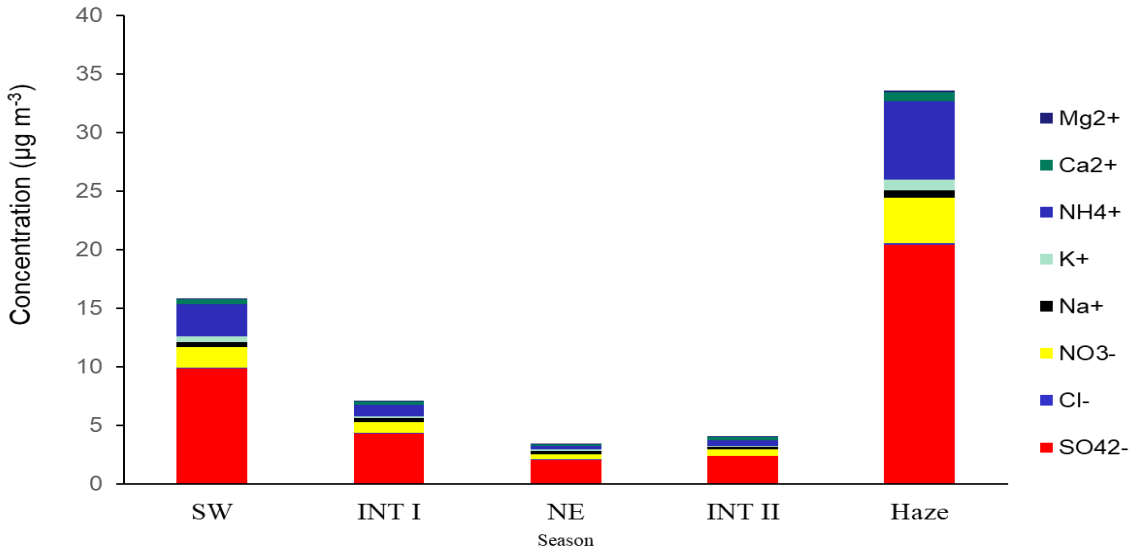


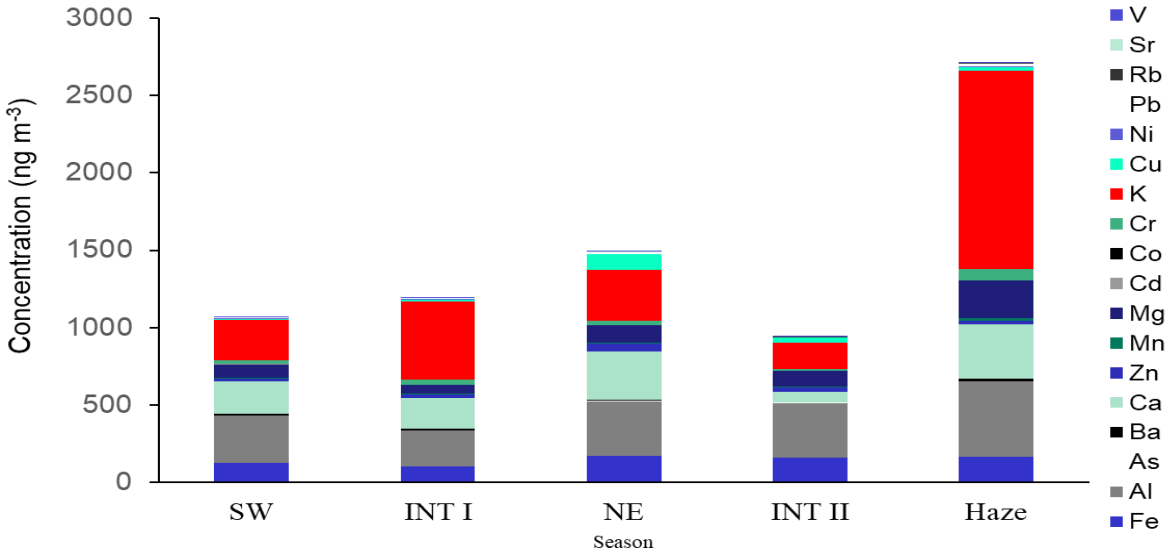
Sulong et al., 2017, Sci Total Environ)

Biomass Burning Episode



$PM_{2.5}$: Inorganic Composition

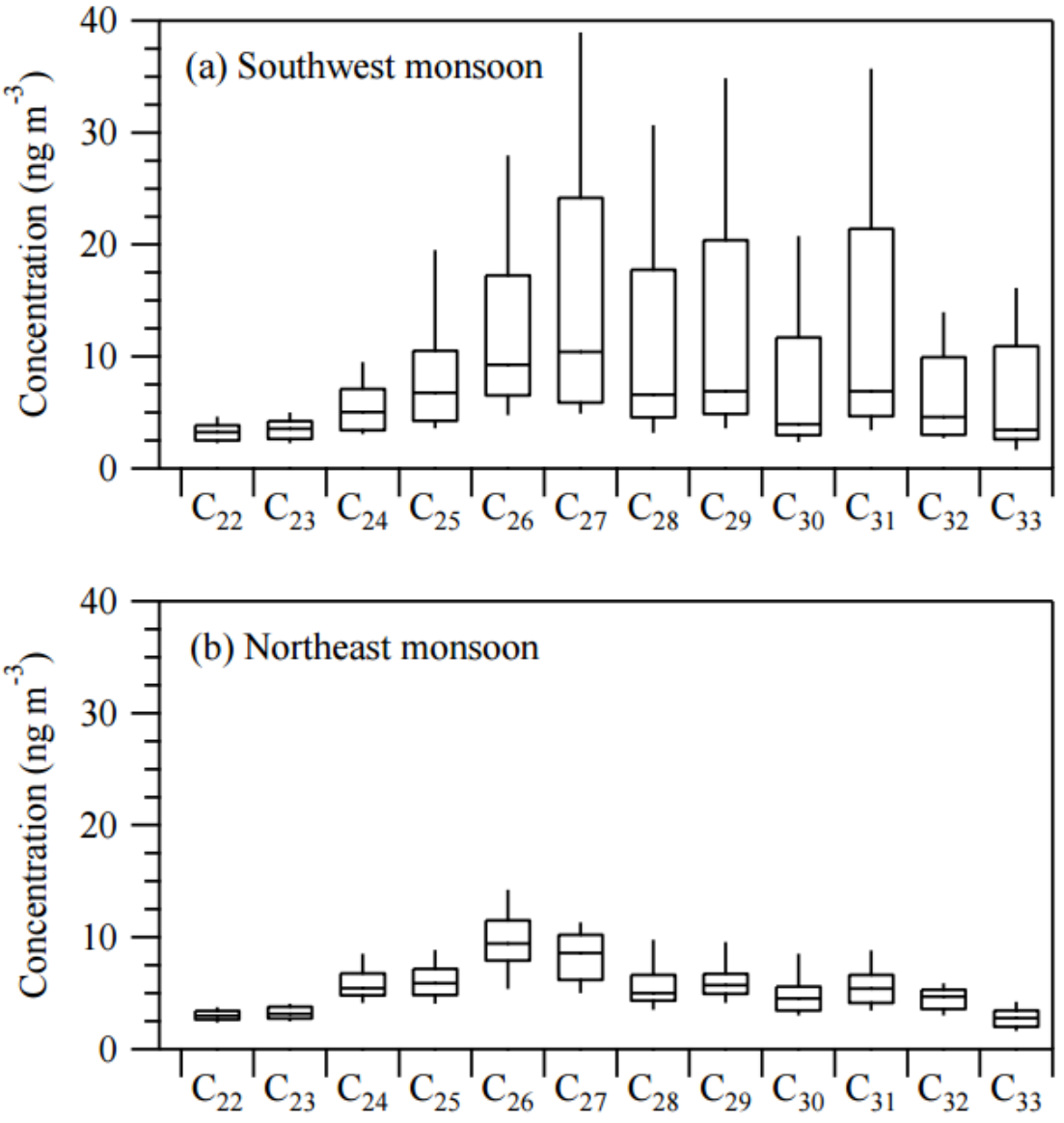




$PM_{2.5}$: Organic Composition

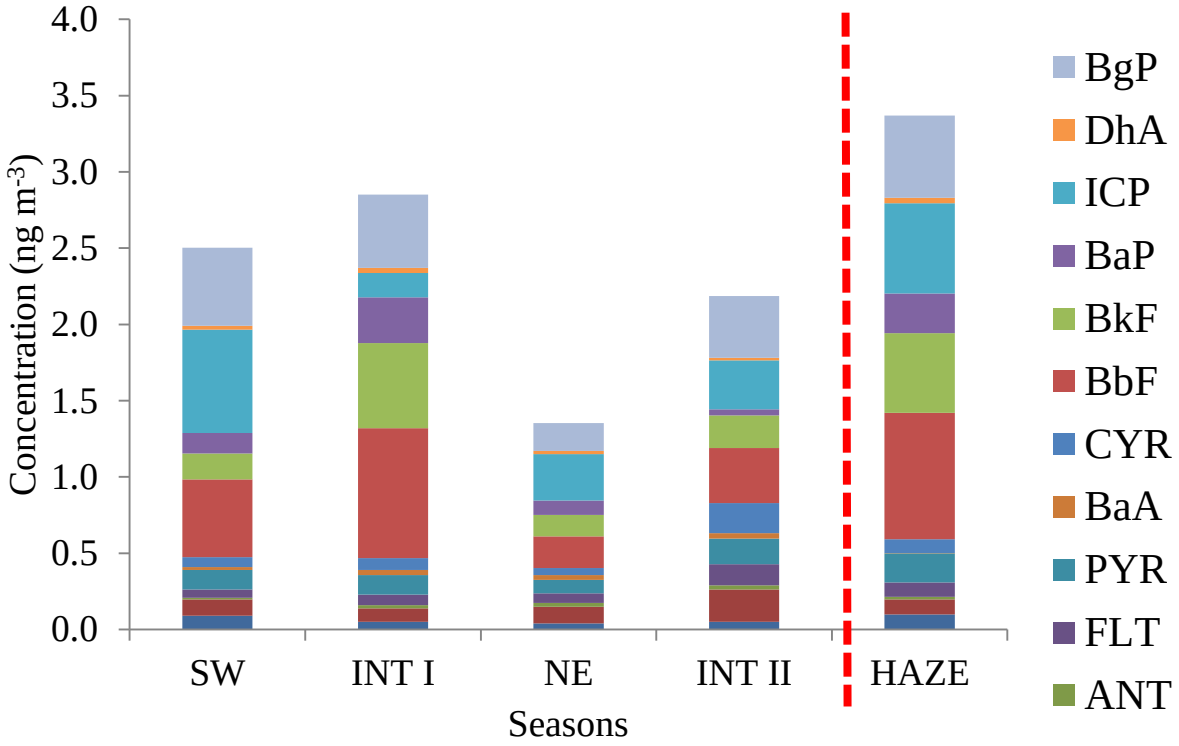
Compounds	Southwestern monsoon (June–September)		Post-monsoon (October–November)		Northeastern monsoon (December–March)		Pre-monsoon (April–May)	
	Av ± SD	Range	Av ± SD	Range	Av ± SD	Range	Av ± SD	Range
OC and EC ($\mu g\,m^{-3}$)								
OC	10 ± 7.8	3.6–36	5.6 ± 2.4	2.5–11	5.2 ± 1.4	2.7–8.2	4.2 ± 1.4	2.8–7.3
EC	3.0 ± 0.95	1.0–5.6	3.2 ± 1.3	1.1–5.9	3.4 ± 1.1	1.6–6.1	2.6 ± 1.2	1.4–4.5
Biomarkers ($ng\,m^{-3}$)								
Levoglucosan	160 ± 130	32–490	64 ± 39	19–130	40 ± 14	17–64	49 ± 21	23–86
Mannosan	8.4 ± 8.2	1.5–30	3.4 ± 2.6	0.95–9.1	2.6 ± 1.2	0.84–5.3	2.5 ± 1.2	1.2–5.3
Galactosan	2.3 ± 2.3	0.38–8.3	0.86 ± 0.72	0.29–2.8	0.60 ± 0.35	0.13–1.3	0.62 ± 0.34	0.33–1.5
p-Hydroxybenzoic acid	1.9 ± 1.9	0.18–7.5	0.79 ± 0.67	0.036–2.2	0.64 ± 0.30	0.20–1.2	0.50 ± 0.25	0.24–1.0
Vanillin	1.6 ± 1.1	0.54–5.5	1.2 ± 0.66	0.45–2.2	1.0 ± 0.38	0.21–1.7	0.96 ± 0.42	0.30–1.7
Syringaldehyde	0.29 ± 0.22	0.085–1.0	0.59 ± 0.22	0.26–1.2	0.77 ± 0.54	0.074–2.2	0.36 ± 0.22	0.093–0.77
Vanillic acid	0.39 ± 0.39	0.074–1.9	0.11 ± 0.070	0.031–0.22	0.073 ± 0.057	0.013–0.26	0.066 ± 0.027	0.034–0.12
Syringic acid	0.35 ± 0.41	0.075–2.4	0.26 ± 0.21	0.058–0.59	0.17 ± 0.13	0.029–0.64	0.16 ± 0.084	0.049–0.28
Dehydroabietic acid	1.7 ± 1.1	0.10–5.4	1.1 ± 0.69	0.31–2.4	1.1 ± 1.1	0.14–4.6	0.67 ± 0.24	0.16–0.98
Cholesterol	1.8 ± 0.82	0.50–3.7	1.2 ± 0.51	0.57–2.0	0.98 ± 0.51	0.026–2.0	1.3 ± 0.56	0.51–2.0
n-Alkanes ($ng\,m^{-3}$)								
Docosane	3.2 ± 0.82	1.8–5.0	2.9 ± 0.61	2.0–4.0	3.0 ± 0.53	1.9–4.2	4.0 ± 4.8	2.1–19
Tricosane	3.6 ± 1.2	2.0–7.2	3.2 ± 0.91	2.0–4.8	3.2 ± 0.65	1.8–4.4	5.0 ± 7.6	2.1–29
Tetracosane	5.8 ± 3.2	2.5–19	5.7 ± 1.7	3.3–8.7	6.1 ± 2.3	2.9–15	6.3 ± 8.5	2.7–33
Pentacosane	8.9 ± 6.7	3.5–34	5.7 ± 2.3	3.1–11	6.0 ± 1.6	3.7–9.2	5.8 ± 5.5	3.2–23
Hexacosane	13 ± 9.8	4.3–49	8.6 ± 3.7	3.6–18	9.7 ± 2.8	5.0–16	7.1 ± 5.3	3.5–23
Heptacosane	16 ± 14	4.7–64	7.2 ± 2.6	3.6–12	8.2 ± 2.4	3.7–14	5.8 ± 3.4	3.3–16
Octacosane	12 ± 12	2.6–54	4.3 ± 1.8	1.7–7.9	5.9 ± 3.0	2.3–17	3.6 ± 1.7	2.3–8.2
Nonacosane	13 ± 13	3.0–55	4.9 ± 2.1	1.5–8.7	6.3 ± 2.2	3.3–13	4.5 ± 1.4	2.6–7.8
Triacontane	7.9 ± 7.8	2.0–36	3.8 ± 2.0	1.6–9.0	5.2 ± 2.7	2.0–16	3.3 ± 1.7	1.7–8.3
Hentriacontane	14 ± 14	2.8–59	4.8 ± 1.9	1.8–8.4	5.7 ± 2.0	3.3–11	4.3 ± 1.2	2.9–6.9
Dotriacontane	6.7 ± 5.5	1.6–27	3.4 ± 0.72	2.4–4.5	4.6 ± 1.3	2.8–7.8	3.1 ± 0.88	1.8–4.4
Tritriacontane	6.8 ± 7.1	1.2–33	2.5 ± 0.97	1.1–4.2	2.8 ± 0.92	1.2–5.0	2.1 ± 0.72	1.5–3.8

$PM_{2.5}$: Organic Composition



Fujii et al. 2015, Atmos Chem Phys

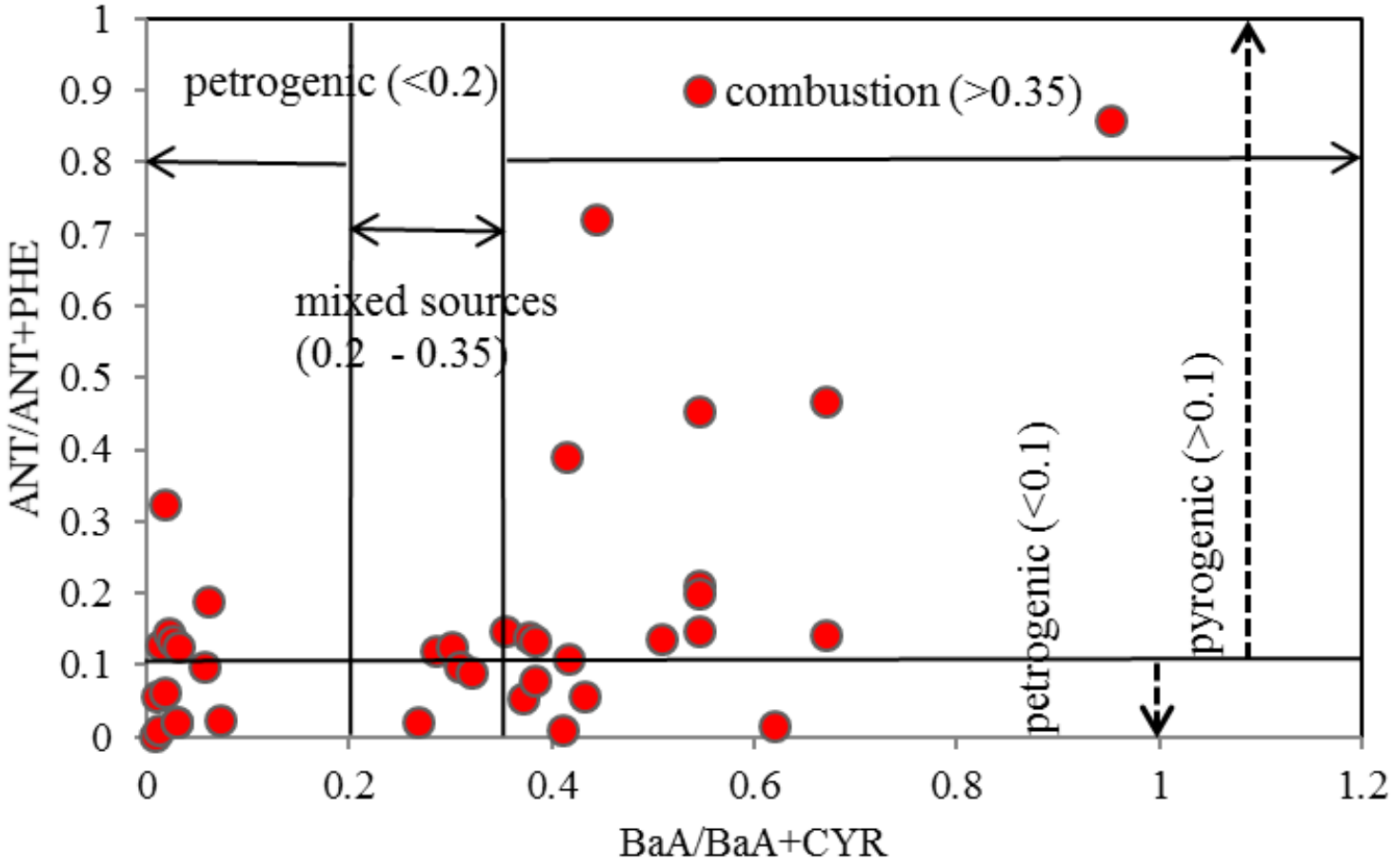
USEPA Priority Pollutants 16 PAHs



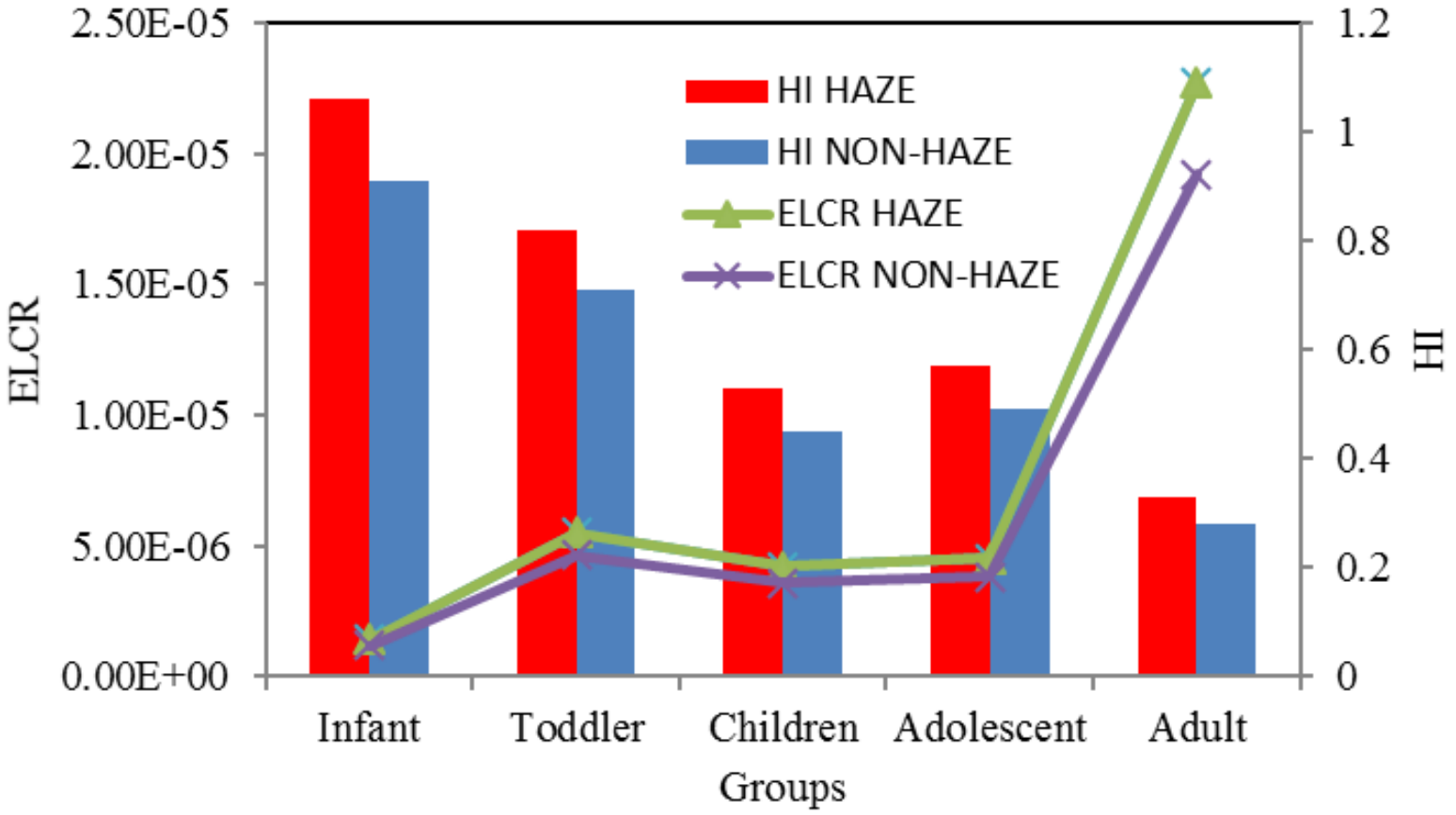
NAP = Napthalene; ACY = Acenapthelyne; ACP = Acenapthene; FLR = flourene; PHE = Phenanthrene; ANT = Anthracene; FLT = Fluoranthene; PYR = Pyrene; BaA = Benzo[a]anthracene; CYR = Chrysene; BbF = Benzo[b]fluoranthene; BkF = Benzo[k]fluoranthene; BaP = Benzo[a]pyrene; IcP = Indeno[1,2,3cd]pyrene; DhA = Dibenzo[a,h]anthracene; BgP = Benzo[g,h,i]perylene

Sulong et al., 2018, Chemosphere

Diagnostic Ratio



Sulong et al., 2018, Chemosphere



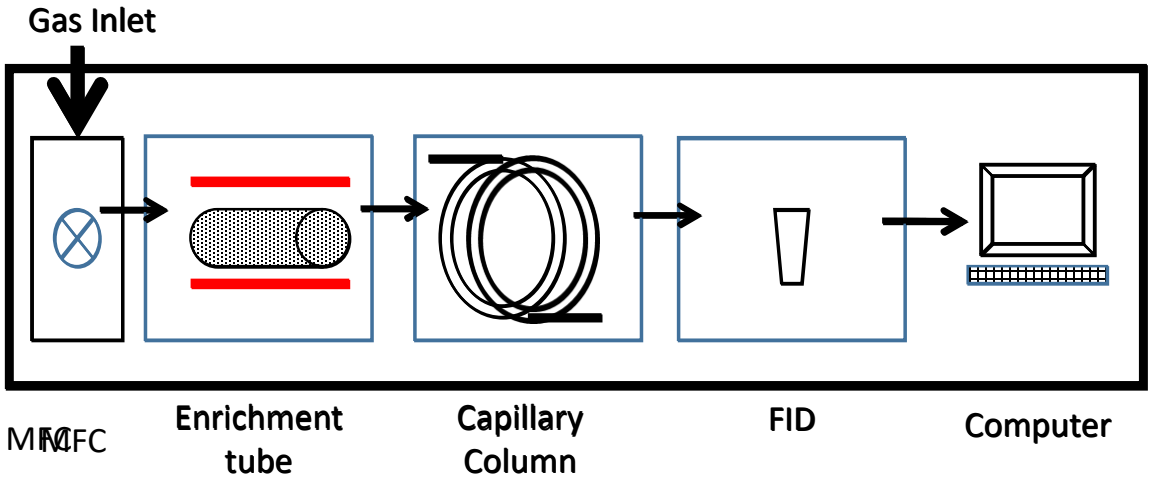
Sulong et al., 2018, Chemosphere

BTEX Monitoring

BTEX Continuous Monitoring

AMA Online Gas Chromatography GC 5000 BTX (AMA Instruments, Germany)

- Suitable for continuous monitoring of VOCs in ambient air in the range C4-C12.
- Capable of monitoring aromatic hydrocarbons i.e. BTEXs
- Using single-tube sample enrichment technology (sorbent tube)

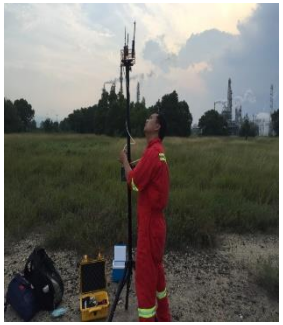


A system setup for automatic sampling, enrichment and GC analysis.

BTEX Active Sampling

Sorbent tube – Tenax® GR (US EPA TO-17)

Flow rate – 50 mL min^{-1}



Thermal Desorption System (TDS Unity-1 and Ultra Series 2 (Markes, UK) couple to Gas Chromatography (GC)- Mass Spectrometer (MS)(Agilent, USA)

BTEX - Continuous Monitoring

Compound	Ambient UKMKL (*n* = 3794)				Ambient UMT (*n* = 1432)				Ambient UMS (*n* = 457)				Ambient FHRC (*n* = 1034)			
	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD
Benzene	6.20	0.57	29.51	3.51	1.63	0.32	25.23	1.51	2.25	0.32	9.19	1.88	0.69	0.03	3.17	0.45
Toluene	22.31	3.59	128.96	11.54	8.06	0.41	106.93	12.92	6.44	0.37	28.87	4.50	2.76	0.04	20.12	2.05
Ethylbenzene	4.52	0.09	26.42	2.25	1.68	0.43	118.14	3.54	1.48	0.43	12.33	1.21	0.36	0.04	2.84	0.36
m,p-Xylene	11.57	0.09	30.64	4.54	2.51	0.43	10.43	1.56	2.94	0.43	15.99	2.18	1.27	0.04	6.64	0.91
o-Xylene	4.96	0.13	12.76	1.87	1.69	0.43	41.76	1.73	1.37	0.43	7.80	1.14	1.10	0.22	4.83	0.83
Total BTEX	49.56	4.47	228.29	23.71	15.57	2.02	302.49	21.26	14.48	1.98	74.18	10.91	6.18	0.37	37.60	4.60

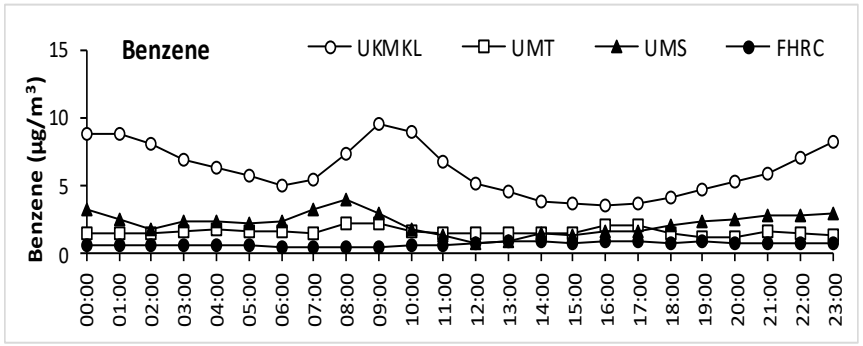
BTEX – Active Sampling

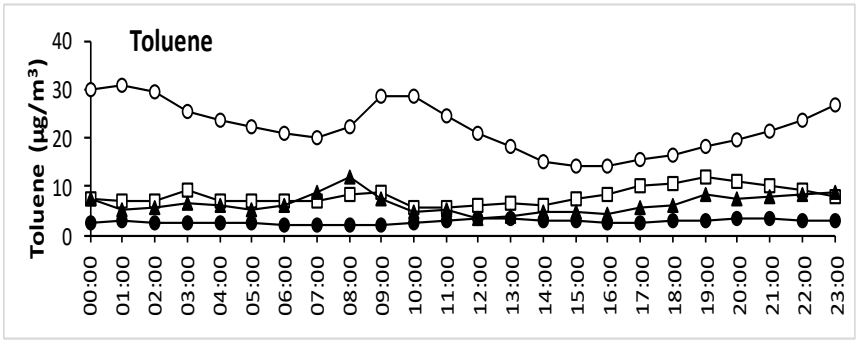
Compound	Ambient UKMKL (n = 13)				Ambient UMT (n = 12)				Ambient UMS (n = 8)				Ambient FHRC (n = 14)			
	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD
Benzene	7.48	2.98	12.86	5.51	1.93	0.35	4.02	1.52	1.20	0.10	3.87	1.30	0.38	0.06	1.30	0.44
Toluene	28.10	17.68	45.93	17.43	9.27	4.60	16.63	4.00	9.27	5.87	15.96	4.22	4.63	2.24	5.64	1.08
Ethylbenzene	9.60	5.73	19.50	4.44	2.41	1.38	3.49	0.73	2.20	1.42	3.53	0.82	1.33	0.82	1.59	0.30
m,p-Xylene	13.87	5.86	35.91	10.25	2.28	0.60	5.08	1.77	1.81	0.47	3.88	1.38	0.39	0.13	0.60	0.17
o-Xylene	9.43	5.51	16.66	4.61	11.24	8.18	13.52	2.07	9.60	7.92	12.06	1.55	7.28	4.09	8.44	1.68
Total BTEX	68.48	37.76	130.95	42.24	27.13	15.11	42.74	10.09	24.08	15.78	39.30	9.27	14.01	7.34	15.57	3.67

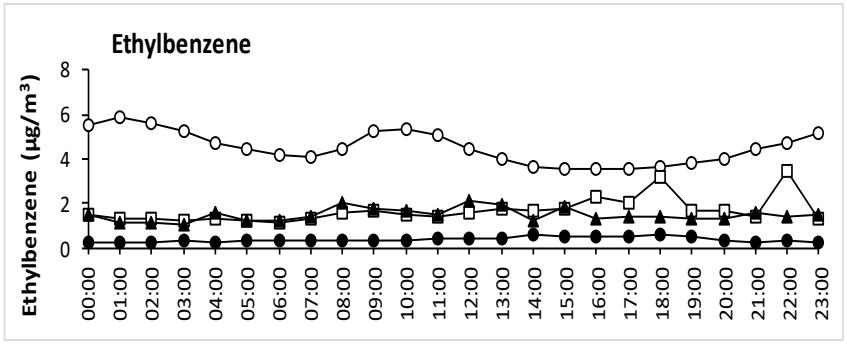
BTEX – Active Sampling – Hotspot site

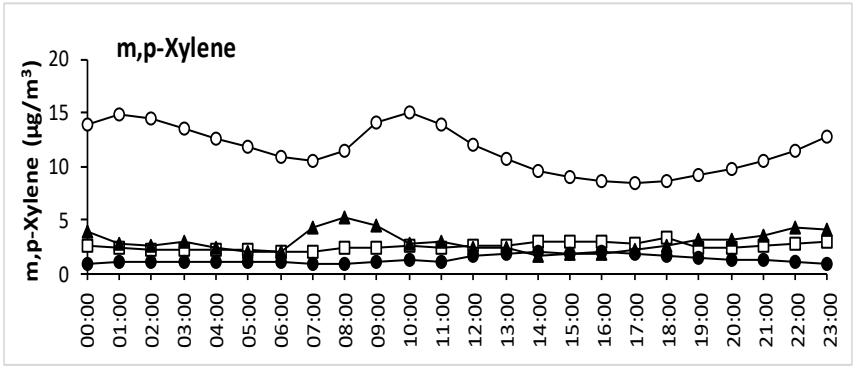
Compound	Roadside (*n*=11)				Petrol Station (*n*=8)				Airport (*n*=6)				Industrial (*n*=13)			
	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD	Avg	Min	Max	SD
Benzene	16.03	6.59	32.89	10.20	10.68	3.61	18.98	5.77	2.00	0.29	2.82	0.89	9.82	7.76	11.41	2.22
Toluene	104.57	64.62	163.66	51.54	31.36	15.73	54.64	16.15	7.89	4.52	9.38	1.79	8.37	3.89	19.88	4.71
Ethylbenzene	19.98	6.29	42.93	12.96	5.21	3.23	7.49	1.51	2.24	1.21	2.54	0.52	2.67	1.72	4.74	0.99
m,p-Xylene	37.85	10.72	88.06	28.03	5.68	1.85	11.71	3.88	0.65	0.30	1.21	0.30	3.70	0.47	14.17	1.64
o-Xylene	14.68	5.17	29.45	11.84	20.15	16.75	24.93	3.10	12.53	7.28	14.77	2.67	7.54	6.16	10.29	3.57
Total BTEX	193.11	93.39	356.99	114.57	73.08	41.18	117.76	30.41	25.30	13.59	30.72	6.17	32.10	20.00	60.49	13.13

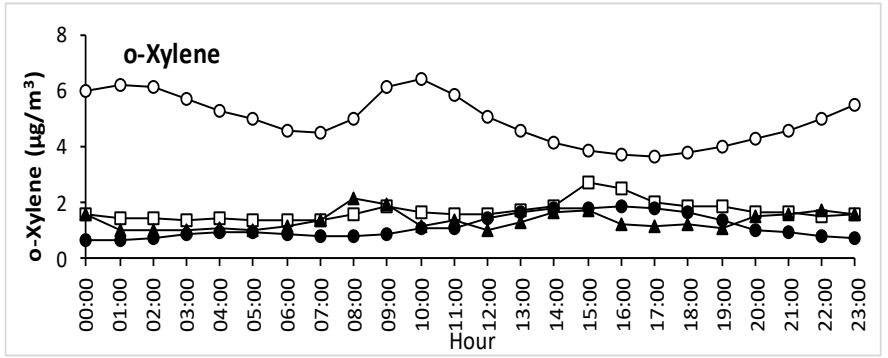
BTEX – Diurnal Concentration











Reference	Study site	Method	Benzene	Toluene	Ethylbenzene	m,p-Xylene	o-Xylene
This study							
UKMKL	Kuala Lumpur	Continuous sampling	6.20	22.31	4.52	11.57	4.96
UKMKL[a]	Kuala Lumpur	Active sampling	7.48	28.1	9.6	13.87	9.43
Kim Oanh et al. (2013)	Bangkok, Thailand (Roadside)	Active sampling	5.2-11	13-33	2.1-4.4	3.4-12	
Phuc and Kim Oanh (2018)	Hanoi, Vietnam (Ambient)	Continuous sampling	9	12	4	6	5
	Hanoi, Vietnam (Road side)	Active sampling	25-32	37-44	9-13	22-30	10-12
Giang and Kim Oanh (2014)	Ho Chi Minh, Vietnam (Ambient)	Continuous sampling	6-53	14-170	3-24	5-59	2-21
Srivastava (2005)	Delhi, India (Ambient)	Active sampling	300	34	34	1	1
Masih et al. (2016)	Northern India (Ambient)	Active sampling	15.9	28.2	3.8	2.8	
Zhang et al. (2012)	Beijing, China (Ambient)	Active sampling	4.95	9.71	3.23	5.36	2.41
Liu et al. (2013)	Beijing, China (Ambient)	Active sampling	2.68	5.88	1.99	3.31	1.9
Hu et al. (2018)	Hufei, China (Roadside)	Active sampling	10.58	13.29	11.01	9.84	0.96
Hoque et al. 2008	Delhi, India (Ambient)	Diffusive sampling	48	85	7	30	15
Dehghani et al. 2018	Shiraz, Iran (Ambient)	Active sampling	26.15	12.97	7.5	19.34	23.38
Hajizadeh et al. (2018)	Shiraz, Iran (Ambient)	Active sampling	21	38	14	41	

Hazard Index

CDI (mg/kg/day)				
BTEX	**UKMKL**	**UMT**	**UMS**	**FHRC**
Benzene	0.0017	0.0004	0.0006	0.0002
Toluene	0.0061	0.0022	0.0018	0.0008
Ethylbenzene	0.0012	0.0005	0.0004	0.0001
m,p-Xylene	0.0032	0.0007	0.0008	0.0003
o-Xylene	0.0014	0.0005	0.0004	0.0003

HQ				
BTEX	**UKMKL**	**UMT**	**UMS**	**FHRC**
Benzene	0.1979	0.0520	0.0718	0.0220
Toluene	0.0043	0.0016	0.0013	0.0005
Ethylbenzene	0.0043	0.0016	0.0014	0.0003
m,p-Xylene	0.1089	0.0236	0.0277	0.0120
o-Xylene	0.0467	0.0159	0.0129	0.0104
Hazard Index	**0.3621**	**0.0947**	**0.1151**	**0.0452**

Life Time Cancer Risk

CDI (mg/kg/day)				
BTEX	**UKMKL**	**UMT**	**UMS**	**FHRC**
Benzene	5.80×10^{-4}	1.52×10^{-4}	2.11×10^{-4}	6.46×10^{-5}
Ethylbenzene	4.23×10^{-4}	1.57×10^{-4}	1.38×10^{-4}	3.37×10^{-5}
LTCR				
	UKMKL	**UMT**	**UMS**	**FHRC**
Benzene	1.59×10^{-5}	4.16×10^{-6}	5.75×10^{-6}	1.77×10^{-6}
Ethylbenzene	1.63×10^{-6}	6.05×10^{-7}	5.33×10^{-7}	1.30×10^{-7}

Conclusion

- $PM_{2.5}$ and surface ozone are two major air pollutants in Kuala Lumpur urban environment
- Motor vehicles are the main sources of air pollutants
- Haze episode influences the concentration and composition of $PM_{2.5}$ that effect the human health.
- BTEX especially from motor vehicles can contribute to the long term carcinogenic effect to population in Kuala Lumpur

THANK YOU

http://www.ukm.my/talib/