10.1071/EN22044
Environmental Chemistry

Supplementary Material

Airborne particulate matter in Southeast Asia: a review on variation, chemical compositions and source apportionment

Supattarachai Saksakulkrai[A], *Somporn Chantara*[B,C] and *Zongbo Shi*[A,*]

[A]School of Geography Earth and Environmental Sciences, University of Birmingham, Birmingham, B15 2TT, UK

[B]Environmental Science Research Center, Chiang Mai University, Chiang Mai, 50200, Thailand

[C]Environmental Chemistry Research Laboratory, Chemistry Department, Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand

*Correspondence to: Email: z.shi@bham.ac.uk

Table S1-1 Contribution of OC and EC (%) to PM mass in SEA countries

Country	Season	Site	PM size	OC	EC	TC	OC/EC	Ref
Thailand								
Phimai	dry	Rural	PM10	28.8	6.1	34.9	4.8	(Li *et al.*, 2013)
Bangkok	dry	traffic	PM2.5			55.8		(Chuersuwan *et al.*, 2008)
	dry	traffic	PM10			42.7		
Chiang Mai	haze	Rural	PM2.5	40.5	6.0	46.5	6.7	(Pani *et al.*, 2019)
	haze	Urban	PM2.5	41.2	8.4	49.7	4.9	
Chiang Mai	LBB	urban	PM2.5	40.2	7.7	47.9	5.2	(Pani *et al.*, 2018)
	MBB	urban	PM2.5	31.4	5.9	37.3	5.3	
	HBB	urban	PM2.5	26.5	4.9	31.4	5.4	
	EBB	urban	PM2.5	32.3	6.0	38.3	5.4	
Chiang Mai	haze	urban	PM2.5	36.7	4.4	41.1	8.3	(Thepnuan *et al.*, 2019)
Chiang Mai	haze	rural	PM2.5	40.9	7.3	48.2	5.6	(Chuang *et al.*, 2013)
Phuket	annual	suburban	PM2.5	7.2	1.5	8.7	4.8	(Choochuay *et al.*, 2020)
Vietnam								
Hanoi	wet	traffic	PM2.5	30.6	8.9	39.6	3.4	(Thuy *et al.*, 2018)
	dry	traffic	PM2.5	37.4	10.1	47.5	3.7	
	wet	mixed	PM2.5	40.2	9.7	49.9	4.2	
	dry	mixed	PM2.5	31.5	8.1	39.6	3.9	
	wet	traffic	PM10	36.6	10.1	46.6	3.6	
	dry	traffic	PM10	73.3	18.3	91.6	4.0	
	wet	mixed	PM10	42.2	8.8	51.0	4.8	
	dry	mixed	PM10	29.2	7.1	36.2	4.1	
Tamdao	wet	rural	PM2.5		8.8			(Co *et al.*, 2014)
	dry	rural	PM2.5		8.0			
Hanoi	dry	urban	PM2.5	19.2	6.2	25.4	3.1	(Hai and Kim Oanh, 2013)
	dry	urban	PM10-2.5	7.2	1.7	9.0	4.2	
Hanoi	annual	suburban	PM2.5		8.1			(Cohen *et al.*, 2010)
Mong Duong	wet	Industrial	PM2.5	9.4	5.7	15.1	1.7	(Hang and Kim Oanh, 2014)
	dry	rural	PM2.5	19.0	3.7	22.7	5.2	
Cam Hai	wet	rural	PM2.5	10.7	3.0	13.7	3.6	
	dry	rural	PM2.5	20.9	2.5	23.4	8.5	
Sonla	BBSC	rural	PM2.5	35.2	5.1	40.3	7.0	(Lee *et al.*, 2016)
	BBIC	rural	PM2.5	46.5	7.5	54.0	6.2	
	BBSS	rural	PM2.5	38.9	6.1	45.0	6.4	
Malaysia								
Kuala Lumpur	haze	suburban	PM2.5	25.3	8.3	33.6	3.1	(Khan *et al.*, 2016)
Kuala Lumpur	annual	urban	PM2.5		15.8			(Rahman *et al.*, 2011)
	annual	urban	PM10		2.6			
Selangor, Malaysia	haze	urban	PM2.5	24.0	9.2	33.3	2.6	(Fujii *et al.*, 2016)
Singapore								
Singapore	non	urban	PM2.5	16.9	8.2	25.1	2.1	(Tham *et al.*, 2019)
	haze	urban	PM2.5	20.1	4.4	24.5	4.6	
	episodic	urban	PM2.5	46.3	3.0	49.4	15.4	
Singapore	haze	urban	PM2.5	52.1	11.2	63.3	4.7	(Hapsari Budisulistiorini *et al.*, 2018)
Singapore	haze	urban	PM2.5	19.7	7.1	26.8	2.8	(See *et al.*, 2006)
	non	urban	PM2.5	17.7	9.1	26.8	1.9	
Indonesia								
Serpong	Aug – Nov 2008	Industrial	PM2.5		17.2			(Santoso *et al.*, 2011)
		Residential	PM2.5		12.9			
Avg SEA				**30.7**	**7.5**	**38.3**	**4.9**	

Table S1-2 Contribution of OC and EC (%) to PM mass in other countries

Country	Season	Site	PM size	OC	EC	TC	OC/EC	Ref
China								
Beijing	haze	urban	PM2.5	14.2	3.4	17.6	4.2	(Zhang *et al.*, 2016)
	non-haze	urban	PM2.5	24.6	7.4	32.0	3.3	
Beijing	haze	urban	PM2.5	10.1	2.3	12.4	4.4	(Shen *et al.*, 2017)
	haze	urban	PM2.5	12.1	3.7	15.7	3.3	
	haze	urban	PM2.5	10.1	4.0	14.1	2.5	
	non-haze	urban	PM2.5	17.7	4.3	22.0	4.1	
Beijing	heavy-polluted	urban	PM2.5	15.8	4.3	20.1	3.7	(Tao *et al.*, 2015)
	clean	urban	PM2.5	25.0	6.4	31.4	3.9	
Beijing	haze	urban	PM2.5	18.6	2.4	21.0	7.6	(Ho *et al.*, 2016)
Xi”an	haze	urban	PM2.5	17.5	3.3	20.8	5.4	
Xiamen	haze	urban	PM2.5	20.0	7.0	27.0	2.9	
Hong Kong	haze	urban	PM2.5	16.5	9.8	26.3	1.7	
Beijing	annual	urban	PM2.5	14.9	4.4	19.3	3.4	(Ji *et al.*, 2016)
Brijing	haze	urban	PM2.5	36.5	15.6	52.1	2.3	(Xu *et al.*, 2018)
Beijing	haze	urban	PM2.5	21.7	5.6	27.3	3.9	(Shao *et al.*, 2018)
	non-haze	urban	PM2.5	13.4	4.1	17.6	3.2	
	avg	urban	PM2.5	19.8	5.3	25.0	3.7	
Nanjing	annual	industrial	PM2.5	19.2	6.4	25.6	3.0	(Li *et al.*, 2016)
	annual	urban	PM2.5	13.0	4.8	17.8	2.7	
Handan	winter 2013	urban	PM2.5	16.0	6.5	22.5	2.5	(Zhao *et al.*, 2019)
	summer 2013	urban	PM2.5	8.5	3.9	12.4	2.2	
	annual 2013	urban	PM2.5	14.2	5.5	19.7	2.6	
Handan	winter 2017	urban	PM2.5	33.6	6.6	40.2	5.1	
	summer 2017	urban	PM2.5	9.3	4.2	13.4	2.2	
	annual 2017	urban	PM2.5	21.0	5.4	26.4	3.9	
Lanzhou	winter	residential	PM2.5	29.4	11.5	40.8	2.6	(Tan *et al.*, 2017)
	summer	residential	PM2.5	28.6	13.0	41.6	2.2	
	annual	residential	PM2.5	29.2	11.8	41.0	2.5	
Ningdong (Yinglite)	winter	industrial	PM2.5	7.0	4.7	11.7	1.5	(Liang *et al.*, 2019)
	summer	industrial	PM2.5	6.1	3.2	9.4	1.9	
Cixi	haze	mixed	PM2.5	16.8	6.1	22.9	2.8	(Lu *et al.*, 2020)
	non-haze	mixed	PM2.5	18.9	7.4	26.3	2.6	
Xi’an	spring	urban	PM2.5	14.8	3.8	18.5	3.9	(Niu *et al.*, 2016)
	summer	urban	PM2.5	14.4	3.3	17.7	4.3	
	autumn	urban	PM2.5	18.1	5.1	23.2	3.5	
	winter	urban	PM2.5	13.7	3.0	16.7	4.6	
	annual	urban	PM2.5	16.9	4.2	21.1	4.0	
Zhengzhou	heavy polluted	urban	PM2.5	16.9	3.5	20.4	4.8	(Jiang *et al.*, 2018)
	other days	urban	PM2.5	14.3	4.7	19.0	3.0	
Chengdu	non-haze	urban	PM2.5	16.6	4.8	21.4	3.4	(Tao *et al.*, 2013)
	dust	urban	PM2.5	8.4	2.1	10.5	4.0	
	haze	urban	PM2.5	21.0	4.5	25.4	4.7	
	annual	urban	PM2.5	15.5	4.3	19.8	3.6	
Avg China				**17.4**	**5.5**	**23.0**	**3.4**	

Table S1-2 (continue)

Country	Season	Site	PM size	OC	EC	TC	OC/EC	Ref
India								
Delhi	annual	industrail	PM2.5	28.2	9.1	37.3	3.1	(Mandal *et al.*, 2014)
Delhi	summer	traffic	PM2.5	30.2	13.4	43.6	2.3	(Pant *et al.*, 2015)
	winter	traffic	PM2.5	37.7	16.7	54.4	2.3	
Delhi	annual	urban	PM2.5	14.1	8.2	22.3	1.7	(Sharma and Mandal, 2017)
	winter	urban	PM2.5	14.7	8.5	23.2	1.7	
	summer	urban	PM2.5	13.8	8.4	22.2	1.6	
Delhi	winter	urban	PM2.5	12.9	5.8	18.7	2.2	(Jain *et al.*, 2020)
	summer	urban	PM2.5	9.5	5.1	14.6	1.9	
	monsoon	urban	PM2.5	9.8	4.4	14.2	2.2	
	annual	urban	PM2.5	12.0	5.6	17.6	2.2	
Pune	May – Oct 2013	urban	PM2.5	30.5	2.3	32.9	13.1	(Pipal and Satsangi, 2015)
		urban	Pm10	20.0	1.5	21.5	13.8	
Trombay	annual	industrial	PM2.5		12.5			(Police *et al.*, 2018)
	annual	industrial	PM2.5		14.2			
Ahmedabad	winter	urban	PM2.5	32.9	5.4	38.2	6.1	(Rengarajan *et al.*, 2011)
Van Vihar National Park	annual		PM2.5	30.0	13.0	43.0	2.3	(Kumar and Sunder Raman, 2020)
Avg India				**21.2**	**8.4**	**26.9**	**3.5**	
UK								
Birmingham	11-21 Sep 2012	Traffic (Tunnel)	PM2.5	30.1	30.0	60.1	1.0	(Pant *et al.*, 2017)
Birmingham	summer 2-18 June 2011	Urbanbg	PM2.5	26.0	9.0	35.1	2.9	(Taiwo, 2016)
			PM2.5-10	13.5	0.3	13.8	42.9	
London	winter	urban	PM2.5	17.5	7.5	25.0	2.3	(Crilley *et al.*, 2015)
Detling , Kent	winter	rural	PM2.5	13.8	3.8	17.5	3.7	
Harwell, Oxfordshire	winter	rural	PM2.5	16.4	5.0	21.4	3.3	
London	winter	urban	PM2.5	22.3	9.6	31.9	2.3	(Yin *et al.*, 2015)
Harwell, Oxfordshire	winter	rural	PM2.5	20.9	6.2	27.1	3.4	
Europe								
Barcelona	annual	urban back	PM2.5	16.1	6.5	22.6	2.5	(Salameh *et al.*, 2015)
Marseille	annual	urban back	PM2.5	31.6	9.2	40.8	3.4	
Genoa	annual	urban back	PM2.5	19.3	10.0	29.3	1.9	
Thessaloniki	annual	urban back	PM2.5	17.7	3.5	21.2	5.1	
Paris, France	annual	suburban	PM2.5	21.1	8.6	29.6	2.5	(Bressi *et al.*, 2013)
	annual	urban	PM2.5	20.3	9.5	29.7	2.1	
	annual	rural	PM2.5	23.0	9.5	32.5	2.4	
America/Canada								
Toronto, Canada	Annual	urban	PM2.5	7.5	7.0	14.5	1.1	(Jeong *et al.*, 2020)
Alberta, Canada	annual	urban	PM2.5	23.3	9.0	32.3	2.6	(Bari and Kindzierski, 2016)
Los Angeles, US	annual	urban	PM2.5-10	8.2	0.7	8.9	11.6	(Cheung *et al.*, 2011)
	annual	rural	PM2.5-10	5.7	0.4	6.1	15.4	

Table S2-1 Contribution of WSIs (%) to PM mass in SEA countries

Country	Season	Site	PM size	Ca^{2+}	Na^{+}	K^{+}	Mg^{2+}	$NH4^{+}$	Cl^{-}	NO_3^{-}	SO_4^{2-}	NO_3^{-}/SO_4^{2-}	Ref
Thailand													
Chiang Mai	haze	Rural	PM2.5	0.4	1.0	1.6		3.1	0.9	6.2	4.4	1.4	(Pani *et al.*, 2019)
	haze	Urban	PM2.5	0.5	1.2	1.6		2.0	1.2	3.5	4.3	0.8	
Chiang Mai	LBB	urban	PM2.5	0.7	4.3	2.5		5.0	1.8	2.5	15.5	0.2	(Pani *et al.*, 2018)
	MBB	urban	PM2.5	0.5	3.6	2.3		3.3	1.1	2.9	8.1	0.4	
	HBB	urban	PM2.5	0.3	2.6	2.0		2.6	0.6	3.0	4.1	0.7	
	EBB	urban	PM2.5	0.3	2.4	1.6		2.4	0.7	2.7	4.5	0.6	
Chiang Mai	haze	urban	PM2.5	1.2		2.0	0.2	5.2	0.2	4.2	13.6	0.3	(Thepnuan *et al.*, 2019)
Chaing Mai	haze	Rural	PM2.5	0.4	0.3	2.6		2.9	0.5	1.3	9.7	0.1	(Chuang *et al.*, 2013)
Chiang Mai	haze	urban	PM2.5	0.6	3.5	2.2		3.3	1.1	2.9	8.4	0.3	(Khamkaew *et al.*, 2016)
	haze	rural	PM2.5	0.5	4.9	2.2		1.2	1.2	5.0	3.0	1.6	
Chiang Mai	hot dry	urban	PM2.5	0.4	0.1	1.3	0.0	2.6	0.1	2.3	8.2	0.3	(Chansuebsri *et al.*, 2022)
	wet	urban	PM2.5		0.8	1.0		2.4	0.2	2.3	9.1	0.3	
	cold dry	urban	PM2.5		0.0	1.8		2.3	0.1	3.3	8.0	0.4	
	hot dry	Rural near source	PM2.5	0.1	0.2	1.2		1.9	0.1	2.4	6.1	0.4	
	wet	Rural near source	PM2.5		0.8	0.8		2.1	0.3	2.1	8.2	0.3	
	cold dry	Rural near source	PM2.5	0.1	0.5	1.1		1.5	0.4	1.1	5.7	0.2	
Phimai	dry	Rural	PM10	1.2	1.1	1.7	0.5	6.7	0.2	3.0	19.4	0.2	(Li *et al.*, 2013)
Bangkok	dry	traffic	PM2.5					0.7	1.2	1.3	2.7	0.5	(Chuersuwan *et al.*, 2008)
	dry	traffic	PM10					0.6	1.9	1.3	2.1	0.6	
Phuket	annual	suburban	PM2.5	2.3	3.5	0.7	0.3	0.7	1.3	1.3	5.5	0.2	(Choochuay *et al.*, 2020)
Vietnam													
Tamdao	wet	Rural	PM2.5	0.4	0.3	1.6	0.0	14.0	0.1	0.4	30.4	0.0	(Co *et al.*, 2014)
	dry	Rural	PM2.5	0.6	1.0	2.2	0.2	7.7	0.8	3.1	19.4	0.2	
Hanoi	dry	Urban	PM2.5		0.6	1.2		10.1		8.9	21.8	0.4	(Hai and Kim Oanh, 2013)
	dry	Urban	PM10-2.5		2.5	0.3		3.1		5.9	4.1	1.4	
Mong Duong	wet	indust	PM2.5	0.9	0.3	0.3	0.2	2.3	0.2	0.3	7.1	0.0	(Hang and Kim Oanh, 2014)
	dry		PM2.5	0.8	0.3	0.8	0.2	4.5	0.5	2.7	11.8	0.2	
Cam Hai	wet	Rural	PM2.5	0.4	0.4	0.4	0.0	4.1	0.2	0.5	10.0	0.1	
	dry		PM2.5	0.4	0.2	1.1	0.0	6.2	0.4	2.8	17.4	0.2	
Sonla	BBSX	Rural	PM2.5	0.2	0.2	1.4		5.2	0.2	4.0	14.4	0.3	(Lee *et al.*, 2016)
	BBIC	Rural	PM2.5	0.2	0.0	1.7		2.8	0.2	1.7	7.9	0.2	
	BBSS	Rural	PM2.5	0.3	0.0	1.3		5.1	0.3	1.9	15.1	0.1	
Malaysia													
Bangi, Selangor	haze	suburban	PM2.5	0.2	0.3	0.8	0.6		0.2	1.3	3.9	0.3	(Jaafar *et al.*, 2018)
Kuala Lumpur	haze	suburban	PM2.5	1.1	0.8	1.2	0.3	3.0	0.1	1.5	10.8	0.1	(Khan *et al.*, 2016)
Kuala Lumpur	wet	urban	PM2.5	1.4	1.2	0.6	0.3	2.0	0.2	3.7	8.3	0.5	(Khan *et al.*, 2017)
Bachok	wet	Rural	PM2.5	0.6	7.0	2.4	0.6	10.4	4.1	3.8	66.1	0.1	(Farren *et al.*, 2019)

Table S2-1 (continue)

Country	Season	Site	PM size	Ca^{2+}	Na^{+}	K^{+}	Mg^{2+}	$NH4^{+}$	Cl^{-}	NO_3^-	SO_4^{2-}	NO_3^- /SO_4^{2-}	Ref
Singapore													
Singapore	non	urban	PM2.5			1.3					19.5		(Tham *et al.*, 2019)
	haze	urban	PM2.5			1.1					13.2		
	episodic	urban	PM2.5			0.5					2.9		
Singapore	haze	urban	PM2.5	0.9	0.4	0.9		5.4	0.6	4.1	11.2	0.4	(Hapsari Budisulistiorini *et al.*, 2018)
Singapore	haze	urban	PM2.5		2.8	2.8		5.0	4.1	3.9	20.9	0.2	(See *et al.*, 2006)
	non	urban	PM2.5		4.1	2.2		4.9	3.2	3.1	22.8	0.1	
Indonesia													
Riau	haze	Near source	PM2.5					1.0	1.1	0.1	0.5	0.2	(Fujii *et al.*, 2019)
	haze	background	PM2.5					0.8	0.1	0.7	1.6	0.4	
Avg SEA				**0.6**	**1.6**	**1.4**	**0.3**	**3.8**	**0.8**	**2.7**	**11.4**	**0.4**	

Table S2-2 Contribution of WSIs (%) to PM mass in other countries

Country	Season	Site	PM size	Ca^{2+}	Na^{+}	K^{+}	Mg^{2+}	$NH4^{+}$	Cl^{-}	NO_3^{-}	SO_4^{2-}	NO_3^{-}/SO_4^{2-}	Ref
China													
Beijing	haze	urban	PM2.5	0.8	0.4	1.0	0.3	14.5	0.8	18.4	40.3	0.5	(Zhang *et al.*, 2016)
	non-haze	urban	PM2.5	2.4	0.7	1.3	0.4	10.5	0.7	14.4	26.4	0.5	
Beijing	haze	urban	PM2.5	0.6	0.3	0.7	0.1	12.4	2.1	24.1	19.7	1.2	(Shen *et al.*, 2017)
	haze	urban	PM2.5	0.7	0.3	0.7	0.1	13.3	0.6	16.2	24.5	0.7	
	haze	urban	PM2.5	0.4	0.3	1.0	0.1	17.2	2.3	17.4	26.1	0.7	
	non-haze	urban	PM2.5	2.9	0.5	2.0	0.2	6.3	1.4	8.2	11.2	0.7	
Beijing	Heavy-polluted	urban	PM2.5	0.2	0.5	1.2		12.5	3.4	14.9	18.6	0.8	(Tao *et al.*, 2015)
	Clean	urban	PM2.5	0.9	0.7	1.1		8.4	4.8	10.7	12.3	0.9	
Beijing	haze	urban	PM2.5					9.5		16.2	19.5	0.8	(Ho *et al.*, 2016)
Xi'an	haze	urban	PM2.5					11.0		22.4	20.6	1.1	
Xiamen	haze	urban	PM2.5					11.6		22.7	31.6	0.7	
Hong Kong	haze	urban	PM2.5					0.6		4.6	11.0	0.4	
Beijing	annual	urban	PM2.5										(Ji *et al.*, 2016)
Beijing	haze	urban	PM2.5	0.3	0.6	2.2	0.4	8.8	5.0	18.2	14.6	1.2	(Zhang *et al.*, 2018)
	non-haze	urban	PM2.5	1.2	0.9	0.3	0.6	0.1	6.2	26.9	14.0	1.9	
Beijing	haze	urban	PM2.5	2.1	1.5	1.9	0.3	8.1	4.9	4.3	9.5	0.4	(Xu *et al.*, 2018)
Beijing	haze	urban	PM2.5	0.3	0.3	0.7		8.3	2.2	15.7	11.3	1.4	(Shao *et al.*, 2018)
	non-haze	urban	PM2.5	0.6	0.3	0.5		4.6	1.3	8.0	5.8	1.4	
	avg	urban	PM2.5	0.3	0.3	0.7		7.4	2.0	14.3	10.0	1.4	
Nanjing	annual	industrial	PM2.5	1.2	0.9	0.5		3.8	2.6	9.7	20.9	0.5	(Li *et al.*, 2016)
	annual	urban	PM2.5	1.1	0.9	0.6		4.9	2.1	12.4	18.3	0.7	
Taiyuan	annual	urban	PM2.5	1.3	2.4	0.8	0.4	4.9	3.1	5.6	14.3	0.4	(He *et al.*, 2017)
Shenzhen	winter	suburban	PM2.5	3.4	4.8			9.7	2.5	8.1	20.0	0.4	(Dai *et al.*, 2013)
	summer	suburban	PM2.5	4.0	9.3			4.2	3.4	6.1	11.4	0.5	
Handan 2013	winter	urban	PM2.5	0.3		1.0		9.0	4.6	10.0	15.0	0.7	(Zhao *et al.*, 2019)
	Summer	urban	PM2.5	0.4		0.7		7.5	1.1	9.3	22.4	0.4	
	annual	urban	PM2.5	0.6		0.9		8.4	3.7	7.4	16.5	0.5	
Handan 2017	winter	urban	PM2.5	0.5		1.5		10.4	6.6	16.3	16.0	1.0	
	summer	urban	PM2.5	0.5		0.5		9.6	1.1	7.7	20.7	0.4	
	annual	urban	PM2.5	0.6		0.9		9.9	0.9	15.3	15.1	1.0	
Lanzhou	winter	residential	PM2.5	1.8	0.7	1.0		5.6	4.3	6.0	9.8	0.6	(Tan *et al.*, 2017)
	summer	residential	PM2.5	3.8	0.8	1.1		5.7	2.0	5.5	12.6	0.4	
	annual	residential	PM2.5	2.3	0.8	1.0		5.6	3.8	5.9	10.4	0.6	
Ningdong (Yinglite)	winter	industrial	PM2.5	4.1	0.6	0.4		2.9	1.1	4.7	5.9	0.8	(Liang *et al.*, 2019)
	summer	industrial	PM2.5	6.5	0.4	0.2		1.0	0.3	1.6	5.7	0.3	

Table S2-2 (continue)

Country	Season	Site	PM size	Ca^{2+}	Na^{+}	K^{+}	Mg^{2+}	$NH4^{+}$	Cl^{-}	NO_3^{-}	SO_4^{2-}	NO_3^{-}/SO_4^{2-}	Ref
Zhengzhou	haze	urban	PM2.5					11.4		32.6	10.3	3.2	(Dong *et al.*, 2020)
	sandy haze	urban	PM2.5					10.3		29.9	13.7	2.2	
	non-haze	urban	PM2.5					13.0		26.9	12.7	2.1	
Cixi	haze	mixed	PM2.5					0.8	0.3	1.1	0.8	1.3	(Lu *et al.*, 2020)
	non-haze	mixed	PM2.5					0.3	0.4	0.2	0.2	0.8	
Xi'an	spring	urban	PM2.5	2.2	1.1	0.6	0.2	4.9	2.0	10.6	12.1	0.9	(Niu *et al.*, 2016)
	summer	urban	PM2.5	1.9	0.9	0.6	0.1	6.7	0.6	9.1	21.6	0.4	
	autumn	urban	PM2.5	1.1	0.6	0.8	0.1	4.9	2.1	9.5	10.8	0.9	
	winter	urban	PM2.5	1.0	1.1	1.1	0.2	6.5	3.2	11.1	12.0	0.9	
	annual	urban	PM2.5	1.5	1.0	0.8	0.2	5.7	2.2	10.1	13.1	0.8	
Zhengzhou	heavy polluted	urban	PM2.5					8.3		11.5	15.1	0.8	(Jiang *et al.*, 2018)
	other days	urban	PM2.5					8.9		12.1	16.6	0.7	
Chengdu	non-haze	urban	PM2.5	1.6	0.4	2.3		4.2	1.9	8.6	13.3	0.6	(Tao *et al.*, 2013)
	dust	urban	PM2.5	3.0	0.7	0.8		0.3	1.2	2.4	5.2	0.5	
	haze	urban	PM2.5	1.3	0.2	4.1		4.7	4.2	7.9	11.8	0.7	
	annual	urban	PM2.5	1.8	0.4	2.3	0.0	3.5	2.0	7.3	11.6	0.6	
Avg China				**1.6**	**1.1**	**1.1**	**0.2**	**7.2**	**2.5**	**12.0**	**14.9**	**0.9**	
India													
Delhi	summer	traffic	PM2.5		0.7	1.5		8.5	3.7	7.5	17.1	0.4	(Pant *et al.*, 2015)
	winter	traffic	PM2.5		0.2	1.4		12.4	10.0	11.9	9.4	1.3	
Delhi	annual	urban	PM2.5		3.6	3.9		8.7	5.8	8.6	10.4	0.8	(Sharma and Mandal, 2017)
	winter	urban	PM2.5		2.5	2.9		8.1	5.3	9.0	8.2	1.1	
	summer	urban	PM2.5		4.8	5.3		10.1	6.6	7.1	12.3	0.6	
Delhi	summer	urban	PM2.5	3.9	4.1	3.9	0.5	8.5	8.3	4.5	10.0	0.4	(Saxena *et al.*, 2017)
	monsoon	urban	PM2.5	5.1	17.5	5.9	2.5	6.9	15.6	8.6	23.8	0.4	
	winter	urban	PM2.5	1.6	3.2	2.8	0.5	6.8	6.6	8.7	8.5	1.0	
	spring	urban	PM2.5	2.2	3.6	3.0	0.3	8.9	6.8	7.4	10.2	0.7	
	annual	urban	PM2.5	2.5	5.1	3.4	0.8	8.2	8.8	8.8	11.7	0.8	
Delhi	winter	urban	PM2.5	1.6	3.1	2.8	0.2	9.1	6.0	11.0	10.2	1.1	(Jain *et al.*, 2020)
	summer	urban	PM2.5	3.1	3.7	3.6	0.4	6.5	6.9	6.3	10.1	0.6	
	monsoon	urban	PM2.5	4.2	5.9	3.9	0.9	4.4	6.0	5.1	14.2	0.4	
	annual	urban	PM2.5	2.3	3.7	3.3	0.4	7.5	6.3	8.9	10.6	0.8	
Ahmedabad	winter	urban	PM2.5	0.9	0.8	1.6	0.1	5.8	0.0	2.2	17.4	0.1	(Rengarajan *et al.*, 2011)
Van Vihar National Park	annual		PM2.5	1.8	3.6	2.2	0.4	4.7	3.3	6.9	7.6	0.9	(Kumar and Sunder Raman, 2020)
Avg India				**2.6**	**4.1**	**3.2**	**0.6**	**7.8**	**6.6**	**7.6**	**12.0**	**0.7**	

Table S2-2 (continue)

Country	Season	Site	PM size	Ca^{2+}	Na^{+}	K^{+}	Mg^{2+}	$NH4^{+}$	Cl^{-}	NO_3^{-}	SO_4^{2-}	NO_3^{-} /SO_4^{2}-	Ref
UK													
Birmingham	summer 2-18 June 2011	urban background	PM2.5	0.4	4.4			11.8	4.2	10.9	24.5	0.4	(Taiwo, 2016)
			PM2.5-10	1.9	5.7			17.0	15.0	26.8	3.9	6.9	
London	Winter	urban	PM2.5			0.4							(Crilley *et al.*, 2015)
Detling , Kent	winter	rural	PM2.5										
Harwell, Oxfordshire	winter	rural	PM2.5			0.5							
London	winter	urban	PM2.5						4.3	22.3	11.5	1.9	(Yin *et al.*, 2015)
Harwell, Oxfordshire	winter	rural	PM2.5						4.6	29.1	15.5	1.9	
Europe													
Barcelona	annual	urban back	PM2.5		1.6			5.4		5.4	15.1	0.4	(Salameh *et al.*, 2015)
Marseille	annual	urban back	PM2.5		0.5	0.5		8.7		8.7	11.2	0.8	
Genoa	annual	urban back	PM2.5		0.7	0.4		3.6		3.6	25.7	0.1	
Thessaloniki	annual	urban back	PM2.5		0.5	0.3		5.6		6.5	10.5	0.6	
Paris, France	annual	suburban	PM2.5	0.5	1.1	0.9	0.2	9.9	1.2	19.1	13.8	1.4	(Bressi *et al.*, 2013)
	annual	urban	PM2.5	0.8	1.2	0.8	0.2	9.5	1.3	19.6	13.5	1.5	
	annual	rural	PM2.5	0.4	1.1	1.0	0.2	9.5	1.3	17.5	15.1	1.2	
America													
Toronto, Canada	Annual	urban	PM2.5		0.4		0.1	9.0	0.3	16.8	18.6	0.9	(Jeong *et al.*, 2020)
Alberta, Canada	annual	urban	PM2.5	0.1	0.4	0.4	0.6	4.4	0.3	4.4	8.4	0.5	(Bari and Kindzierski, 2016)
Los Angeles, US	annual	urban	PM2.5-10					0.4	4.8	16.2	5.4	3.0	(Cheung *et al.*, 2011)
	annual	rural	PM2.5-10					0.2	2.1	4.8	2.2	2.2	

Table S3-1 Contribution of crustal and trace elements (%) to PM in SEA countries

Country	Season	Site	PM size	Na	K	Mg	Al	Si	Ca	Ti	V	Mn	Fe	Ni	Cu	Zn	Pb	As	Ref
Thailand																			
Bangkok	dry	traffic	PM2.5	2.116	1.420	0.681	2.768		4.319		1.609	0.072	2.072	0.377	0.116	1.130	0.261	0.449	(Chuersuwan *et al.*, 2008)
	dry	traffic	PM10	1.739	1.119	0.768	2.794		4.431		1.045	0.083	1.970	0.028	0.083	0.777	0.167	0.296	
Chiang Mai	LBB	urban	PM2.5		3.929	1.071	2.679									0.893			(Pani *et al.*, 2018)
	MBB	urban	PM2.5		3.548	1.075	1.828									0.430			
	HBB	urban	PM2.5		3.269	1.538	1.218									0.064			
	EBB	urban	PM2.5		3.139	1.211	1.704					0.045		0.045		0.448			
Chiang Mai	haze	urban	PM2.5		3.545	1.128	1.869					0.021		0.032	0.021	0.494			(Khamkaew *et al.*, 2016)
	haze	rural	PM2.5		3.217	1.020	2.005					0.024		0.036	0.012	0.240			
Vietnam																			
Hanoi	annual	suburban	PM2.5	0.228	1.804		0.415	2.000	0.850	0.057	0.006	0.113	0.730	0.007	0.019	0.902	0.437		(Cohen *et al.*, 2010)
Mong Duong	wet	indust	PM2.5			0.171	0.143	0.571	1.143	0.029	0.011	0.086	0.857	0.029	0.086	0.286	0.200		(Hang and Kim Oanh, 2014)
	dry		PM2.5			0.167	0.333	1.333	0.833	0.033	0.013	0.050	0.667	0.050	0.033	0.333	0.167		
Cam Hai	wet	Rural	PM2.5			0.011	0.148	0.741	0.370	0.074	0.026	0.074	0.741	0.074	0.011	0.370	0.370		
	dry		PM2.5			0.002	0.189	0.566	0.755	0.038	0.019	0.094	0.377	0.038	0.038	0.377	0.377		
Tamdao, Veit	wet	Rural	PM2.5				1.600	4.800	1.200	0.400		0.160	1.200		0.008	0.400	0.400		(Co *et al.*, 2014)
	dry	Rural	PM2.5			0.196	1.961	4.902	1.176	0.008	0.196	0.020	0.392	0.004	0.020	0.098	0.039		
Malaysia																			
Kuala Lumpur	haze	suburban	PM2.5		0.656	0.046	0.065				0.007	0.007	0.031	0.004	0.013	0.086	0.025	0.018	(Khan *et al.*, 2016)
Kuala	wet	urban	PM2.5	1.435	0.435	0.391	0.609		0.348		0.024	0.022		0.007	0.038	0.046	0.043	0.005	(Khan *et al.*, 2017)
Kuala lumpur	annual	urban	PM2.5	1.043	1.453	0.447	0.559	1.192	0.484	0.030	0.015	0.022	0.410	0.011	0.063	0.145	0.119	0.034	(Rahman *et al.*, 2011)
	annual	urban	PM10	1.602	1.825	1.024	3.649	7.566	4.406	0.196	0.022	0.040	1.958	0.018	0.049	0.134	0.098	0.036	
Selangor	haze	urban	PM2.5		1.971		0.400	0.953	0.252	0.029			0.229			0.132	0.084		(Fujii *et al.*, 2016)
Singapore																			
Singapore	haze	urban	PM2.5			0.236	2.683	0.301	1.534	0.034	0.071	0.034	1.242	0.282	0.902	0.753	0.278		(See *et al.*, 2006)
	non	urban	PM2.5			0.439	2.076	0.443	1.031	0.064	0.124	0.059	1.465	0.544	1.457	1.191	0.300		
Avg SEA				**1.360**	**2.238**	**0.612**	**1.441**	**2.114**	**1.542**	**0.083**	**0.228**	**0.057**	**0.956**	**0.093**	**0.175**	**0.442**	**0.210**	**0.140**	

Table S3-2 Contribution of crustal and trace elements (%) to PM in other countries

Country	Season	Site	PM size	Na	K	Mg	Al	Si	Ca	Ti	V	Mn	Fe	Ni	Cu	Zn	Pb	As	Ref
China																			
Beijing	Haze	urban	PM2.5	0.549	1.037	0.305	0.579		1.037		0.001	0.049	0.671	0.001	0.030	0.395	0.258	0.055	(Shen *et al.*, 2017)
	Haze	urban	PM2.5	0.976	1.037	0.451	1.116		1.280		0.004	0.051	0.854	0.005	0.024	0.237	0.182	0.020	
	Haze	urban	PM2.5	0.560	1.120	0.184	0.464		1.360		0.007	0.042	0.800	0.006	0.021	0.332	0.236	0.014	
	Non-haze	urban	PM2.5	0.980	1.569	1.333	2.941		3.922		0.006	0.100	2.549	0.005	0.041	0.229	0.176	0.020	
Nanjing	annual	industrial	PM2.5				0.600			0.050		0.051	0.650	0.011	0.048	0.341	0.159	0.009	(Li *et al.*, 2016)
	annual	urban	PM2.5				0.547			0.052		0.052	0.619	0.012	0.053	0.360	0.171	0.009	
Ji'nan, Shangdong		urban	PM2.5				0.644			0.040		0.059	1.030	0.010	0.030	0.347	0.158	0.040	(Zhou *et al.*, 2014)
		industrial	PM2.5				0.515			0.038		0.085	1.854	0.008	0.031	0.338	0.154	0.046	
Lanzhou	Winter	residential	PM2.5							0.119	0.010	0.178		0.012	0.057	0.412	0.876	0.028	(Tan *et al.*, 2017)
	summer	residential	PM2.5							0.269	0.011	0.182		0.013	0.069	0.393	0.416	0.029	
	annual	residential	PM2.5							0.153	0.010	0.182		0.012	0.061	0.417	0.796	0.029	
Ningdong (Yinglite)	winter	industrial	PM2.5	0.314	0.333	0.574	2.065		4.832	0.061		0.051	0.988	0.003	0.003	0.051	0.035	0.013	(Liang *et al.*, 2019)
	summer	industrial	PM2.5	0.337	0.516	1.274	4.611		12.434	0.121		0.058	2.027	0.005	0.005	0.058	0.016	0.005	
Zhengzhou	haze	urban	PM2.5		1.094		1.356	1.481	1.663			0.090	1.179	0.002	0.034	0.224	0.078	0.026	(Dong *et al.*, 2020)
	Sandy haze	urban	PM2.5		1.680		3.569	8.227	2.541			0.083	2.522	0.003	0.014	0.137	0.040	0.014	
	Non-haze	urban	PM2.5		1.700		3.277	5.356	6.617			0.182	3.119	0.004	0.028	0.320	0.060	0.053	
Cixi	Haze	mixed	PM2.5	0.485	0.351	0.152	0.285	0.971	1.036	0.009	0.006	0.025	0.313	0.004	0.021	0.315	0.054		(Lu *et al.*, 2020)
	Non-haze	mixed	PM2.5	0.674	0.399	0.155	0.517	1.118	0.685	0.013	0.009	0.031	0.541	0.006	0.039	0.373	0.062		
Zhengzhou	Heavy polluted	urban	PM2.5			0.138	0.416					0.033	0.361	0.002	0.014	0.293	0.080	0.010	(Jiang *et al.*, 2018)
	Other days	urban	PM2.5			0.364	0.735					0.053	0.730	0.003	0.023	0.415	0.172	0.013	
Chengdu	Non-haze	urban	PM2.5				1.097	0.907	0.898	0.104			1.287						(Tao *et al.*, 2013)
	Dust	urban	PM2.5				5.361	5.567	3.353	0.363			4.412						
	haze	urban	PM2.5				0.351	0.339	0.300	0.045			0.581						
	annual	urban	PM2.5				1.809	1.712	1.291	0.143			1.794						
Avg China				**0.609**	**0.985**	**0.493**	**1.565**	**2.853**	**2.883**	**0.105**	**0.007**	**0.082**	**1.375**	**0.006**	**0.032**	**0.299**	**0.209**	**0.024**	

Table S3-2 (Continue)

Country	Season	Site	PM size	Na	K	Mg	Al	Si	Ca	Ti	V	Mn	Fe	Ni	Cu	Zn	Pb	As	Ref
India																			
Delhi	annual	urban	SPM	0.698	0.867	1.162	2.444		3.356		0.097	0.136	3.010	0.027	0.676	0.856	0.081		(Shridhar *et al.*, 2010)
	annual	rural	SPM	0.670	0.925	1.027	2.678		3.077		0.065	0.075	2.190	0.015	0.211	0.386	0.052		
Delhi	summer	traffic	PM2.5				1.392	3.230	1.340	0.120	0.017	0.052	1.220	0.007	0.034	0.344	0.137		(Pant *et al.*, 2015)
	winter	traffic	PM2.5				0.625	0.646	0.401	0.025	0.004	0.029	0.415	0.004	0.025	0.231	0.217		
Delhi	annual	urban	PM2.5			0.773	2.351	1.371	2.932	0.088		0.016	0.207		0.032	0.104	0.016	0.056	(Sharma and Mandal, 2017)
	winter	urban	PM2.5			0.903	1.704	1.036	2.179	0.112		0.015	0.026		0.046	0.133	0.026	0.077	
	summer	urban	PM2.5			0.554	3.036	1.855	3.831	0.060		0.012	0.145		0.012	0.036	0.012	0.012	
Delhi	Winter	urban	PM2.5				1.164			0.049		0.011	0.464		0.066	0.295	0.224	0.093	(Jain *et al.*, 2020)
	summer	urban	PM2.5				1.573			0.087		0.039	0.767		0.107	0.311	0.223	0.049	
	Monsoon	urban	PM2.5				1.928			0.101		0.029	1.000		0.116	0.319	0.290	0.029	
	annual	urban	PM2.5				1.427			0.069		0.008	0.595		0.076	0.290	0.229	0.069	
Trombay	2010	industrial	PM2.5	1.261	0.830	0.704	2.355	2.767	1.154	0.123	0.063	0.038	1.164	0.044	0.031	0.270	0.459	0.006	(Police *et al.*, 2018)
	2011	industrial	PM2.5	1.917	1.141	1.202	2.404	3.646	1.531	0.130	0.112	0.065	1.477	0.087	0.047	0.191	0.365	0.007	
Ahmedabad	winter	urban	PM2.5				1.257												(Rengarajan *et al.*, 2011)
Van Vihar National Park	annual		PM2.5		2.307		2.573	3.050	0.900	0.098	0.011	0.041	1.100	0.007	0.041	0.559	0.150	0.005	(Kumar and Sunder Raman, 2020)
Avg India				**1.137**	**1.214**	**0.904**	**1.927**	**2.200**	**2.070**	**0.089**	**0.053**	**0.040**	**0.984**	**0.027**	**0.109**	**0.309**	**0.177**	**0.040**	
UK																			
Birmingham	11-21 Sep 2012	Traffic (Tunnel)	PM2.5						0.003	0.030	0.002	0.050			0.170	0.166			(Pant *et al.*, 2017)
Birmingham	summer 2-18 June 2011	Urban background	PM2.5									0.738	0.148	0.148	0.148	0.240			(Taiwo, 2016)
			PM2.5-10									0.739	0.092	0.370	0.333	0.037			
London	winter	urban	PM2.5				0.280	0.892											(Yin *et al.*, 2015)
Harwell, Oxfordshire	winter	rural	PM2.5				0.245	0.700											

Table S3-2 (Continue)

Country	Season	Site	PM size	Na	K	Mg	Al	Si	Ca	Ti	V	Mn	Fe	Ni	Cu	Zn	Pb	As	Ref
Europe																			
Barcelona	annual	urban back	PM2.5		0.688	0.253			0.780		0.032	0.027	0.833	0.016	0.038	0.226	0.032		(Salameh *et al.*, 2015)
Marseille	annual	urban back	PM2.5		1.148	0.735			5.571		0.031	0.056	1.352	0.020	0.087	0.122	0.041		
Genoa	annual	urban back	PM2.5		0.714	0.257			0.786		0.100	0.029	1.014	0.050	0.043	0.136	0.043		
Thessaloniki	annual	urban back	PM2.5		1.164	1.186			5.495		0.030	0.245	2.441	0.070	0.226	0.207	0.110		
America																			
Toronto, Canada	Annual	urban	PM2.5		0.418		0.201	0.490	0.552	0.025	0.002	0.017	0.543	0.002	0.025	0.090	0.021	0.005	(Jeong *et al.*, 2020)
Alberta, Canada	annual	urban	PM2.5				0.045		0.000	0.004	0.001	0.034	0.176	0.005	0.021	0.080	0.005	0.002	(Bari and Kindzierski, 2016)
Los Angeles, US	annual	urban	PM2.5-10			1.332	2.550		2.855	0.250			4.239		0.199	0.078			(Cheung *et al.*, 2011)
	annual	rural	PM2.5-10			0.910	3.574		2.273	0.321			3.275		0.229	0.055			

References

Bari, M.A., Kindzierski, W.B., 2016. Eight-year (2007-2014) trends in ambient fine particulate matter (PM2.5) and its chemical components in the Capital Region of Alberta, Canada. Environ. Int. 91, 122–132. https://doi.org/10.1016/j.envint.2016.02.033

Bressi, M., Sciare, J., Ghersi, V., Bonnaire, N., Nicolas, J.B., Petit, J.E., Moukhtar, S., Rosso, A., Mihalopoulos, N., Féron, A., 2013. A one-year comprehensive chemical characterisation of fine aerosol (PM2.5) at urban, suburban and rural background sites in the region of Paris (France). Atmos. Chem. Phys. 13, 7825–7844. https://doi.org/10.5194/acp-13-7825-2013

Chansuebsri, S., Kraisitnitikul, P., Wiriya, W., Chantara, S., 2022. Fresh and aged PM2.5 and their ion composition in rural and urban atmospheres of Northern Thailand in relation to source identification. Chemosphere 286, 131803. https://doi.org/10.1016/j.chemosphere.2021.131803

Cheung, K., Daher, N., Kam, W., Shafer, M.M., Ning, Z., Schauer, J.J., Sioutas, C., 2011. Spatial and temporal variation of chemical composition and mass closure of ambient coarse particulate matter (PM10-2.5) in the Los Angeles area. Atmos. Environ. 45, 2651–2662. https://doi.org/10.1016/j.atmosenv.2011.02.066

Choochuay, C., Pongpiachan, S., Tipmanee, D., Deelaman, W., Suttinun, O., Wang, Q., Xing, L., Li, G., Han, Y., Palakun, J., Poshyachinda, S., Aukkaravittayapun, S., Surapipith, V., Cao, J., 2020. Long-range transboundary atmospheric transport of polycyclic aromatic hydrocarbons, carbonaceous compositions, and water-soluble ionic species in southern thailand. Aerosol Air Qual. Res. 20, 1591–1606. https://doi.org/10.4209/aaqr.2020.03.0120

Chuang, M.T., Chou, C.C.K., Sopajaree, K., Lin, N.H., Wang, J.L., Sheu, G.R., Chang, Y.J., Lee, C. Te, 2013. Characterization of aerosol chemical properties from near-source biomass burning in the northern Indochina during 7-SEAS/Dongsha experiment. Atmos. Environ. 78, 72–81. https://doi.org/10.1016/j.atmosenv.2012.06.056

Chuersuwan, N., Nimrat, S., Lekphet, S., Kerdkumrai, T., 2008. Levels and major sources of PM2.5 and PM10 in Bangkok Metropolitan Region. Environ. Int. 34, 671–677. https://doi.org/10.1016/j.envint.2007.12.018

Co, H.X., Dung, N.T., Oanh, N.T.K., Hang, N.T., Phuc, N.H., Le, H.A., 2014. Levels and composition of ambient particulate matter at a mountainous rural site in northern Vietnam. Aerosol Air Qual. Res. 14, 1917–1928. https://doi.org/10.4209/aaqr.2013.09.0300

Cohen, D.D., Crawford, J., Stelcer, E., Bac, V.T., 2010. Characterisation and source apportionment of fine particulate sources at Hanoi from 2001 to 2008. Atmos. Environ. 44, 320–328. https://doi.org/10.1016/j.atmosenv.2009.10.037

Crilley, L.R., Bloss, W.J., Yin, J., Beddows, D.C.S., Harrison, R.M., Allan, J.D., Young, D.E., Flynn, M., Williams, P., Zotter, P., Prevot, A.S.H., Heal, M.R., Barlow, J.F., Halios, C.H., Lee, J.D., Szidat, S., Mohr, C., 2015. Sources and contributions of wood smoke during winter in London: Assessing local and regional influences. Atmos. Chem. Phys. 15, 3149–3171. https://doi.org/10.5194/acp-15-3149-2015

Dai, W., Gao, J., Cao, G., Ouyang, F., 2013. Chemical composition and source identification of PM2.5 in the suburb of Shenzhen, China. Atmos. Res. 122, 391–400. https://doi.org/10.1016/j.atmosres.2012.12.004

Dong, Z., Su, F., Zhang, Z., Wang, S., 2020. Observation of chemical components of PM2.5 and secondary inorganic aerosol formation during haze and sandy haze days in Zhengzhou, China. J. Environ. Sci. (China) 88, 316–325. https://doi.org/10.1016/j.jes.2019.09.016

Farren, N.J., Dunmore, R.E., Mead, M.I., Nadzir, M.S.M., Samah, A.A., Phang, S.M., Bandy, B.J., Sturges, W.T., Hamilton, J.F., 2019. Chemical characterisation of water-soluble ions in atmospheric particulate matter on the east coast of Peninsular Malaysia. Atmos. Chem. Phys. 19, 1537–1553. https://doi.org/10.5194/acp-19-1537-2019

Fujii, Y., Huboyo, H.S., Tohno, S., Okuda, T., Syafrudin, 2019. Chemical speciation of water-soluble ionic components in PM2.5 derived from peatland fires in Sumatra Island. Atmos. Pollut. Res. 10, 1260–1266. https://doi.org/10.1016/j.apr.2019.02.009

Fujii, Y., Mahmud, M., Tohno, S., Okuda, T., Mizohata, A., 2016. A case study of PM2.5 characterization in Bangi, Selangor, Malaysia during the southwest monsoon season. Aerosol Air Qual. Res. 16, 2685–2691. https://doi.org/10.4209/aaqr.2015.04.0277

Hai, C.D., Kim Oanh, N.T., 2013. Effects of local, regional meteorology and emission sources on mass and compositions of particulate matter in Hanoi. Atmos. Environ. 78, 105–112. https://doi.org/10.1016/j.atmosenv.2012.05.006

Hang, N.T., Kim Oanh, N.T., 2014. Chemical characterization and sources apportionment of fine particulate pollution in a mining town of Vietnam. Atmos. Res. 145–146, 214–225. https://doi.org/10.1016/j.atmosres.2014.04.009

Hapsari Budisulistiorini, S., Riva, M., Williams, M., Miyakawa, T., Chen, J., Itoh, M., Surratt, J.D., Kuwata, M., 2018. Dominant contribution of oxygenated organic aerosol to haze particles from real-time observation in Singapore during an Indonesian wildfire event in 2015. Atmos. Chem. Phys. 18, 16481–16498. https://doi.org/10.5194/acp-18-16481-2018

He, Q., Yan, Y., Guo, L., Zhang, Y., Zhang, G., Wang, X., 2017. Characterization and source analysis of water-soluble inorganic ionic species in PM 2 . 5 in Taiyuan city , China. Atmos. Res. 184, 48–55. https://doi.org/10.1016/j.atmosres.2016.10.008

Ho, K., Sai, S., Ho, H., Huang, R., Chuang, H., Cao, J., Han, Y., Lui, K., Ning, Z., Chuang, K., Cheng, T., Lee, S., Hu, D., Wang, B., Zhang, R., 2016. Chemical composition and bioreactivity of PM 2 . 5 during 2013 haze events in China 126, 162–170. https://doi.org/10.1016/j.atmosenv.2015.11.055

Jaafar, S.A., Latif, M.T., Razak, I.S., Wahid, N.B.A., Khan, M.F., Srithawirat, T., 2018. Composition of carbohydrates, surfactants, major elements and anions in PM2.5 during the 2013 Southeast Asia high pollution episode in Malaysia. Particuology 37, 119–126. https://doi.org/10.1016/j.partic.2017.04.012

Jain, S., Sharma, S.K., Vijayan, N., Mandal, T.K., 2020. Seasonal characteristics of aerosols (PM2.5 and PM10) and their source apportionment using PMF: A four year study over Delhi, India. Environ. Pollut. 262, 114337. https://doi.org/10.1016/j.envpol.2020.114337

Jeong, C.H., Traub, A., Huang, A., Hilker, N., Wang, J.M., Herod, D., Dabek-Zlotorzynska, E., Celo, V., Evans, G.J., 2020. Long-term analysis of PM2.5 from 2004 to 2017 in Toronto: Composition, sources, and oxidative potential. Environ. Pollut. 263, 114652. https://doi.org/10.1016/j.envpol.2020.114652

Ji, D., Zhang, J., He, J., Wang, X., Pang, B., Liu, Z., Wang, L., Wang, Y., 2016. Characteristics of atmospheric organic and elemental carbon aerosols in urban Beijing, China. Atmos. Environ. 125, 293–306. https://doi.org/10.1016/j.atmosenv.2015.11.020

Jiang, N., Li, Q., Su, F., Wang, Q., Yu, X., Kang, P., Zhang, R., Tang, X., 2018. Chemical characteristics and source apportionment of PM2.5 between heavily polluted days and other days in Zhengzhou, China. J. Environ. Sci. (China) 66, 188–198. https://doi.org/10.1016/j.jes.2017.05.006

Khamkaew, C., Chantara, S., Janta, R., Pani, S.K., Prapamontol, T., Kawichai, S., Wiriya, W., Lin, N.H., 2016. Investigation of biomass burning chemical components over Northern Southeast Asia during 7-SEAS/BASELInE 2014 campaign. Aerosol Air Qual. Res. 16, 2655–2670. https://doi.org/10.4209/aaqr.2016.03.0105

Khan, M.F., Hwa, S.W., Hou, L.C., Mustaffa, N.I.H., Amil, N., Mohamad, N., Sahani, M., Jaafar, S.A., Nadzir, M.S.M., Latif, M.T., 2017. Influences of inorganic and polycyclic aromatic hydrocarbons on the sources of PM2.5 in the Southeast Asian urban sites. Air Qual. Atmos. Heal. 10, 999–1013. https://doi.org/10.1007/s11869-017-0489-5

Khan, M.F., Sulong, N.A., Latif, M.T., Nadzir, M.S.M., Amil, N., Hussain, D.F.M., Lee, V., Hosaini, P.N., Shaharom, S., Yusoff, N.A.Y.M., Hoque, H.M.S., Chung, J.X., Sahani, M., Tahir, N.M., Juneng, L., Maulud, K.N.A., Abdullah, S.M.S., Fujii, Y., Tohno, S., Mizohata, A., 2016. Comprehensive assessment of PM2.5 physicochemical properties during the Southeast Asia dry season (southwest monsoon). J. Geophys. Res. 121, 14589–14611. https://doi.org/10.1002/2016JD025894

Kumar, S., Sunder Raman, R., 2020. Source apportionment of fine particulate matter over a National Park in Central India. Sci. Total Environ. 720, 137511. https://doi.org/10.1016/j.scitotenv.2020.137511

Lee, C. Te, Ram, S.S., Nguyen, D.L., Chou, C.C.K., Chang, S.Y., Lin, N.H., Chang, S.C., Hsiao, T.C., Sheu, G.R., Ou-Yang, C.F., Chi, K.H., Wang, S.H., Wu, X.C., 2016. Aerosol chemical profile of near-source biomass burning smoke in sonla, vietnam during 7-SEAS campaigns in 2012 and 2013. Aerosol Air Qual. Res. 16, 2603–2617. https://doi.org/10.4209/aaqr.2015.07.0465

Li, C., Tsay, S.C., Hsu, N.C., Kim, J.Y., Howell, S.G., Huebert, B.J., Ji, Q., Jeong, M.J., Wang, S.H., Hansell, R.A., Bell, S.W., 2013. Characteristics and composition of atmospheric aerosols in Phimai, central Thailand during BASE-ASIA. Atmos. Environ. 78, 60–71. https://doi.org/10.1016/j.atmosenv.2012.04.003

Li, H., Yang, M., Li, F., Wang, J., Sun, Y., Wang, C., 2016. Chemical characterization and source apportionment of PM 2 . 5 aerosols in a megacity of Southeast China. Atmos. Res. 181, 288–299. https://doi.org/10.1016/j.atmosres.2016.07.005

Liang, X., Huang, T., Lin, S., Wang, J., Mo, J., Gao, H., Wang, Z., Li, J., Lian, L., Ma, J., 2019. Chemical composition and source apportionment of PM 1 and PM 2.5 in a national coal chemical industrial base of the Golden Energy Triangle, Northwest China. Sci. Total Environ. 659, 188–199. https://doi.org/10.1016/j.scitotenv.2018.12.335

Lu, H., Zhu, Z., Wang, S., 2020. A full-scale analysis of chemical characteristics of PM2.5 and PM10 during haze and non-haze episodes in Cixi city, China. Atmos. Pollut. Res. 11, 1000–1008. https://doi.org/10.1016/j.apr.2020.02.014

Mandal, P., Sarkar, R., Mandal, A., Saud, T., 2014. Seasonal variation and sources of aerosol pollution in Delhi , India 529–534. https://doi.org/10.1007/s10311-014-0479-x

Niu, X., Cao, J., Shen, Z., Ho, S.S.H., Tie, X., Zhao, S., Xu, H., Zhang, T., Huang, R., 2016. PM2.5 from the Guanzhong Plain: Chemical composition and implications for emission reductions. Atmos. Environ. 147, 458–469. https://doi.org/10.1016/j.atmosenv.2016.10.029

Pani, S.K., Chantara, S., Khamkaew, C., Lee, C. Te, Lin, N.H., 2019. Biomass burning in the northern peninsular Southeast Asia: Aerosol chemical profile and potential exposure. Atmos. Res. 224, 180–195. https://doi.org/10.1016/j.atmosres.2019.03.031

Pani, S.K., Lin, N.H., Chantara, S., Wang, S.H., Khamkaew, C., Prapamontol, T., Janjai, S., 2018. Radiative response of biomass-burning aerosols over an urban atmosphere in northern peninsular Southeast Asia. Sci. Total Environ. 633, 892–911. https://doi.org/10.1016/j.scitotenv.2018.03.204

Pant, P., Shi, Z., Pope, F.D., Harrison, R.M., 2017. Characterization of Traffic-Related Particulate Matter Emissions in a Road Tunnel in Birmingham , UK : Trace Metals and Organic Molecular Markers 117–130. https://doi.org/10.4209/aaqr.2016.01.0040

Pant, P., Shukla, A., Kohl, S.D., Chow, J.C., Watson, J.G., Harrison, R.M., 2015. Characterization of ambient PM 2 . 5 at a pollution hotspot in New Delhi , India and inference of sources. Atmos. Environ. 109, 178–189. https://doi.org/10.1016/j.atmosenv.2015.02.074

Pipal, A.S., Satsangi, P.G., 2015. Study of carbonaceous species , morphology and sources of fi ne (PM 2 . 5) and coarse (PM 10) particles along with their climatic nature in India. Atmos. Res. 154, 103–115. https://doi.org/10.1016/j.atmosres.2014.11.007

Police, S., Kumar, S., Tiwari, M., Girish, G., 2018. Particuology Chemical composition and source apportionment of PM 2 . 5 and PM 2 . 5 – 10 in Trombay (Mumbai , India), a coastal industrial area. Particuology 37, 143–153. https://doi.org/10.1016/j.partic.2017.09.006

Rahman, S.A., Hamzah, M.S., Wood, A.K., Elias, M.S., Salim, N.A.A., Sanuri, E., 2011. Sources apportionment of fine and coarse aerosol in Klang Valley, Kuala Lumpur using positive matrix factorization. Atmos. Pollut. Res. 2, 197–206. https://doi.org/10.5094/APR.2011.025

Rengarajan, R., Sudheer, A.K., Sarin, M.M., 2011. Wintertime PM2.5 and PM10 carbonaceous and inorganic constituents from urban site in western India. Atmos. Res. 102, 420–431. https://doi.org/10.1016/j.atmosres.2011.09.005

Salameh, D., Detournay, A., Pey, J., Pérez, N., Liguori, F., Saraga, D., Bove, M.C., Brotto, P., Cassola, F., Massabò, D., Latella, A., Pillon, S., Formenton, G., Patti, S., Armengaud, A., Piga, D., Jaffrezo, J.L., Bartzis, J., Tolis, E., Prati, P., Querol, X., Wortham, H., Marchand, N., 2015. PM2.5 chemical composition in five European Mediterranean cities: A 1-year study. Atmos. Res. 155, 102–117. https://doi.org/10.1016/j.atmosres.2014.12.001

Santoso, M., Lestiani, D.D., Mukhtar, R., Hamonangan, E., Syafrul, H., Markwitz, A., Hopke, P.K., 2011. Preliminary study of the sources of ambient air pollution in Serpong, Indonesia. Atmos. Pollut. Res. 2, 190–196. https://doi.org/10.5094/APR.2011.024

Saxena, M., Sharma, A., Sen, A., Saxena, P., Saraswati, Mandal, T.K., Sharma, S.K., Sharma, C., 2017. Water soluble inorganic species of PM10 and PM2.5 at an urban site of Delhi, India: Seasonal variability and sources. Atmos. Res. 184, 112–125. https://doi.org/10.1016/j.atmosres.2016.10.005

See, S.W., Balasubramanian, R., Wang, W., 2006. A study of the physical, chemical, and optical properties of ambient aerosol particles in Southeast Asia during hazy and nonhazy days. J. Geophys. Res. Atmos. 111, 1–12. https://doi.org/10.1029/2005JD006180

Shao, P., Tian, H., Sun, Y., Liu, H., Wu, B., Liu, S., Liu, X., Wu, Y., Liang, W., Wang, Y., Gao, J., Xue, Y., Bai, X., Liu, W., Lin, S., Hu, G., 2018. Characterizing remarkable changes of severe haze events and chemical compositions in multi-size airborne particles (PM1, PM2.5 and PM10) from January 2013 to 2016–2017 winter in Beijing, China. Atmos. Environ. 189, 133–144. https://doi.org/10.1016/j.atmosenv.2018.06.038

Sharma, S.K., Mandal, T.K., 2017. Urban Climate Chemical composition of fi ne mode particulate matter (PM 2 . 5) in an urban area of Delhi , India and its source apportionment. Urban Clim. 21, 106–122. https://doi.org/10.1016/j.uclim.2017.05.009

Shen, R., Schäfer, K., Shao, L., Schnelle-Kreis, J., Wang, Y., Li, F., Liu, Z., Emeis, S., Schmid, H.P., 2017. Chemical characteristics of PM2.5 during haze episodes in spring 2013 in Beijing. Urban Clim. 22, 51–63. https://doi.org/10.1016/j.uclim.2016.01.003

Shridhar, V., Khillare, P.S., Agarwal, T., Ray, S., 2010. Metallic species in ambient particulate matter at rural and urban location of Delhi 175, 600–607. https://doi.org/10.1016/j.jhazmat.2009.10.047

Taiwo, A.M., 2016. Source Apportionment of Urban Background Particulate Matter in Birmingham , United Kingdom Using a Mass Closure Model 2015, 1244–1252. https://doi.org/10.4209/aaqr.2015.09.0537

Tan, J., Zhang, L., Zhou, X., Duan, J., Li, Y., Hu, J., He, K., 2017. Chemical characteristics and source apportionment of PM2.5 in Lanzhou, China. Sci. Total Environ. 601–602, 1743–1752. https://doi.org/10.1016/j.scitotenv.2017.06.050

Tao, J., Zhang, L., Engling, G., Zhang, R., Yang, Y., Cao, J., Zhu, C., Wang, Q., Luo, L., 2013. Chemical composition of PM2.5 in an urban environment in Chengdu, China: Importance of springtime dust storms and biomass burning. Atmos. Res. 122, 270–283. https://doi.org/10.1016/j.atmosres.2012.11.004

Tao, J., Zhang, L., Gao, J., Wang, H., Chai, F., Wang, S., 2015. Aerosol chemical composition and light scattering during a winter season in Beijing. Atmos. Environ. 110, 36–44. https://doi.org/10.1016/j.atmosenv.2015.03.037

Tham, J., Sarkar, S., Jia, S., Reid, J.S., Mishra, S., Sudiana, I.M., Swarup, S., Ong, C.N., Yu, L.E., 2019. Impacts of peat-forest smoke on urban PM2.5 in the Maritime Continent during 2012–2015: Carbonaceous profiles and indicators. Environ. Pollut. 248, 496–505. https://doi.org/10.1016/j.envpol.2019.02.049

Thepnuan, D., Chantara, S., Lee, C. Te, Lin, N.H., Tsai, Y.I., 2019. Molecular markers for biomass burning associated with the characterization of PM 2.5 and component sources during dry season haze episodes in Upper South East Asia. Sci. Total Environ. 658, 708–722. https://doi.org/10.1016/j.scitotenv.2018.12.201

Thuy, N.T.T., Dung, N.T., Sekiguchi, K., Thuy, L.B., Hien, N.T.T., Yamaguchi, R., 2018. Mass concentrations and carbonaceous compositions of pm0.1, pm2.5, and pm10 at urban locations in hanoi, vietnam. Aerosol Air Qual. Res. 18, 1591–1605. https://doi.org/10.4209/aaqr.2017.11.0502

Xu, X., Zhang, H., Chen, J., Li, Q., Wang, X., Wang, W., Zhang, Q., Xue, L., Ding, A., Mellouki, A., 2018. Six sources mainly contributing to the haze episodes and health risk assessment of PM2.5 at Beijing suburb in winter 2016. Ecotoxicol. Environ. Saf. 166, 146–156. https://doi.org/10.1016/j.ecoenv.2018.09.069

Yin, J., Cumberland, S.A., Harrison, R.M., Allan, J., Young, D.E., Williams, P.I., Coe, H., 2015. Receptor modelling of fine particles in southern England using CMB including comparison with AMS-PMF factors. Atmos. Chem. Phys. 15, 2139–2158. https://doi.org/10.5194/acp-15-2139-2015

Zhang, R., Sun, X., Shi, A., Huang, Y., Yan, J., Nie, T., Yan, X., Li, X., 2018. Secondary inorganic aerosols formation during haze episodes at an urban site in Beijing, China. Atmos. Environ. 177, 275–282. https://doi.org/10.1016/j.atmosenv.2017.12.031

Zhang, Yang, Huang, W., Cai, T., Fang, D., Wang, Y., Song, J., Hu, M., Zhang, Yuanxun, 2016. Concentrations and chemical compositions of fine particles (PM2.5) during haze and non-haze days in Beijing. Atmos. Res. 174–175, 62–69. https://doi.org/10.1016/j.atmosres.2016.02.003

Zhao, L., Wang, L., Tan, J., Duan, J., Ma, X., Zhang, C., Ji, S., Qi, M., Lu, X.H., Wang, Y., Wang, Q., Xu, R., 2019. Changes of chemical composition and source apportionment of PM2.5 during 2013–2017 in urban

Handan, China. Atmos. Environ. 206, 119–131. https://doi.org/10.1016/j.atmosenv.2019.02.034

Zhou, S., Yuan, Q., Li, W., Lu, Y., Zhang, Y., Wang, W., 2014. Trace metals in atmospheric fine particles in one industrial urban city: Spatial variations, sources, and health implications. J. Environ. Sci. (China) 26, 205–213. https://doi.org/10.1016/S1001-0742(13)60399-X