Source apportionment of $PM_{2.5}$ during haze and non-haze episode in Kuala Lumpur

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Presentation Outline

- Introduction
- Main Methodology
- Chemical Massa Closure and Source Apportionment – Inorganic Substances (2011-2012)
- Composition of Organic Substances (2011-2012)
- Source apportionment based on organic composition
- Recent study on $PM_{2.5}$ 2015
- Conclusion

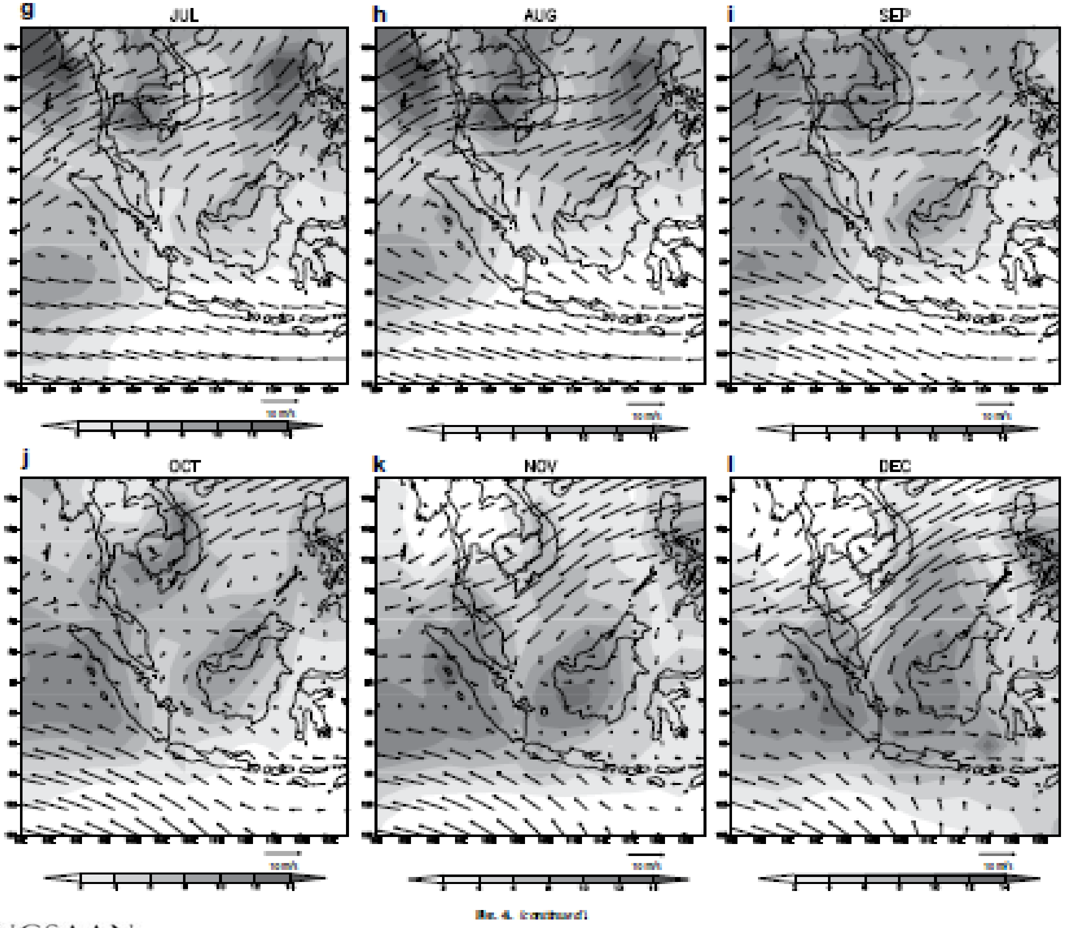
Introduction

- The biomass burning in South East Asia region has been reported since late of 19th century
- Since then several major forest fires in South East Asia have been recorded in 1972, 1987, 1990, 1994, 1997, 2004, 2005, 2012, 2013, 2014 and the latest in 2015.

Trigger to Biomass Burning

- In South East Asia biomass burning has become a traditional method of clearing land in the practice of shifting cultivation, which involves field rotation and the slashing and burning of a new plot of land once the existing plot has lost its fertility

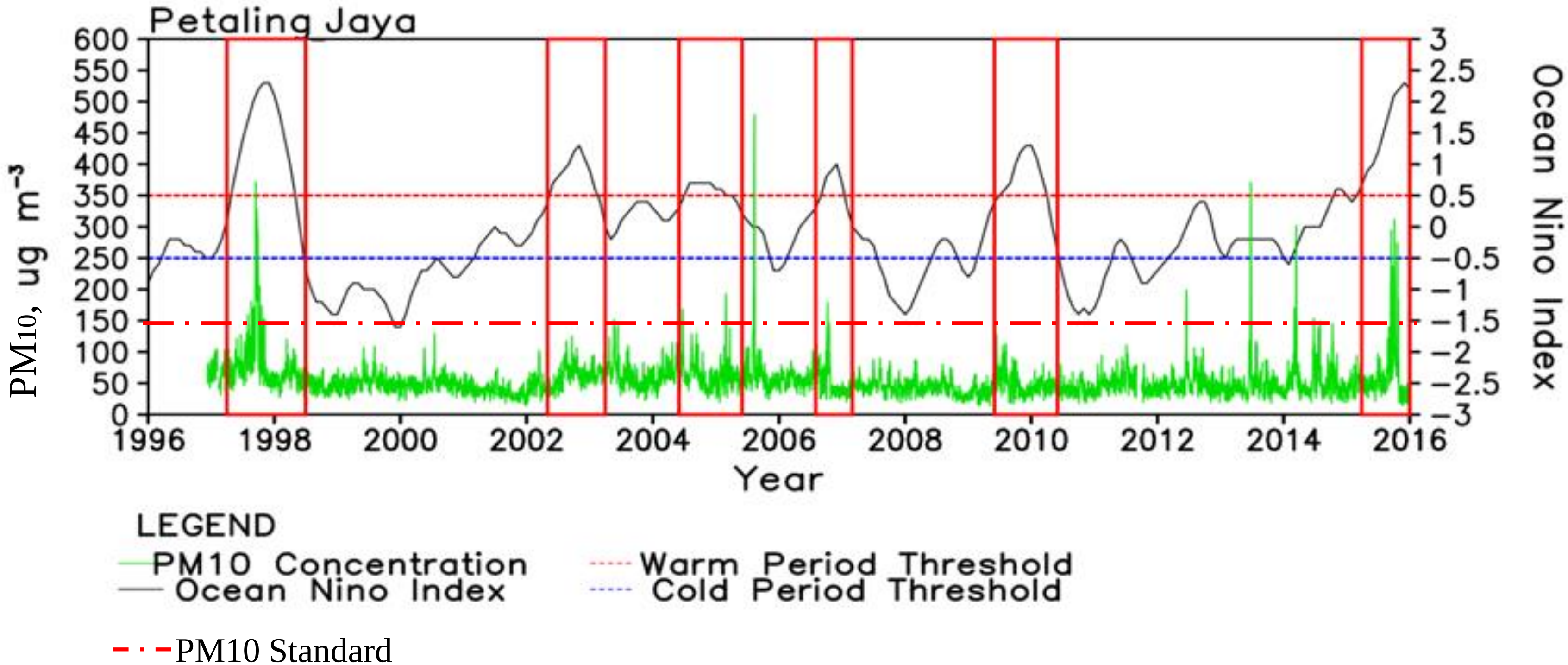
Wind Pattern



June to September Southwest monsoon

Atmosphere Investigation

PM_{10} Concentration in Petaling Jaya during El-Niño and La-Niña



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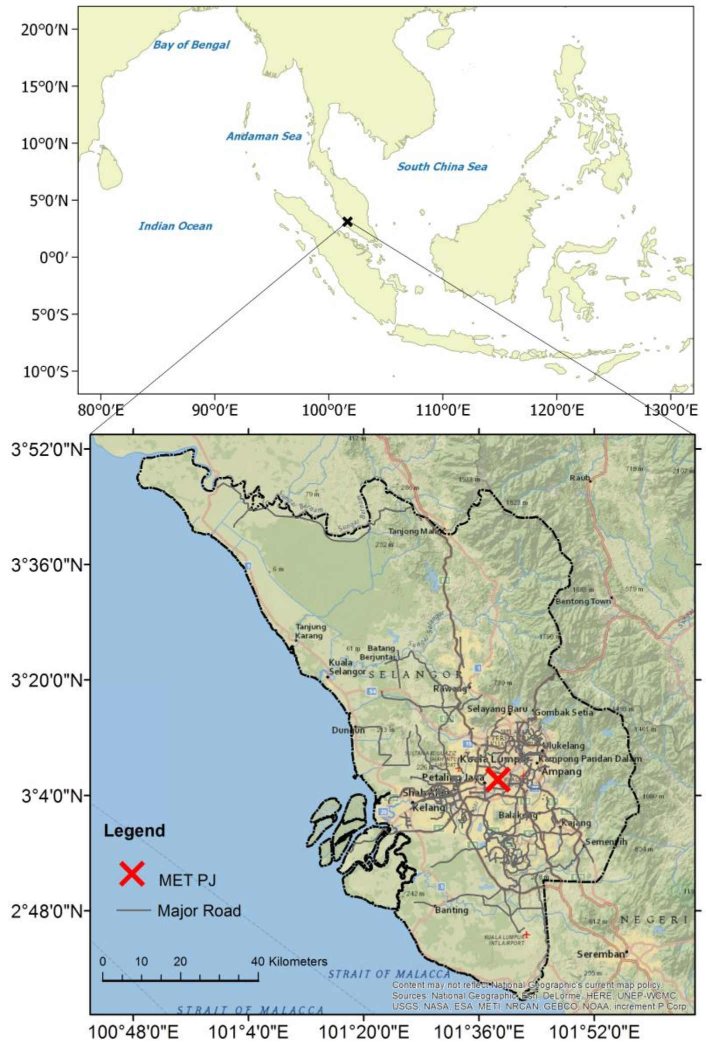
Research Objectives

1. To characterize the **seasonal variability** of the $PM_{2.5}$ mass concentration and particle number concentration (PNC)
2. To determines the **chemical compositions** of $PM_{2.5}$ in the urban environment
3. To identify the **major sources** of $PM_{2.5}$ in different seasons using source apportionment analysis – Positive Matrix Factorisation (PMF)

METHODOLOGY

Met Department, PJ
2011-2012
UKM Kuala Lumpur
2015-2016



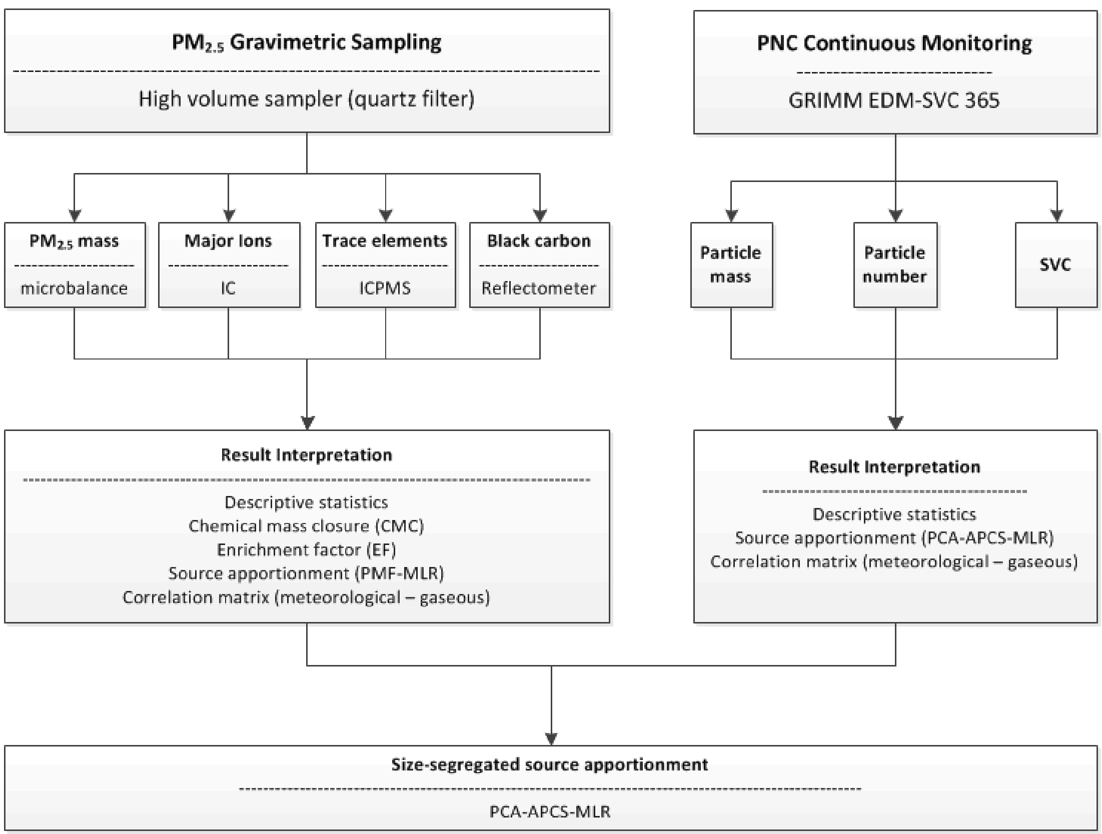
Aerosol Continuous Monitoring

- GRIMM EDM-SVC 365
- Flowrate of 1.2 L min^{-1}
- 1-min interval continuously
- 31 size channels : 265 – 34000 nm
- 2012 Jan – 2012 July
- Measuring principle: laser light scattering

$PM_{2.5}$ Gravimetric Sampling

- Tisch HVS $PM_{2.5}$
- Flowrate of 1.13 m^3 min^{-1}
- 24 h sampling/filter
- Quartz filter [Whatman QM-A; 8’ X 10’]
- 2011 August – 2012 July

Inorganic Composition



Organic Substances

- OC / EC - DRI model 2001 OC / EC carbon analyser - IMPROVE_A protocol.
- Solvent-extractable organic compounds (SEOC; biomarkers derived from biomass burning sources and n-alkanes) - GC-MS
- Analyses were conducted at Kyoto University

Chemical Mass Closure (CMC)

$$[PM_{2.5}] = [\text{Sea salt}] + [\text{Dust}] + [\text{SIA}] + [\text{TE}] + [\text{BC}] + [K^+] + [\text{Unidentified}] \qquad (3)$$

where, $[\text{Sea salt}] = [Na^+] + [Cl^-] + [Mg^{2+}] + [ss\text{-}K^+] + [ss\text{-}Ca^{2+}] + [ss\text{-}SO_4^{2-}]$;

with $[ss\text{-}K^+] = 0.036 \times [Na^+]$; $[ss\text{-}Ca^{2+}] = 0.038 \times [Na^+]$; and

$[ss\text{-}SO_4^{2-}] = 0.252 \times [Na^+]$

$[\text{Dust}] = [nss\text{-}Ca^{2+}] / 0.11$

$[\text{SIA}] = [nss\text{-}SO_4^{2-}] + [NO_3^-] + [NH_4^+]$;with $[nss\text{-}SO_4^{2-}] = [SO_4^{2-}] – [ss\text{-}SO_4^{2-}]$;

"nss-" standing for "non-sea salt"

US EPA Model

- **US EPA Models, Tools and Databases for Air Research**

  http://www.epa.gov/air-research/models-tools-and-databases-air-research

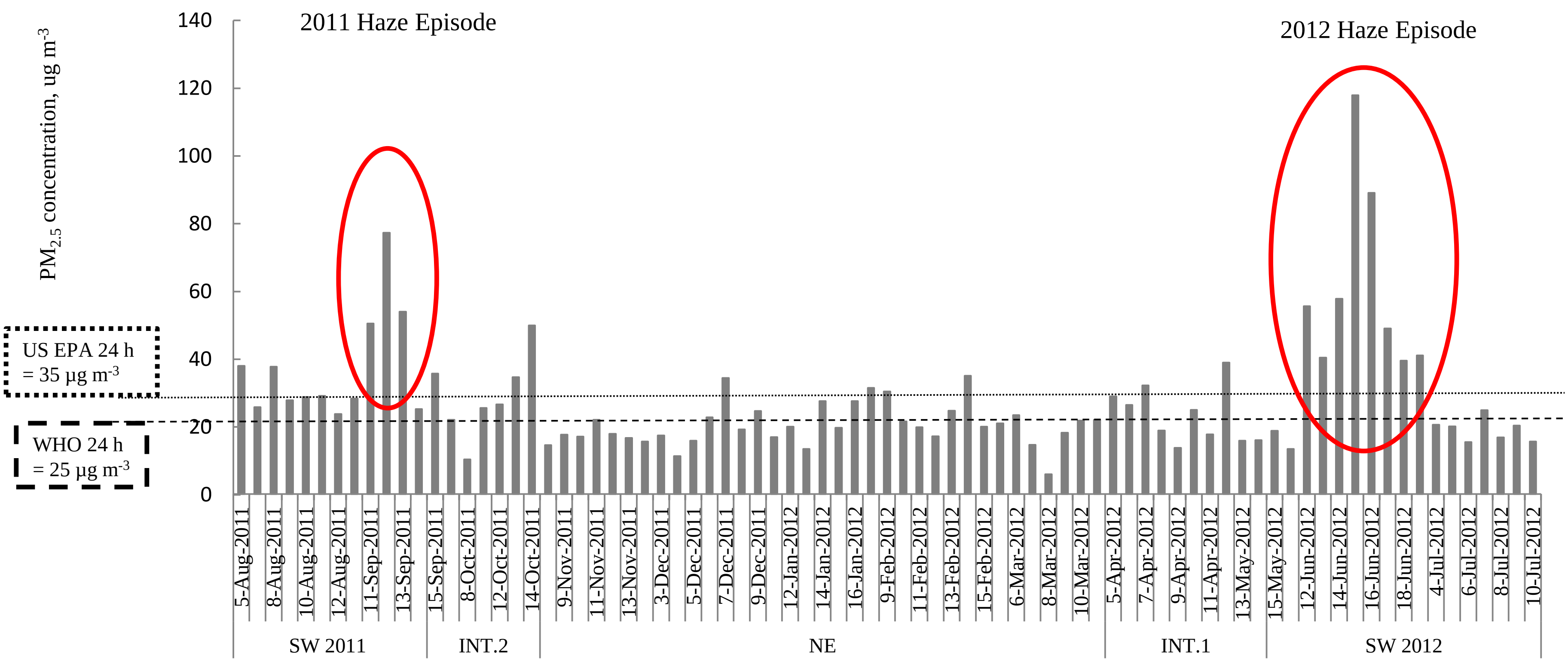
- Positive Matrix Factorization Model for environmental data analyses

  http://www.epa.gov/air-research/positive-matrix-factorization-model-environmental-data-analyses

- Download PMF 5.0

  http://www.epa.gov/sites/production/files/2015-03/epa_pmf_5.0_setup.exe

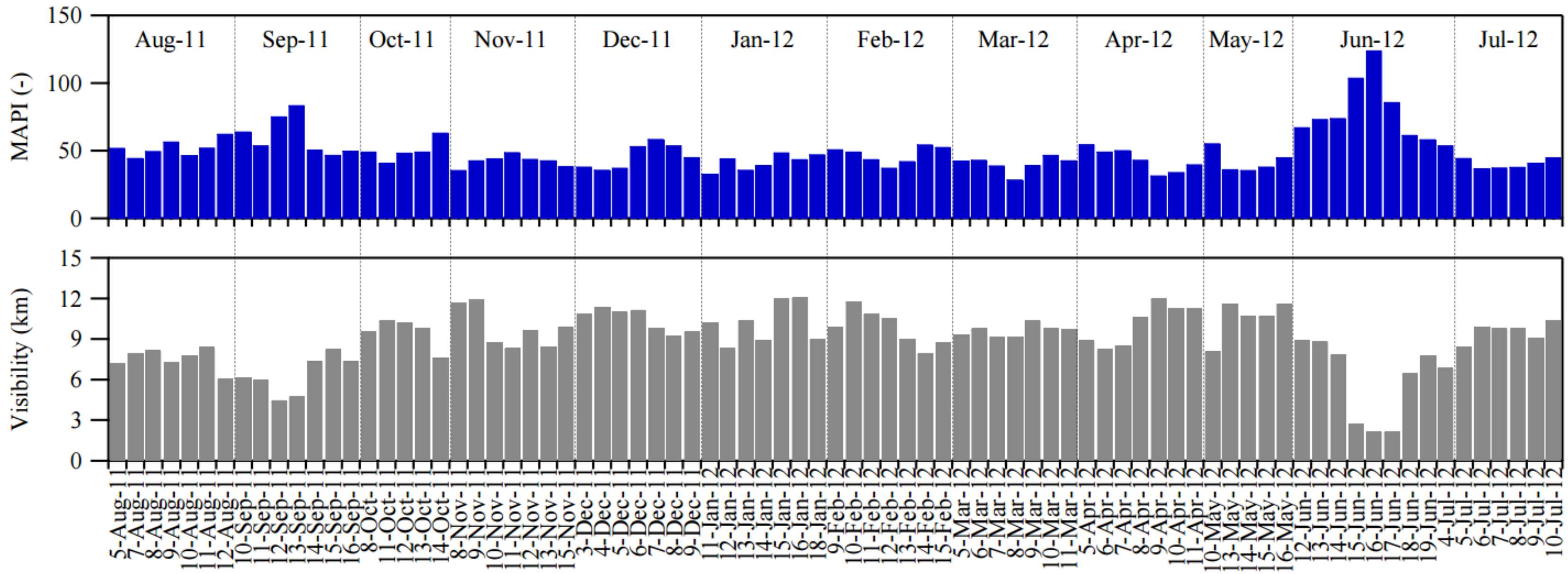
RESULTS



- Avg = 28 ± 18 µg m^{-3} ; 2.8 fold the WHO annual guideline
- Ranged = 6 to 118 µg m^{-3} ; 43% (samples) exceedance daily WHO guideline
- Except NE monsoon, other seasons >50% exceedance WHO & EU standards

Source: Amil et al.(2016)

Malaysian Air Pollutants Index (MAPI) and Visibility



Source: Fujii et al.(2015)

Descriptive statistics of $PM_{2.5}$ mass and particulate matter (PM) ratio in different monsoon

Elements	ANNUAL 5 Aug 2011–18 July 2012 $n = 81$	SW 15 May–14 Sept $n = 29$	INT.2 15 Sept–31 Oct $n = 7$	NE 1 Nov–14 Mar $n = 35$	INT.1 15 Mar–14 May $n = 10$	HAZE $n = 11$
$PM_{2.5}$ ($\mu g\, m^{-3}$)	28 ± 17 (6–118)	38 ± 24 (14–118)	29 ± 12 (10–50)	21 ± 6 (6–35)	23 ± 8 (14–39)	61 ± 24 (40–118)
$PM_{2.5}$ / PM_{10}	0.72 ± 0.18	0.72 ± 0.10	0.62 ± 0.17	0.71 ± 0.13	0.85 ± 0.40	0.74 ± 0.070
$PM_{2.5}$ / TSP	0.46 ± 0.13	0.50 ± 0.081	0.44 ± 0.12	0.40 ± 0.087	0.54 ± 0.22	0.54 ± 0.069
PM_{10} / TSP	0.63 ± 0.12	0.70 ± 0.087	0.71 ± 0.058	0.57 ± 0.12	0.65 ± 0.087	0.73 ± 0.12

(SW, API; more than 50)

Source: Amil et al. (2016)

METEOROLOGICAL FACTORS AND CHEMICAL COMPOSITION

Air quality, meteorological parameters and PM2.5 composition (annual and different monsoon)

Elements	Unit	ANNUAL 5 Aug 2011 - 18 July 2012 n = 81	SW 15 May - 14 Sept n = 29	INT.2 15 Sept - 30 Oct n = 7
API	-	50 ± 16 (29 - 127)	60 ± 21 (36 - 127)	49 ± 6 (40 - 59)
T	^oC	28.5 ± 1.19 (26.1 - 31.6)	28.9 ± 1.36 (26.4 - 31.6)	28.5 ± 1.20 (27.1 - 30.4)
RH	%	71.2 ± 7.91 (50.4 - 86.7)	68.2 ± 9.22 (50.4 - 86. 7)	72.9 ± 8.50 (59.7 - 82.7)
WS	ms^{-1}	1.29 ± 0.194 (0.873 - 1.77)	1.39 ± 0.187 (0.966 - 1.77)	1.25 ± 0.198 (1.01 - 1.53)
WD	Degree	129 ± 31.6 (23.1 - 208)	123 ± 38.0 (23.1 - 205)	128 ± 22.0 (100 - 167)
Rainfall	mm	10.4 ± 17.5 (0.000 - 85.4)	6.27 ± 10.6 (0.000 - 34.2)	8.46 ± 16.9 (0.000 - 45.4)
CO	ppm	1.29 ± 0.31 (0.61 - 2.16)	1.26 ± 0.32 (0.61 - 1.99)	1.43 ± 0.32 (1.10 - 1.93)
O_3	ppm	0.012 ± 0.006 (0.000 - 0.029)	0.010 ± 0.007 (0.000 - 0.025)	0.017 ± 0.008 (0.010 - 0.029)
SO_2	ppm	0.003 ± 0.001 (0.001 - 0.008)	0.004 ± 0.002 (0.001 - 0.008)	0.004 ± 0.001 (0.002 - 0.005)
NO_X	ppm	0.062 ± 0.013 (0.028 - 0.109)	0.057 ± 0.012 (0.028 - 0.076)	0.072 ± 0.013 (0.059 - 0.091)
NO	ppm	0.030 ± 0.010 (0.008 - 0.067)	0.025 ± 0.008 (0.008 - 0.041)	0.033 ± 0.008 (0.025 - 0.047)
NO_2	ppm	0.032 ± 0.007 (0.016 - 0.049)	0.032 ± 0.007 (0.016 - 0.048)	0.038 ± 0.006 (0.034 - 0.049)
SO_4^{2-}	$\mu g\ m^{-3}$	1.3 ± 0.88	1.8 ± 1.2	1.6 ± 0.78
ss-SO_4^{2-}	$\mu g\ m^{-3}$	0.076 ± 0.090	0.060 ± 0.023	0.022 ± 0.0079
nss-SO_4^{2-}	$\mu g\ m^{-3}$	1.3 ± 0.90	1.8 ± 1.2	1.61 ± 0.79
NO_3^-	$\mu g\ m^{-3}$	0.21 ± 0.13	0.19 ± 0.077	0.29 ± 0.22
NH_4^+	$\mu g\ m^{-3}$	0.99 ± 0.85	1.5 ± 1.2	1.00 ± 0.64
SIA	$\mu g\ m^{-3}$	2.4 ± 1.7	3.3 ± 2.3	2.8 ± 1.6
SIA/$PM_{2.5}$	%	8.5 ± 3.0	8.7 ± 3.4	9.6 ± 3.0
NR	-	0.26	0.31	0.21
SO_4^{2-}-SO_2	$\mu g\ m^{-3}$	1.3 - 8.2	1.8 - 9.5	1.6 - 10

Source: Amil et al.(2016)

Air quality, meteorological parameters and PM2.5 composition (haze and different monsoon)

Elements	Unit	NE 1 Nov - 14 Mar n = 35	INT.1 15 Mar - 14 May n = 10	HAZE n = 11
API	-	44 ± 8 (29 - 58)	45 ± 9 (33 - 58)	78 ± 22 (49 - 127)
T	^{o}C	28.1 ± 1.02 (26.1 - 30.4)	28.8 ± 0.78 (27.5 - 30.2)	29.5 ± 1.33 (26.7 - 31.6)
RH	%	73.6 ± 6.79 (56.5 - 85.5)	70.5 ± 4.01 (65.1 – 77.0)	63.0 ± 9.91 (50.4 - 81.6)
WS	ms^{-1}	1.20 ± 0.167 (0.873 - 1.46)	1.32 ± 0.18 (1.08 - 1.71)	1.49 ± 0.138 (1.27 - 1.70)
WD	Degree	132 ± 31.2 (83.2- 208)	128 ± 25.1 (103 - 178)	103 ± 33.2 (23.1 - 137)
Rainfall	mm	15.1 ± 22.7 (0.000 - 85.4)	7.04 ± 9.69 (0.000 – 24.0)	2.28 ± 5.18 (0.000 - 15.8)
CO	ppm	1.29 ± 0.30 (0.92 - 2.16)	1.32 ± 0.28 (0.84 - 1.75)	1.45 ± 0.31 (0.89 - 1.99)
O_3	ppm	0.013 ± 0.005 (0.004 - 0.025)	0.014 ± 0.004 (0.003 - 0.018)	0.016 ± 0.004 (0.011 - 0.025)
SO_2	ppm	0.003 ± 0.001 (0.001 – 0.005)	0.003 ± 0.001 (0.001 – 0.005)	0.003 ± 0.001 (0.001 - 0.005)
NO_X	ppm	0.065 ± 0.014 (0.044 - 0.109)	0.059 ± 0.011 (0.039 - 0.072)	0.057 ± 0.013 (0.028 - 0.074)
NO	ppm	0.034 ± 0.010 (0.021 - 0.067)	0.029 ± 0.008 (0.013 - 0.039)	0.022 ± 0.008 (0.008 - 0.038)
NO_2	ppm	0.031 ± 0.006 (0.021 - 0.049)	0.030 ± 0.008 (0.018 - 0.044)	0.035 ± 0.008 (0.020 - 0.048)
SO_4^{2-}	$\mu g\ m^{-3}$	0.98 ± 0.41	1.1 ± 0.70	2.4 ± 1.2
ss-SO_4^{2-}	$\mu g\ m^{-3}$	0.048 ± 0.029	0.16 ± 0.15	0.059 ± 0.00
nss-SO_4^{2-}	$\mu g\ m^{-3}$	0.95 ± 0.42	0.90 ± 0.60	2.4 ± 1.2
NO_3^-	$\mu g\ m^{-3}$	0.19 ± 0.13	0.27 ± 0.13	0.22 ± 0.14
NH_4^+	$\mu g\ m^{-3}$	0.65 ± 0.34	0.82 ± 0.49	2.2 ± 1.5
SIA	$\mu g\ m^{-3}$	1.7 ± 0.81	2.0 ± 0.88	4.7 ± 2.6
SIA/$PM_{2.5}$	%	8.2 ± 2.8	8.4 ± 2.3	7.5 ± 2.7
NR	-	0.22	0.17	0.35
SO_4^{2}-SO_2	$\mu g\ m^{-3}$	0.98 - 6.6	1.1 – 8.0	2.4 - 9.1

Source: Amil et al.(2016)

Composition – $PM_{2.5}$ and Major Ions

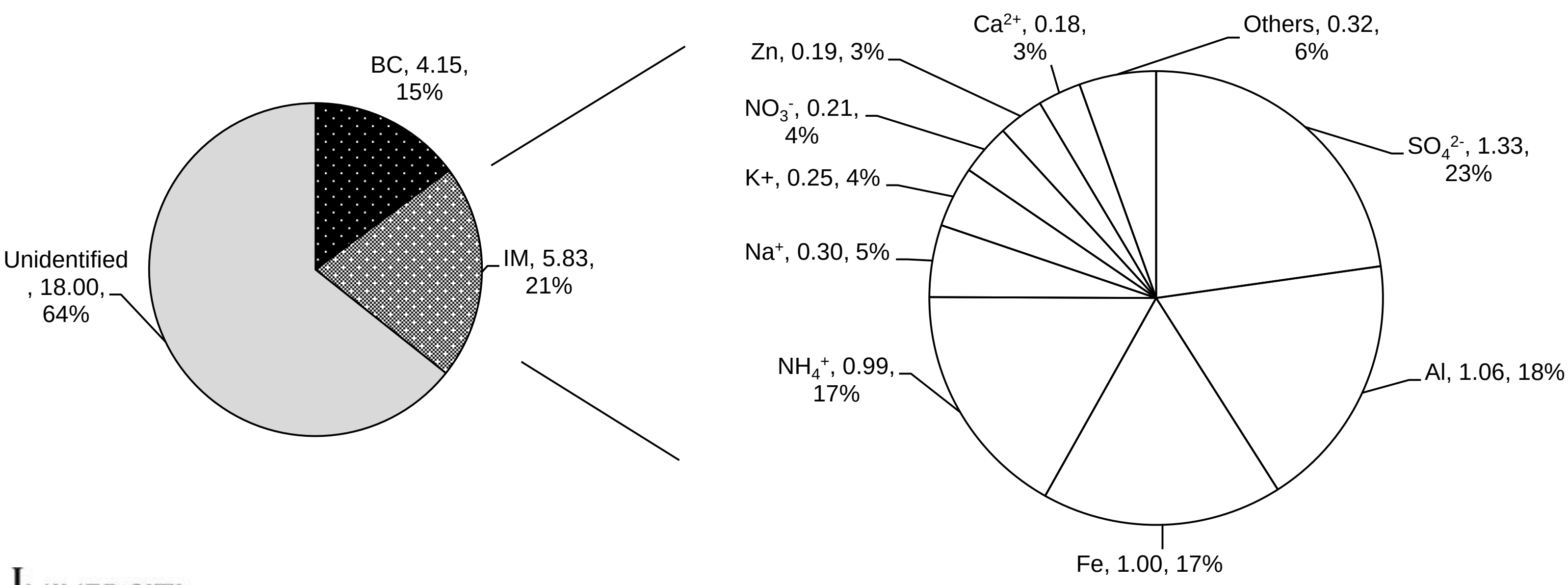
Elements	Unit	**ANNUAL**	**HAZE**
$PM_{2.5}$	µg/m^3	28 ± 17	61 ± 24
F^-	µg/m^3	ud	0.01 ± 0.01
Cl^-	µg/m^3	0.03 ± 0.03	0.03 ± 0.02
Br^-	µg/m^3	0.02 ± 0.01	n.d.
NO_3^-	µg/m^3	0.21 ± 0.13	0.22 ± 0.14
PO_4^{3-}	µg/m^3	0.08 ± 0.06	n.d.
SO_4^{2-}	µg/m^3	1.33 ± 0.88	2.4 ± 1.24
Na^+	µg/m^3	0.3 ± 0.36	0.23 ± 0
NH_4^+	µg/m^3	0.99 ± 0.85	2.21 ± 1.47
K^+	µg/m^3	0.25 ± 0.14	0.51 ± 0.17
Ca^{2+}	µg/m^3	0.18 ± 0.1	0.28 ± 0.21
Mg^{2+}	µg/m^3	0.03 ± 0.04	0.05 ± 0.03

Trace Element – Black Carbon

Elements	Unit	ANNUAL	HAZE
Al	µg/m^3	1.06 ± 1.23	2.79 ± 2.56
Ba	µg/m^3	0.04 ± 0.02	0.05 ± 0.03
Fe	µg/m^3	1 ± 0.71	1.9 ± 1.5
Pb	µg/m^3	0.11 ± 0.12	0.09 ± 0.03
Zn	µg/m^3	0.19 ± 0.1	0.17 ± 0.09
Ag	ng/m^3	0.14 ± 0.1	n.d.
As	ng/m^3	0.38 ± 0.15	0.34 ± 0.06
Cd	ng/m^3	0.13 ± 0.14	0.13 ± 0.05
Cr	ng/m^3	3.94 ± 6.36	2.87 ± 1.91
Be	ng/m^3	ud	1.46 ± 0.75
Co	ng/m^3	0.02 ± 0.01	0.03 ± 0.03
Cu	ng/m^3	2.74 ± 1.89	3.49 ± 1.96
Mn	ng/m^3	0.93 ± 0.64	1.39 ± 1.06
Ni	ng/m^3	0.48 ± 0.47	0.59 ± 0.5
Rb	ng/m^3	1.01 ± 0.5	1.78 ± 0.61
Se	ng/m^3	0.11 ± 0.07	0.21 ± 0.09
Sr	ng/m^3	0.27 ± 0.22	0.46 ± 0.39
U	ng/m^3	ud	3.82 ± 2.83
V	ng/m^3	0.92 ± 0.56	1.02 ± 0.57
BC	µg/m^3	4.15 ± 0.64	4.61 ± 0.33

Overall Inorganic Composition

- Anions + cations + TE + BC = 36% of $PM_{2.5}$ mass
- CMC = BC > SIA > Dust > TE > Sea salt > K^+
- EF = anthropogenic sources (Pb, Se, Zn, Cd, As, Bi, Ba, Cu, Rb, V and Ni) and crustal sources (Sr, Mn, Co, and Li)
- Both primary & secondary pollutants of $PM_{2.5}$ equally important, albeit seasonal variability



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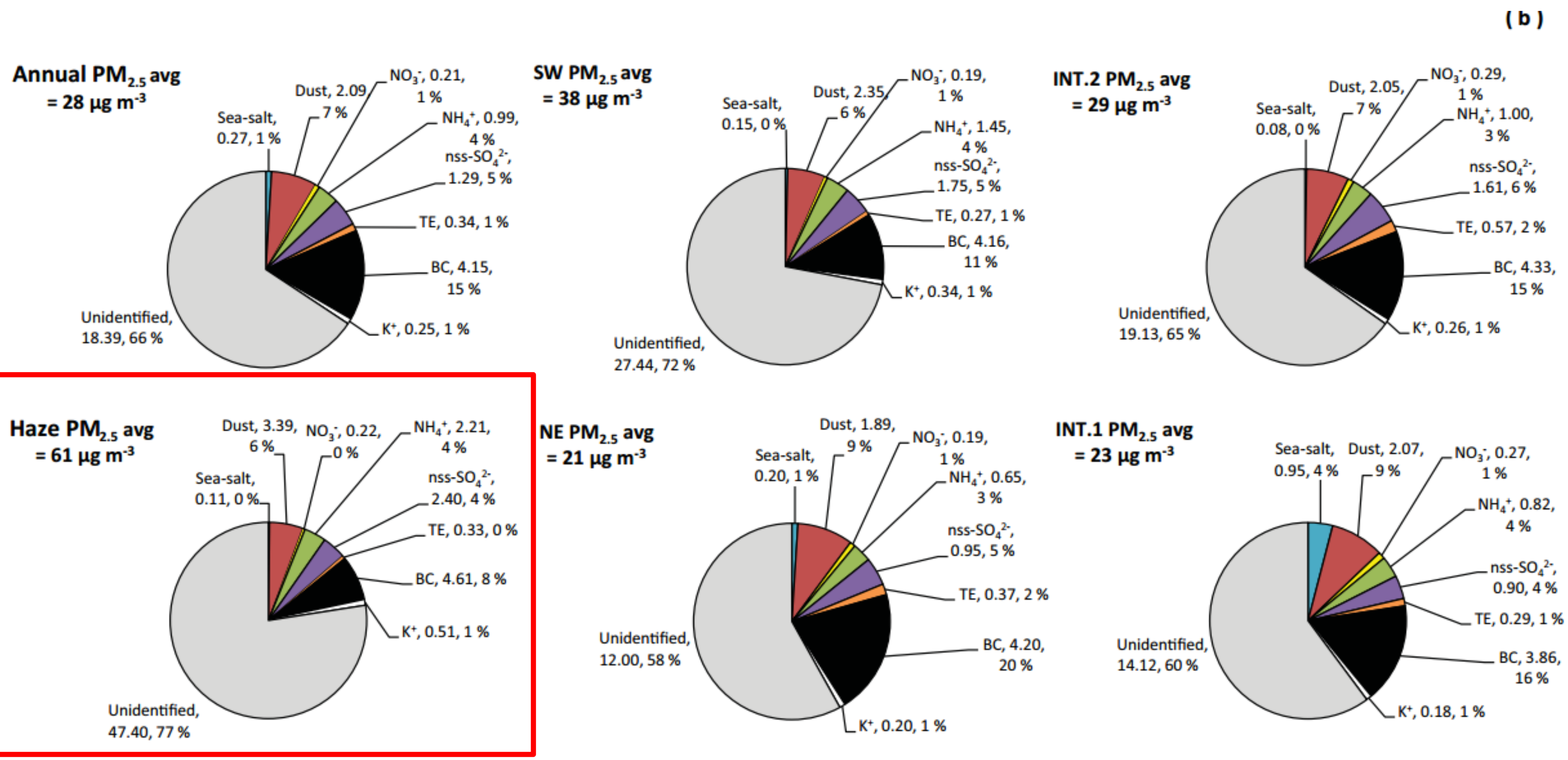
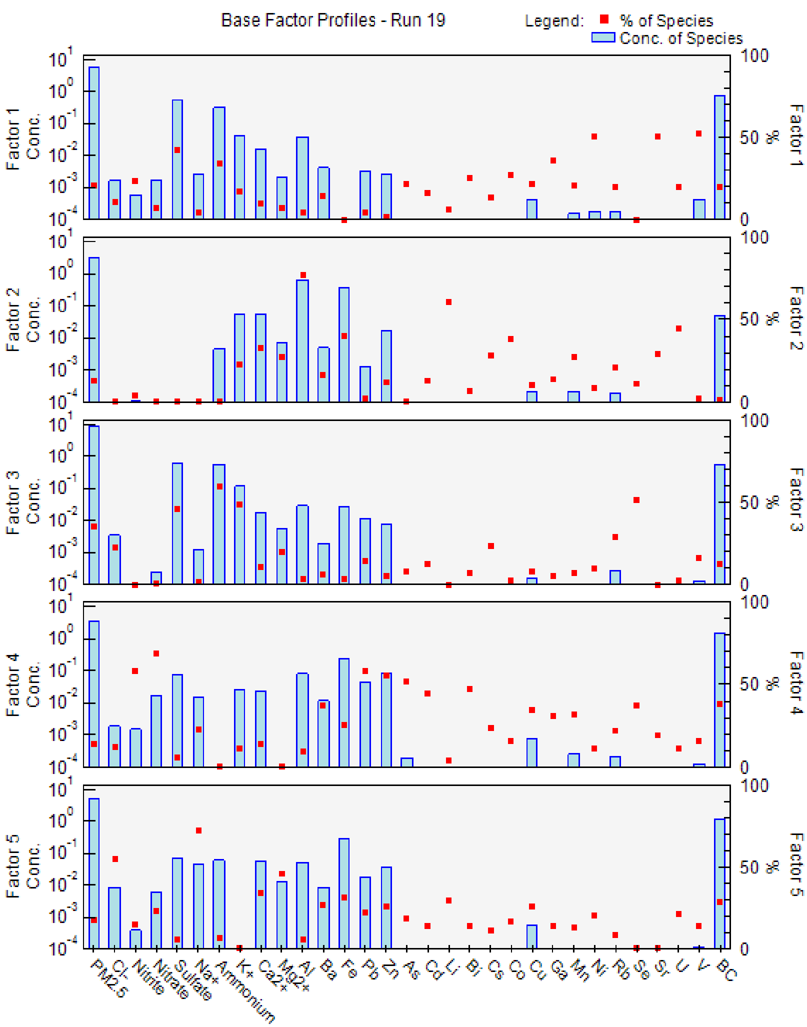
Chemical Mass Closure (CMC)



Source: Amil et al.(2016)

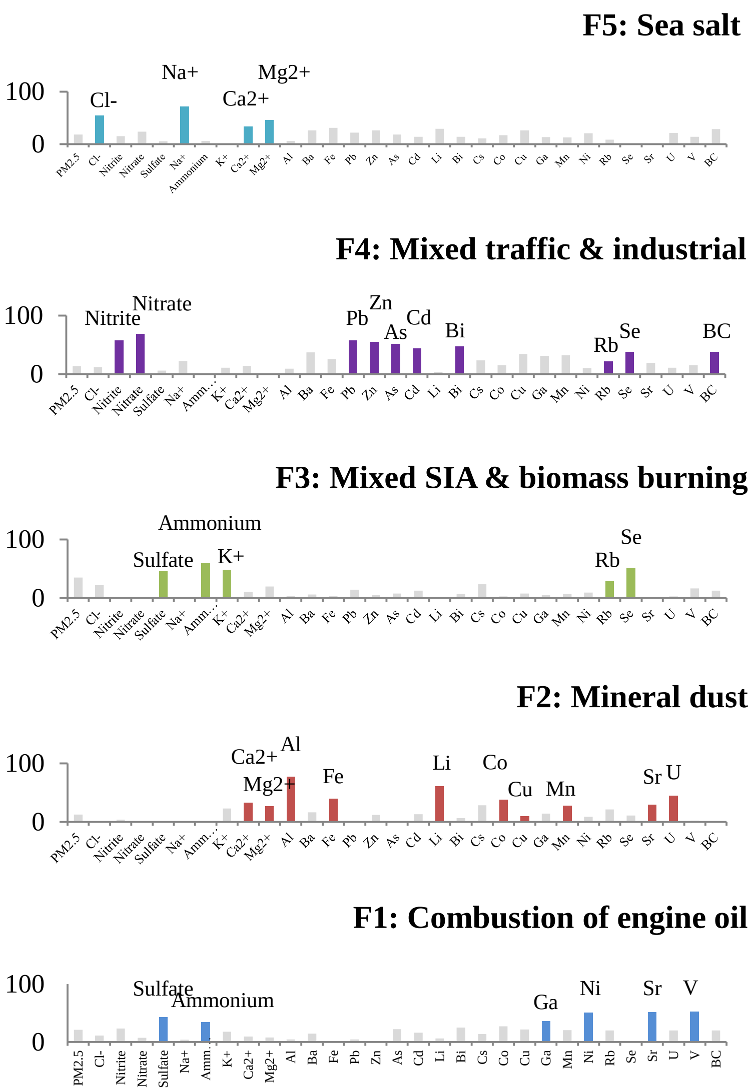
Source Apportionment

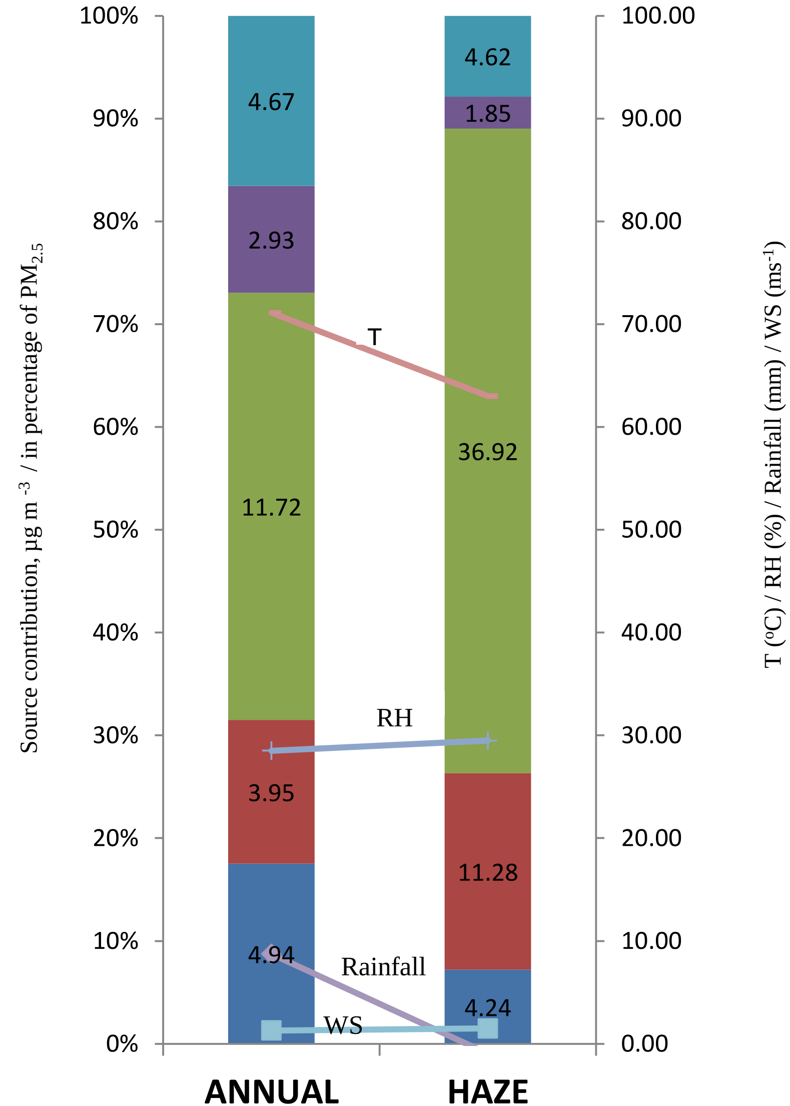


Source contribution, µg m^{-3} (%)	ANNUAL	SW	INT.2	NE	INT.1	HAZE
Factor 1: Combustion of engine oil	4.94 (17%)	6.47 (17%)	7.08 (24%)	3.50 (16%)	3.98 (16%)	4.24 (7%)
Factor 2: Mineral dust	3.95 (14%)	5.49 (15%)	4.58 (16%)	3.18 (15%)	1.62 (7%)	11.28 (19%)
Factor 3: Mixed SIA and biomass burning	11.72 (42%)	19.05 (51%)	9.99 (35%)	7.44 (34%)	6.21 (26%)	36.92 (63%)
Factor 4: Mixed traffic and industrial	2.93 (10%)	1.30 (4%)	5.42 (19%)	4.28 (20%)	1.29 (6%)	1.85 (3%)
Factor 5: Sea salt	4.67 (17%)	4.98 (13%)	1.80 (6%)	3.20 (15%)	10.76 (45%)	4.62 (8%)

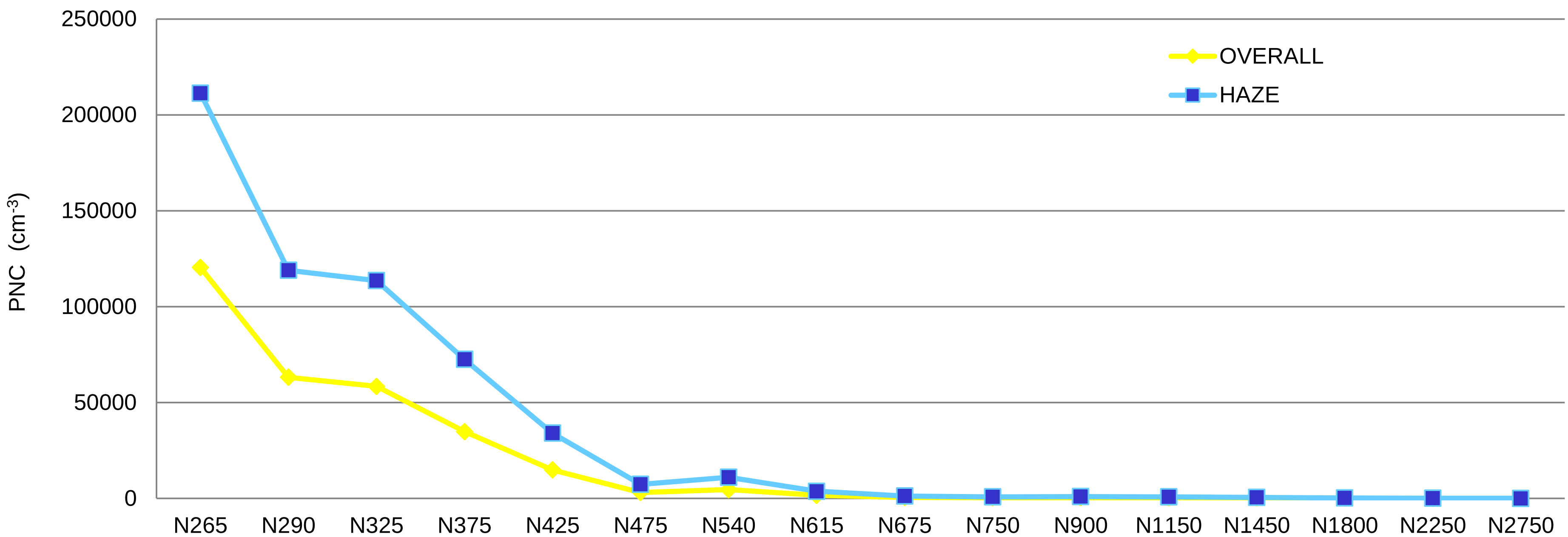
Atmosphere Investigation

PMF-MLR SOURCE APPORTIONMENT: PM2.5 CHEMICAL COMPOSITION (INORGANIC & BC)





PARTICLE NUMBER DISTRIBUTION (PNC) : 265 – 2750 nm (0.265 – 2.75 µm)



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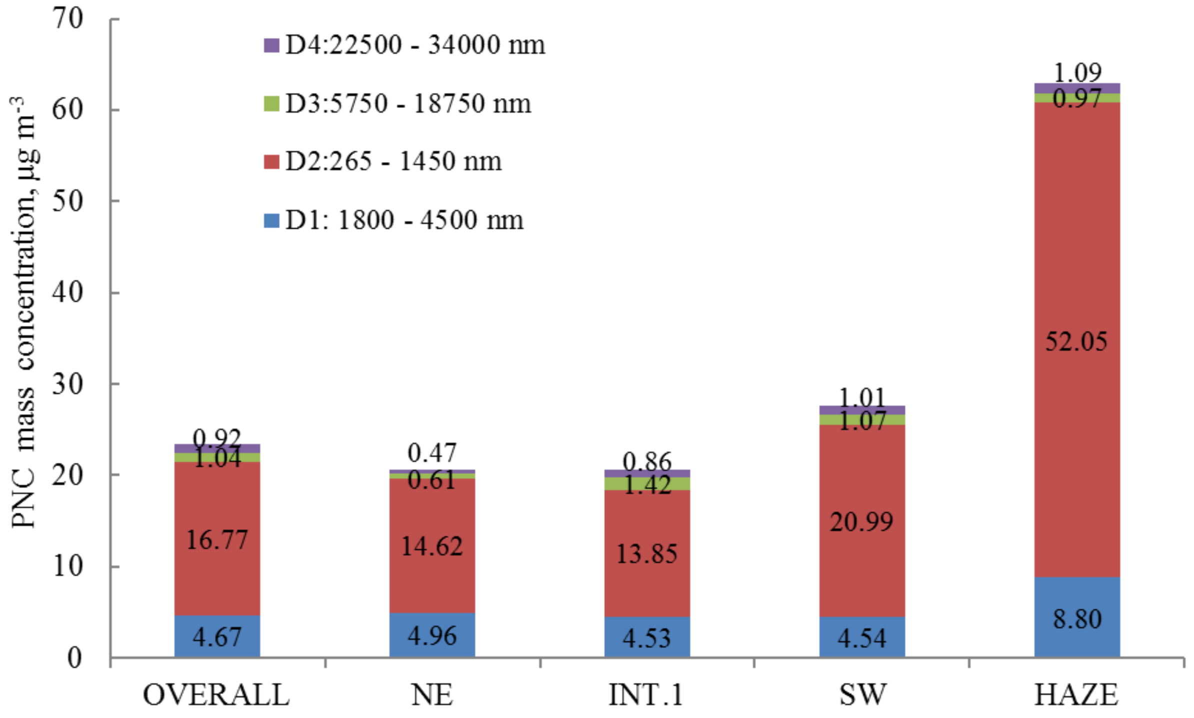
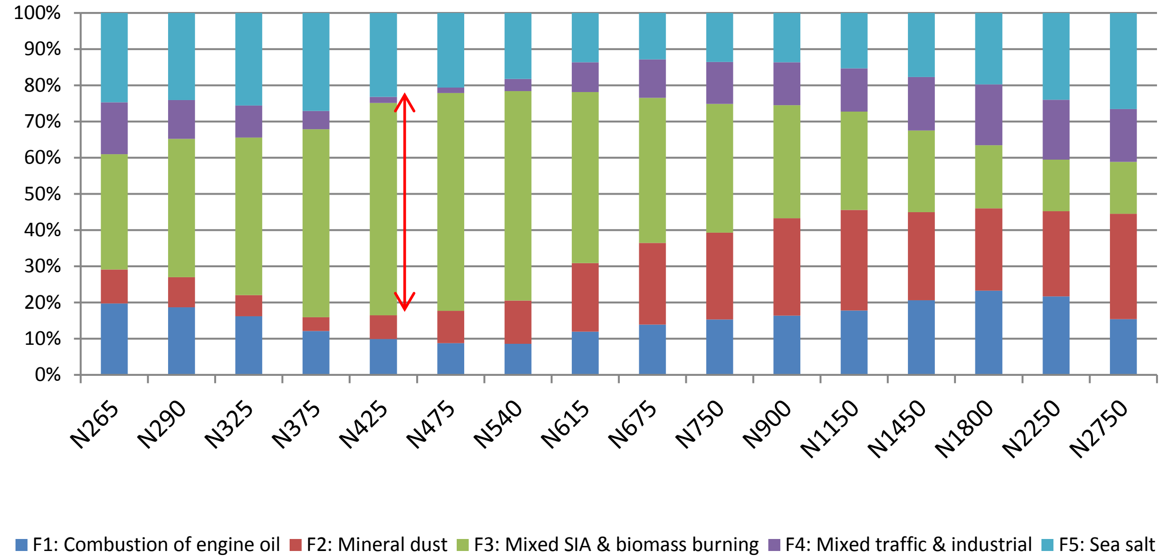
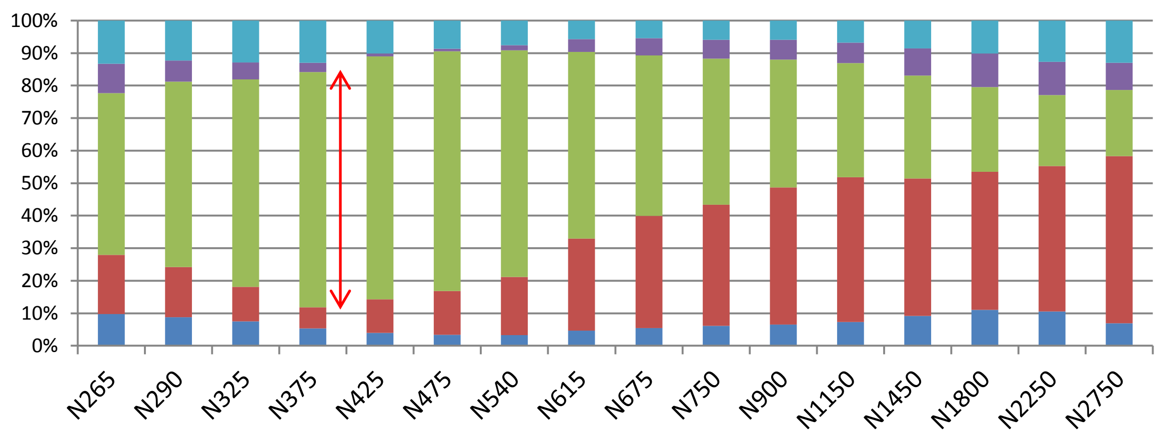


PMF- MLR SOURCE APPORTIONMENT: PNC (265 – 2750 nm) - $PM_{2.5}$ SOURCES

OVERALL (JAN – JULY 2012)



HAZE 2012



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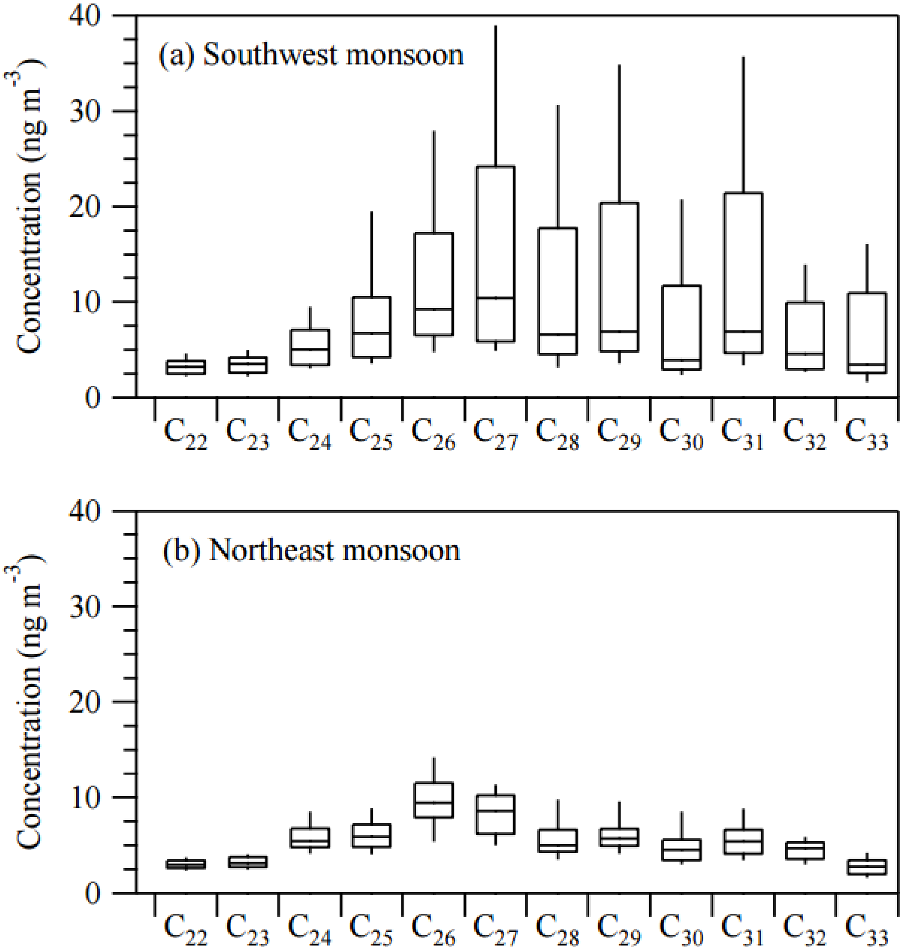
ORGANIC COMPOSITION

Compounds	Southwestern monsoon (June–September) Av ± SD	Range	Post-monsoon (October–November) Av ± SD	Range	Northeastern monsoon (December–March) Av ± SD	Range	Pre-monsoon (April–May) 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


(a) Southwest monsoon
Concentration (ng m-3)
40
30
20
10
0
C22
C23
C24
C25
C26
C27
C28
C29
C30
C31
C32
C33
(b) Northeast monsoon
Concentration (ng m-3)
40
30
20
10
0
C22
C23
C24
C25
C26
C27
C28
C29
C30
C31
C32
C33

Source Apportionment using Organic Substances

- Varimax-rotated PCA was used to identify the possible carbonaceous $PM_{2.5}$ sources at PJ.

- Two data sets were considered: (i) PJ_A data, which includes 25 variables (all quantified compounds) and 81 samples (all samples),

- and (ii) PJ_S data, which includes 25 variables and 65 samples (excluded are the samples acquired in September 2011 and June 2012, which are influenced by Indonesian peatland fires (IPFs).

Source Apportionment

Factor A1, which explains 60%of the variance, is heavily loaded (loading factor: > 0.65) with OC, LG, MN, galactosan, p-hydroxybenzoic acid, VA and C25–C33, which direct towards an IPF source.

Factor A2, which corresponds to 12% of the variance, is heavily loaded with C22–C24, suggesting a petrogenic source (Abas et al., 2004a; Gogou et al., 1996; He et al., 2010).

Factor A3, which explains 8.0% of the variance in the data set, is heavily loaded with SA and dehydroabietic acid, indicating mixed (softwood and hardwood) biomass burning sources.

(a)	A1	A2	A3
OC	0.97	0.10	0.16
EC	0.29	0.37	0.51
Levoglucosan	0.81	−0.05	0.17
Mannosan	0.89	0.00	0.11
Galactosan	0.90	0.02	0.08
p-Hydroxybenzoic acid	0.94	0.04	0.22
Vanillin	0.61	0.15	0.25
Syringaldehyde	−0.17	0.12	0.40
Vanillic acid	0.65	−0.10	0.55
Syringic acid	0.28	−0.11	0.81
Dehydroabietic acid	0.15	−0.01	0.86
Cholesterol	0.36	0.14	0.39
C_{22}	0.03	0.95	0.05
C_{23}	0.07	0.95	0.05
C_{24}	0.30	0.92	0.06
C_{25}	0.81	0.54	0.14
C_{26}	0.86	0.43	0.13
C_{27}	0.95	0.23	0.13
C_{28}	0.96	0.18	0.07
C_{29}	0.97	0.13	0.12
C_{30}	0.92	0.25	0.05
C_{31}	0.97	0.10	0.13
C_{32}	0.93	0.15	0.11
C_{33}	0.97	0.10	0.13
% variance	60	12	8.0
% cumulative	60	72	80

Source Apportionment

(b)	S1	S2	S3	S4	S5
OC	0.47	0.47	0.10	0.08	0.57
EC	0.39	0.20	0.25	0.26	0.65
Levoglucosan	0.09	0.71	−0.03	−0.52	0.19
Mannosan	0.19	0.84	0.02	−0.26	0.28
Galactosan	0.17	0.83	0.06	−0.09	0.41
p-Hydroxybenzoic acid	0.26	0.62	0.08	0.23	0.42
Vanillin	0.22	0.32	0.07	0.05	0.61
Syringaldehyde	0.24	0.13	0.01	0.74	0.07
Vanillic acid	−0.12	0.81	−0.04	0.22	−0.01
Syringic acid	0.02	0.81	0.00	0.37	0.26
Dehydroabietic acid	0.18	0.44	0.04	0.12	0.60
Cholesterol	0.01	0.17	0.15	−0.21	0.77
C_{22}	0.05	−0.02	0.97	−0.04	0.05
C_{23}	0.05	0.00	0.97	−0.04	0.04
C_{24}	0.28	−0.03	0.94	0.04	−0.01
C_{25}	0.33	0.10	0.85	0.05	0.35
C_{26}	0.61	0.05	0.68	0.14	0.24
C_{27}	0.67	0.08	0.53	0.10	0.35
C_{28}	0.86	0.06	0.27	−0.01	0.01
C_{29}	0.89	0.14	0.18	0.08	0.29
C_{30}	0.84	0.03	0.33	0.04	−0.12
C_{31}	0.77	0.24	0.07	0.10	0.47
C_{32}	0.88	−0.04	0.02	0.10	0.16
C_{33}	0.72	0.28	−0.03	0.14	0.49
% variance	43	19	11	5.0	4.5
% cumulative	43	62	72	77	82

Factor S1 explains 43% of the data's variance and is heavily loaded with C27–C33, which suggests tire wear emission.

Factor S2 explains 19% of the variance and is heavily loaded with LG, MN, galactosan, VA and SA, which correspond to a biomass burning source.

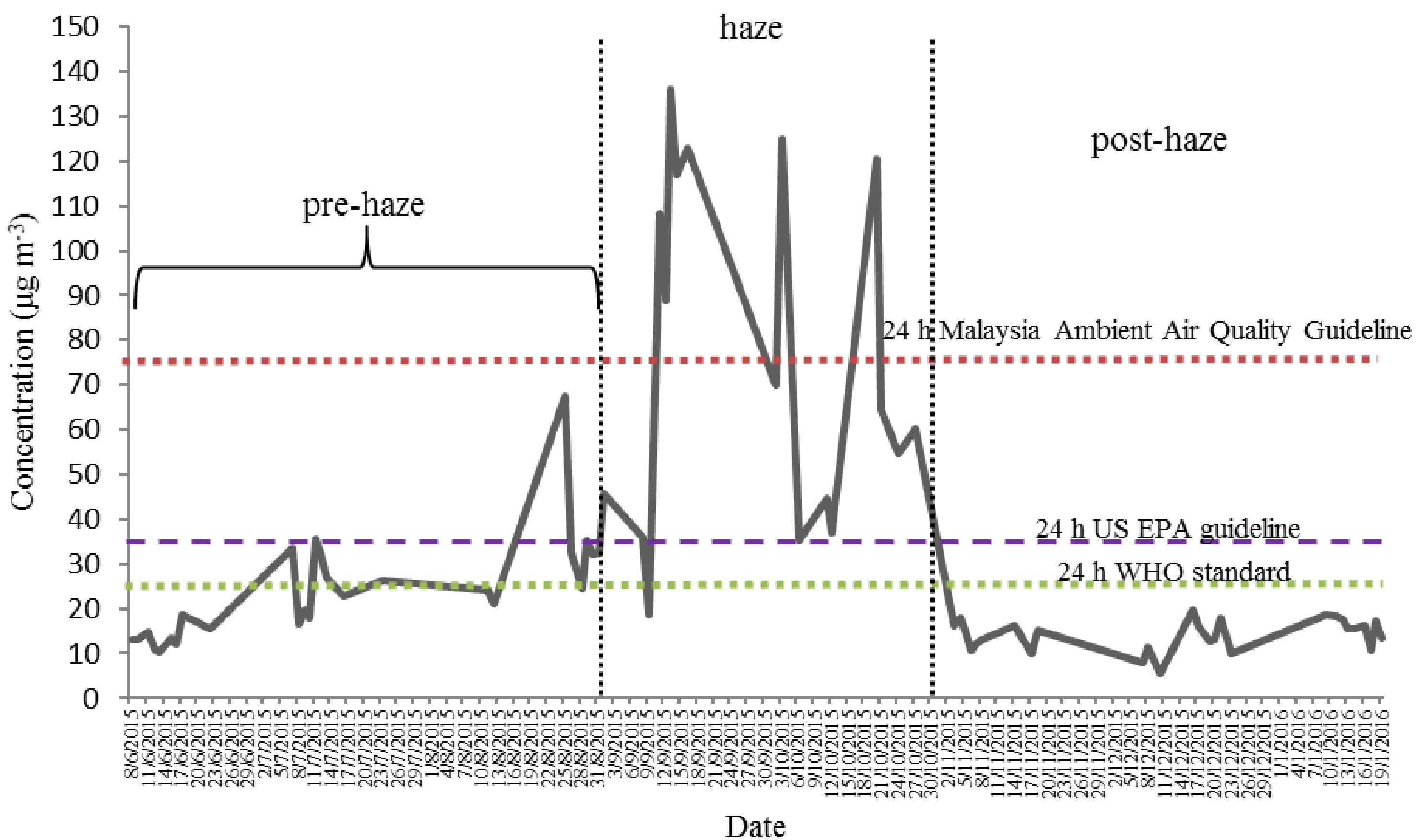
Factor S3, which explains 11% of the variance, is heavily loaded with C22–C26, which indicatea petrogenic source.

Although heavy loading with only syringaldehyde is found in factor S4 (5.0% of the variance), its source could not be identified.

Factor S5 explains 4.5% of the variance and is heavily loaded with EC and cholesterol, which are produced when cooking meat.

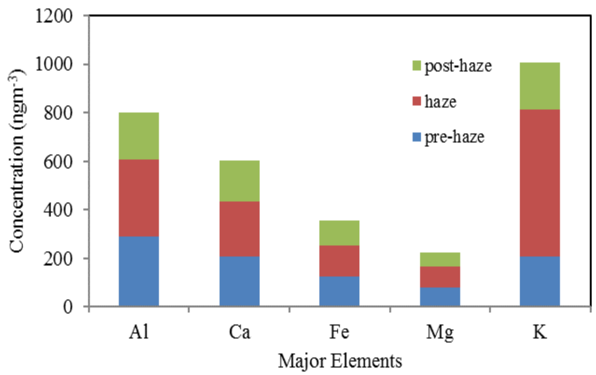
RECENT STUDY
$PM_{2.5}$ in Kuala Lumpur City Centre (2015)

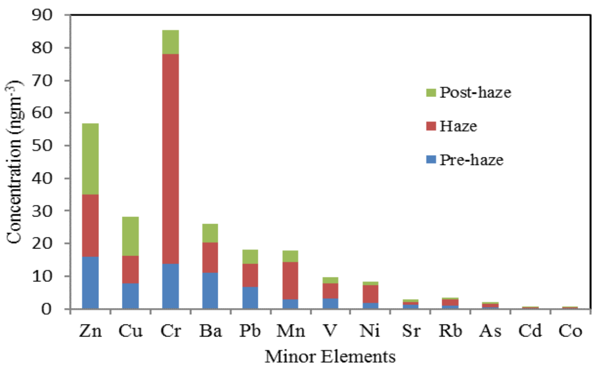
$PM_{2.5}$ Concentrations

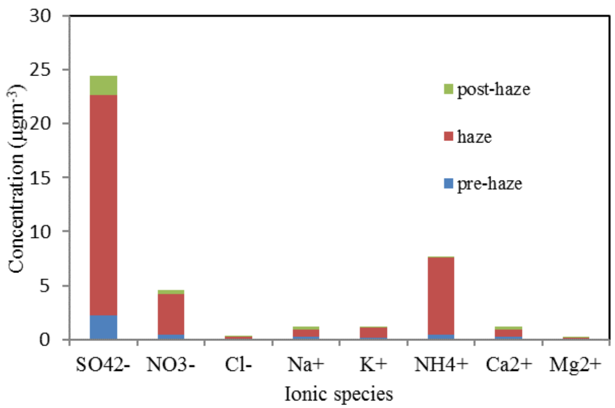


Atmosphere Investigation

Inorganic Composition of $PM_{2.5}$ (2015)







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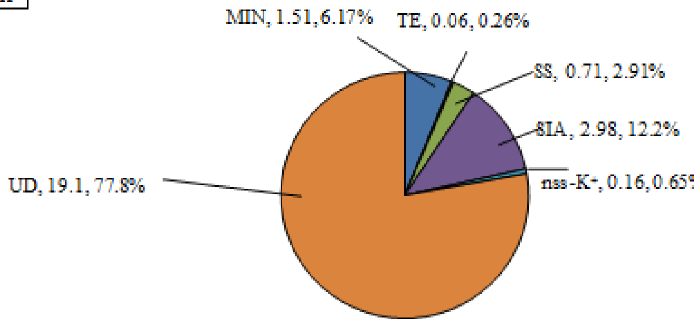
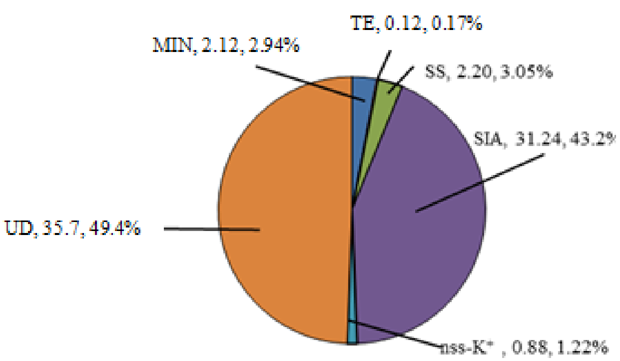
Chemical Mass Closure of $PM_{2.5}$ (2015)

$PM_{2.5} = 24.5 \pm 12.0\ \mu gm^{-3}$



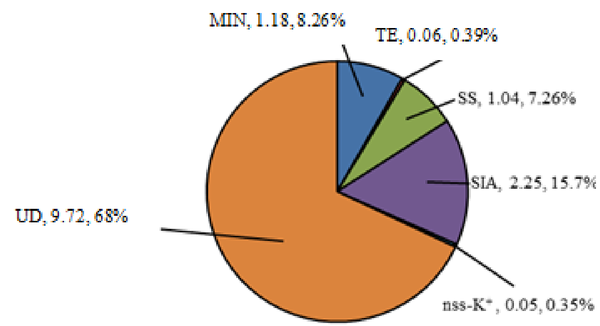
(a) Pre-haze

$PM_{2.5} = 72.3 \pm 38.0\ \mu gm^{-3}$



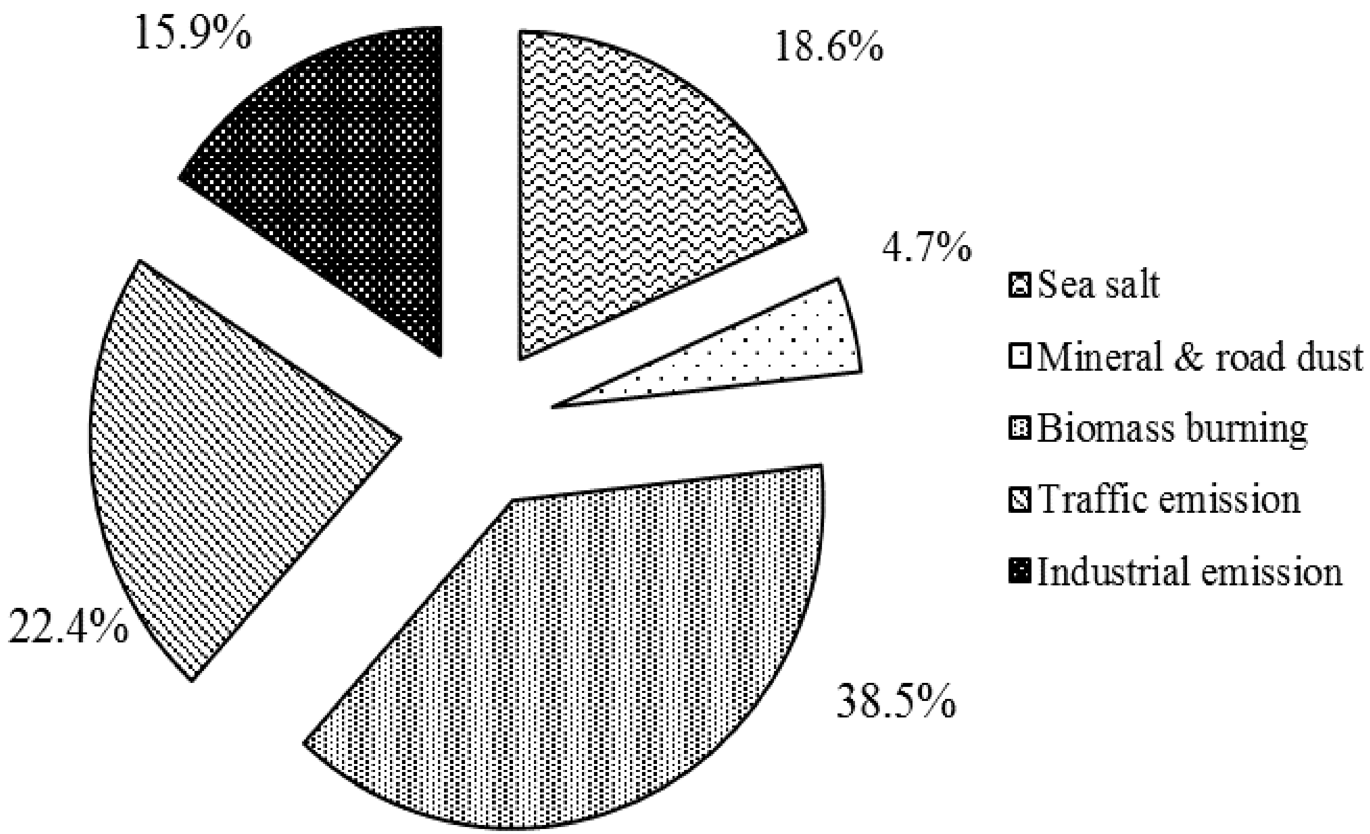
(b) Haze

$PM_{2.5} = 14.3 \pm 3.58\ \mu gm^{-3}$



(c) Post-haze

Source Apportionment of $PM_{2.5}$ (2015)



Need further assessment…

Conclusion

- $PM_{2.5}$ concentration in Kuala Lumpur urban environment exceed the limit of WHO, USEPA and Malaysia Air Quality Standard during haze episode.
- Several ionic compositions (e.g. SO_4^{2-}, NH_4^+, K^+, Ca^{2+}) and trace metals (Al, Fe, U, Be) are significantly higher during haze episode
- Five major sources were determined as main contributor of $PM_{2.5}$ based on inorganic composition.
- Biomarmaker such as Levoglucosan is a good indicator of biomass burning. Long-changed alkanes (C_{25}– C_{31}) dominate the organic molecules in $PM_{2.5}$ during biomass burning.

Conclusion

- PNC dominates by fine and ultrafine particles
- Biomass burning, petrogenic emission, tire wear emission and cooking meat are major sources of organic composition in $PM_{2.5}$.
- Next: Health risk impact assessment

Further Reading

- Fujii, Y., Tohno, S., Amil, N., Latif, M. T., Oda, M., Matsumoto, J., and Mizohata, A. (2015b). Annual variations of carbonaceous PM2.5 in Malaysia: influence by Indonesian peatland fires. Atmos. Chem. Phys. 15, 13319-13329.

- Amil, N., Latif, M. T., Khan, M. F., and Mohamad, M. (2016). Seasonal variability of PM2.5 composition and sources in the Klang Valley urban-industrial environment. Atmos. Chem. Phys. 16, 5357-5381.

- Khan, M. F., Latif, M. T., Saw, W. H., Amil, N., Nadzir, M. S. M., Sahani, M., Tahir, N. M., and Chung, J. X.: Fine particulate matter in the tropical environment: monsoonal effects, source apportionment, and health risk assessment, Atmos. Chem. Phys., 16, 597-617,

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- Malaysian Department of Environment – Air pollution data.