Supplementary of

Highly time-resolved measurements of element concentrations in PM_{10} and $PM_{2.5}$: Comparison of Delhi, Beijing, London, and Krakow

Pragati Rai et al.

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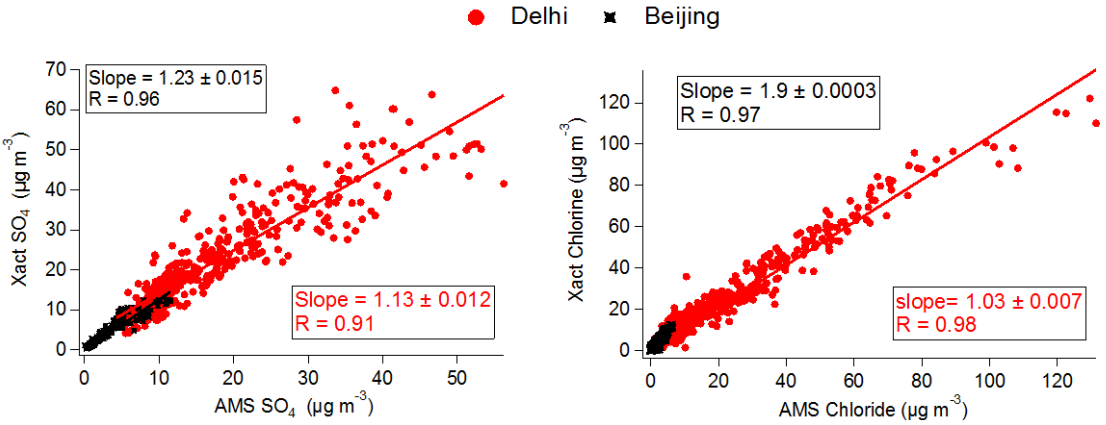
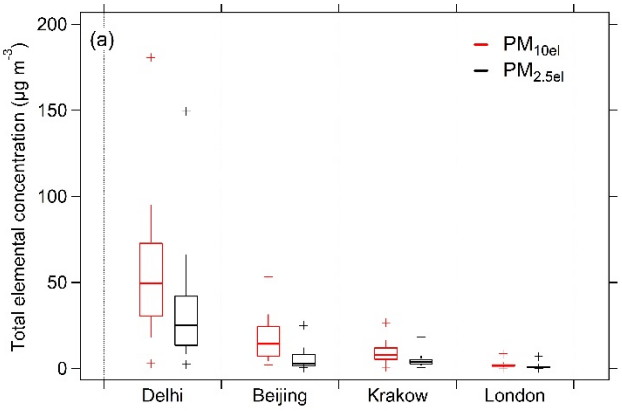


Figure S1: Comparison of Xact $PM_{2.5}$ sulfate (3×S, assuming that all S occurred in the form of sulfate.) vs AMS sulfate (left) and Xact $PM_{2.5}$ Cl vs AMS chloride (right) at Delhi (red; AMS PM_1) and Beijing (black; AMS $PM_{2.5}$) sites.



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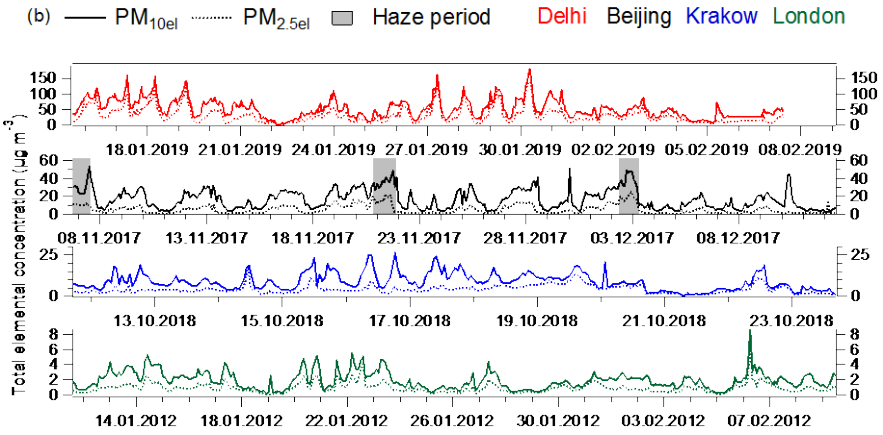


Figure S2: (a) Box-Whisker plots (top to bottom: maximum-p90-p75-p50-p25-p10-minimum) of total PM_{10el} and $PM_{2.5el}$ concentrations and (b) Time series of hourly PM_{10el} and $PM_{2.5el}$ at Delhi, Beijing, Krakow, and London.

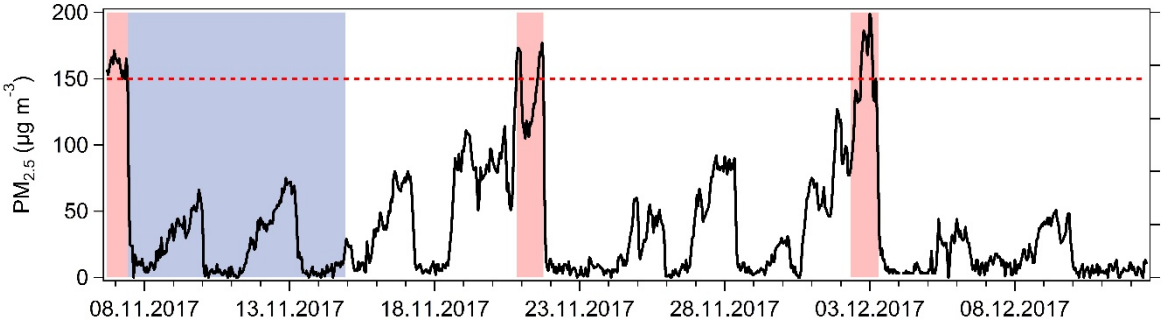


Figure S3: Time series of $PM_{2.5}$ total mass concentration in Beijing measured at the nearest national monitoring network station in Haidian District (2.5 km away from the Xact sampling site). The periods highlighted with a blue background relate to the non-heating period, while the rest belongs to the heating period. The red background colors represent haze events based on $PM_{2.5}$ concentrations ≥ 150 µg m^{-3} with a dashed red line, whereas the remaining periods are called non-haze.

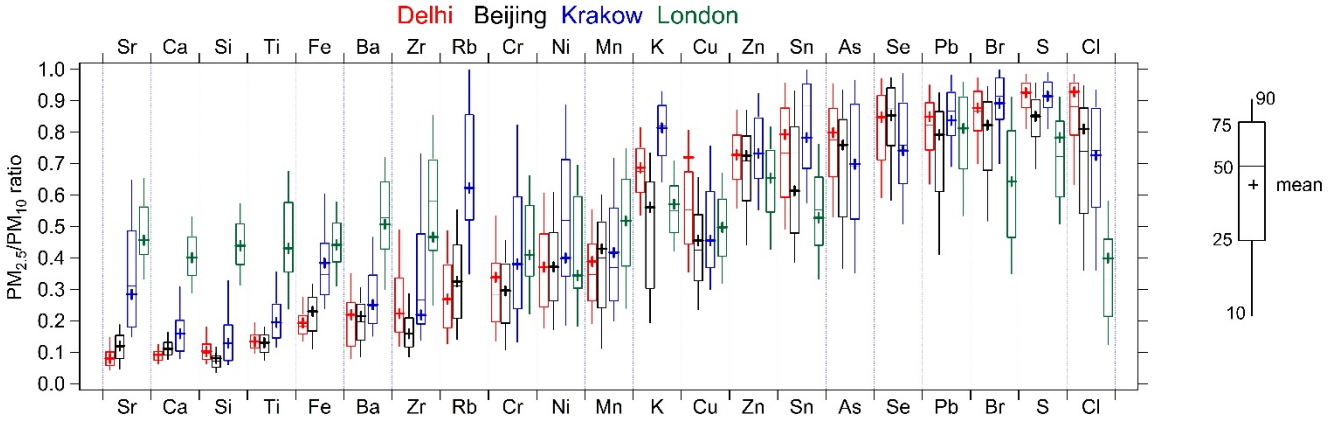


Figure S4: Box-whisker plot of the measured elemental $PM_{2.5}/PM_{10}$ ratios at all four sites. Box: First to third quartile range, −: median line, +: mean, whiskers: 10-90% percentiles. Note that Rb, As and Se were not measured in London. London measurements should be interpreted with caution due to uncertainties in the low size cut-off of the RDI, as discussed in Section 2.2.

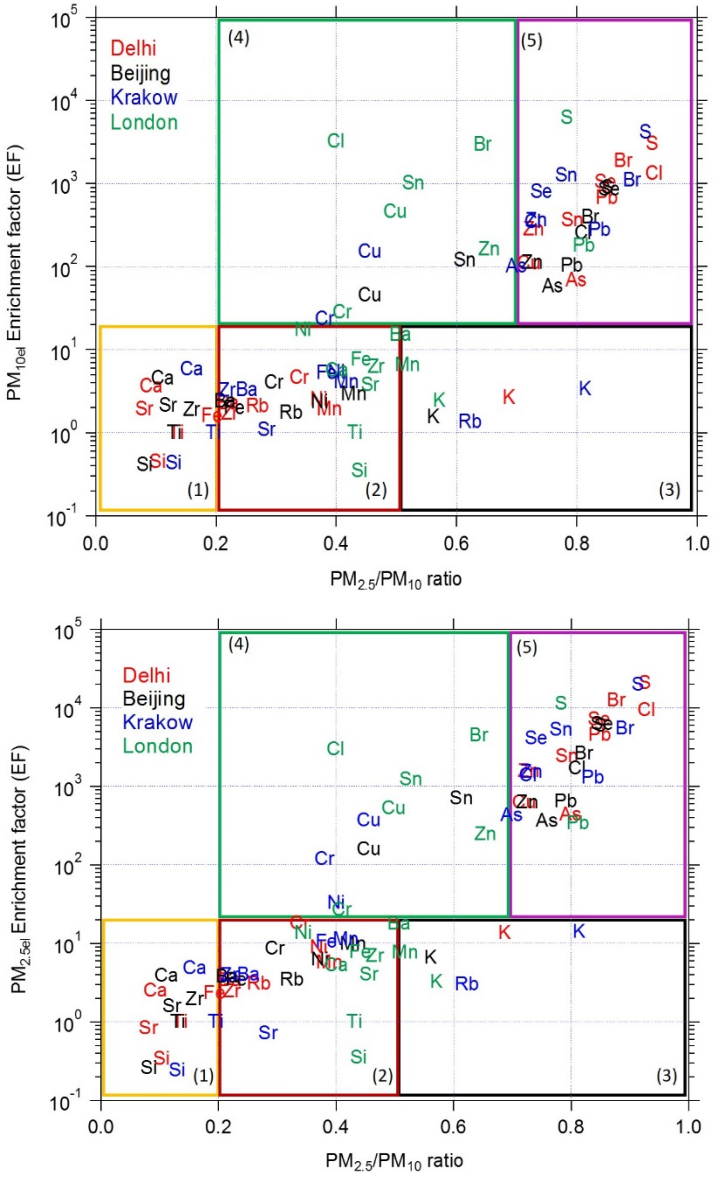


Figure S5: Enrichment factors (EF) vs $PM_{2.5}/PM_{10}$ ratios at all four sites. The upper graph is for PM_{10el} EF vs $PM_{2.5}/PM_{10}$ and the lower graph is for $PM_{2.5el}$ EF vs $PM_{2.5}/PM_{10}$. Note that Rb, As and Se were not measured in London. London measurements should be interpreted with caution (especially with respect to the $PM_{2.5}/PM_{10}$ ratio) due to uncertainties in the low size cut-off of the RDI, as discussed in Section 2.2.

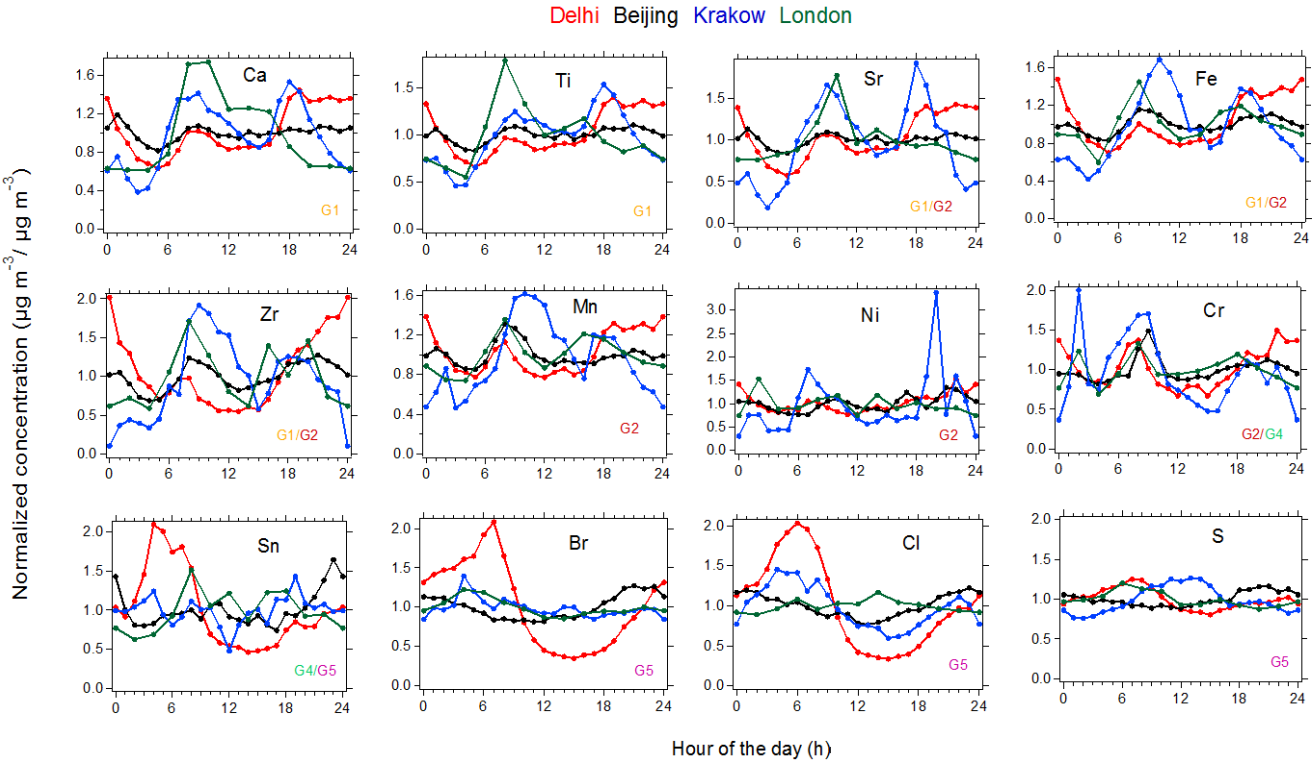
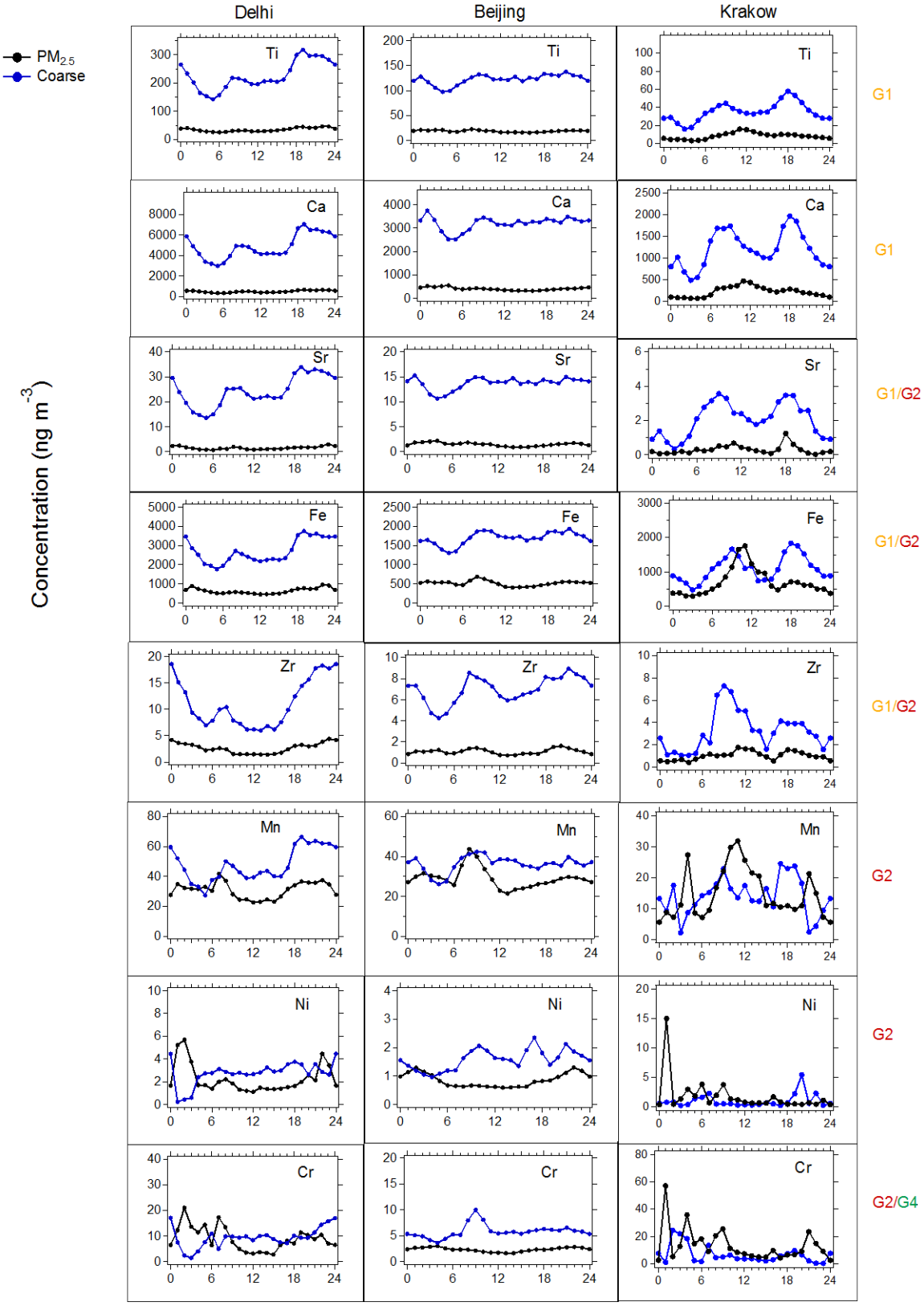


Figure S6: Diurnal patterns (mean) of elements in each group (G1: Group 1, G2: group 2, G3: Group 3, G4: Group 4, G5: Group 5) in PM_{10} normalized by the mean values of the elements in PM_{10} at Delhi, Beijing, Krakow, and London. Note that due to the time resolution of the original data the London data are 2-hour averages, while the other data are one-hour averages.


Delhi
Beijing
Krakow
PM2.5
Coarse
Concentration (ng m-3)
Ti
Ca
Sr
Fe
Zr
Mn
Ni
Cr
G1
G1
G1/G2
G1/G2
G1/G2
G2
G2
G2/G4

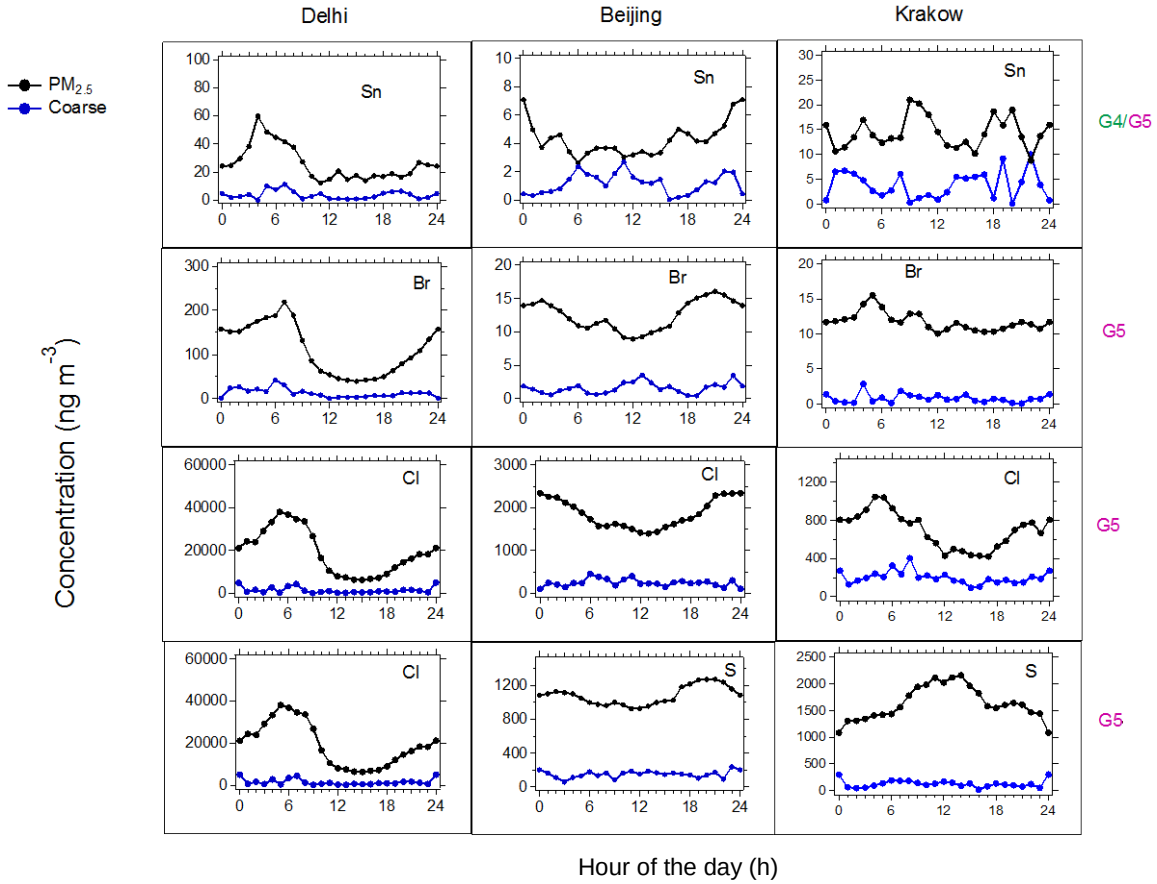


Figure S7: Diurnal patterns (mean) of elements in $PM_{2.5}$ and coarse size fractions (PM_{10}–$PM_{2.5}$) at Delhi, Beijing, and Krakow, in each group (G1: Group 1, G2: group 2, G3: Group 3, G4: Group 4, G5: Group 5).

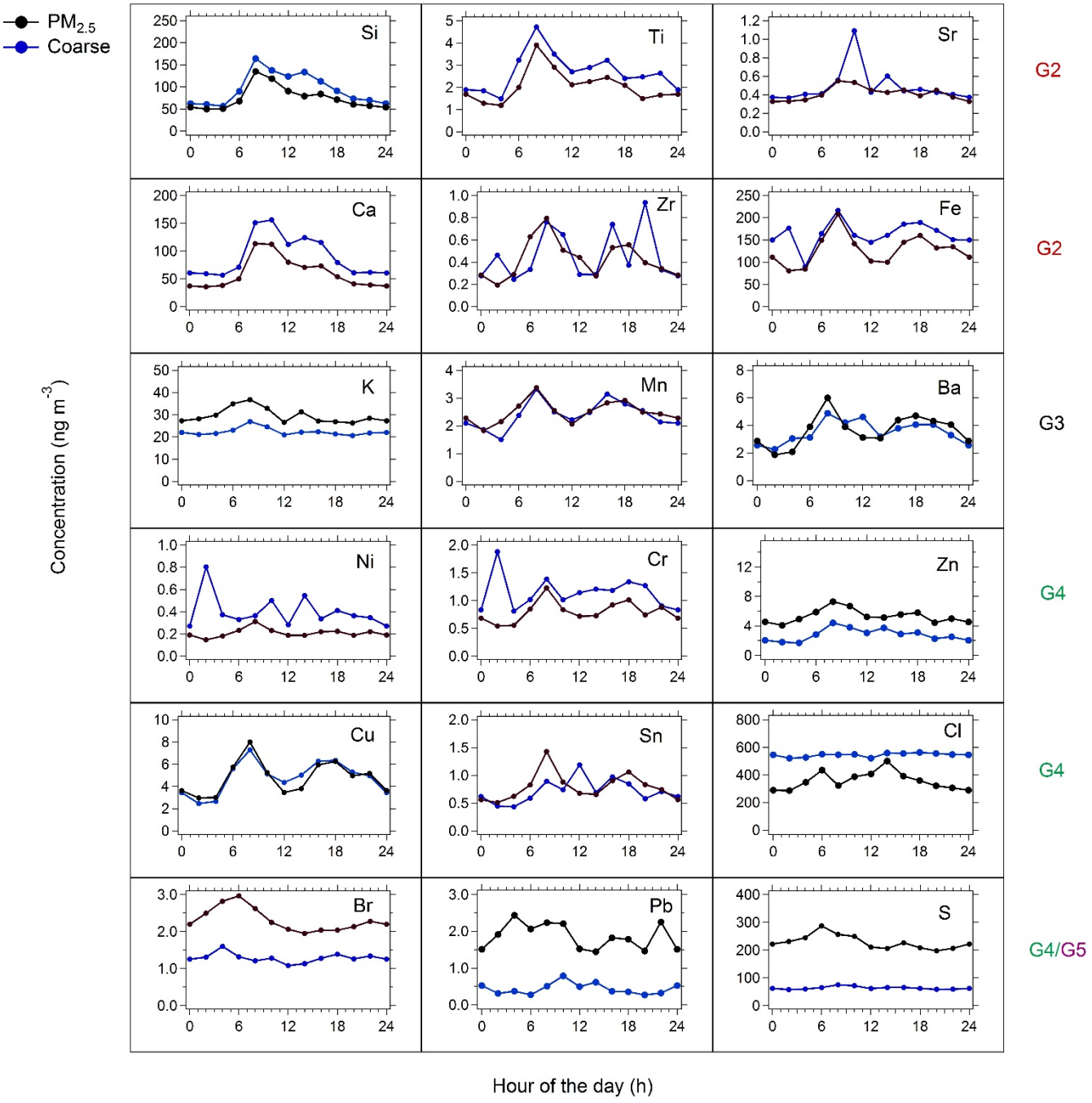


Figure S8: Diurnal patterns (mean) of elements in $PM_{2.5}$ and coarse size fractions (PM_{10}–$PM_{2.5}$) at London, in each group (G2: group 2, G3: Group 3, G4: Group 4, G5: Group 5). Note that Group 1 is absent in London. Note that due to the time resolution of the original data of London, hour of the day on the x-axis represents 2-hour averages. London measurements should be interpreted with caution due to uncertainties in the low size cut-off of the RDI, as discussed in Section 2.2.

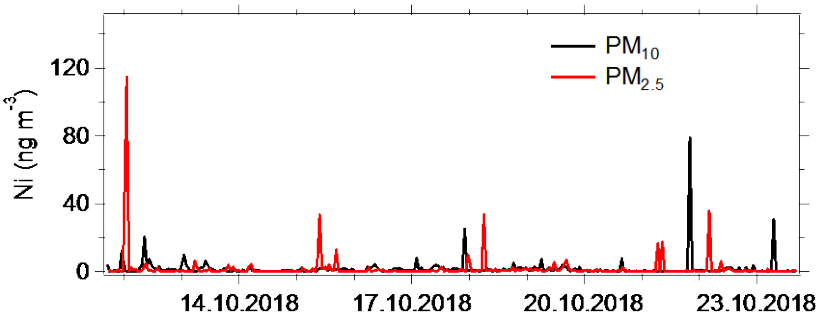


Figure S9: Time series of Ni in PM_{10} (black) and $PM_{2.5}$ (red) in Krakow.

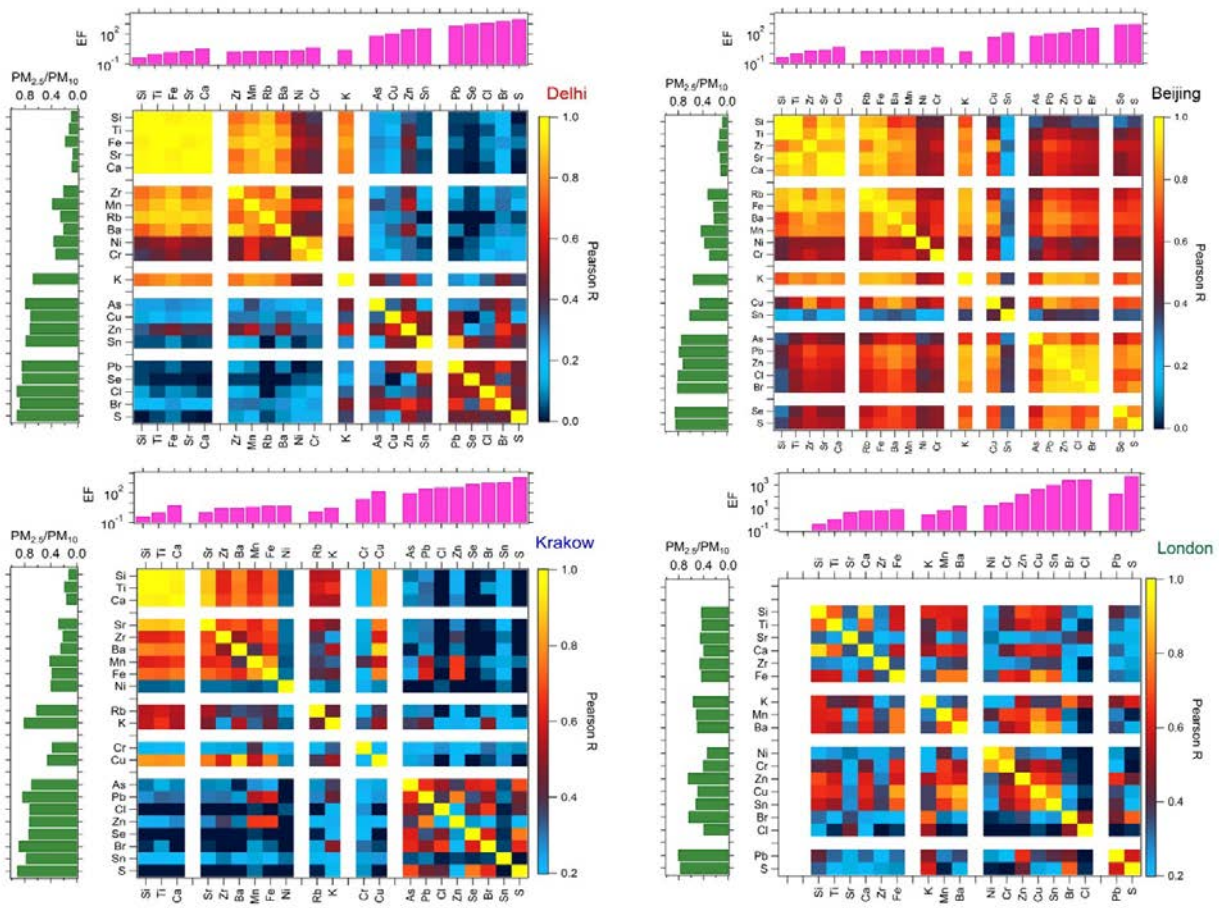


Figure S10: Correlation (Pearson's *R*) matrix of measured elements in elemental PM_{10} at all four sites (white color represents gap between each group elements). Elements are sorted by group along each axis. Note that in London, Group 1 (represented as white gap) is absent as well as Rb, As and Se were not measured. London measurements should be interpreted with caution due to uncertainties in the low size cut-off of the RDI, as discussed in Section 2.2.

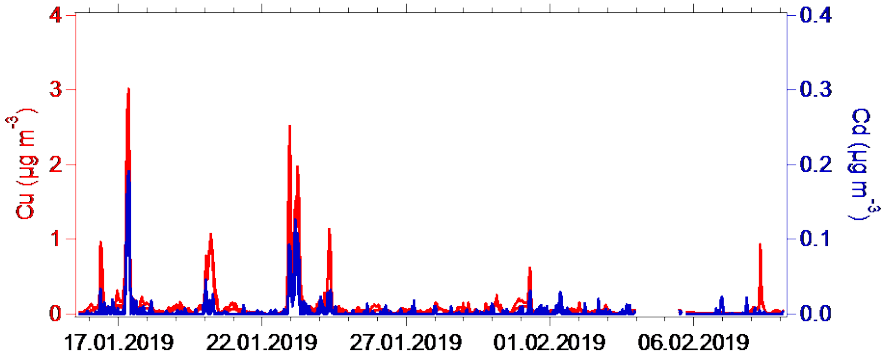


Figure S11: Time series of $PM_{2.5}$ Cu and Cd in Delhi.

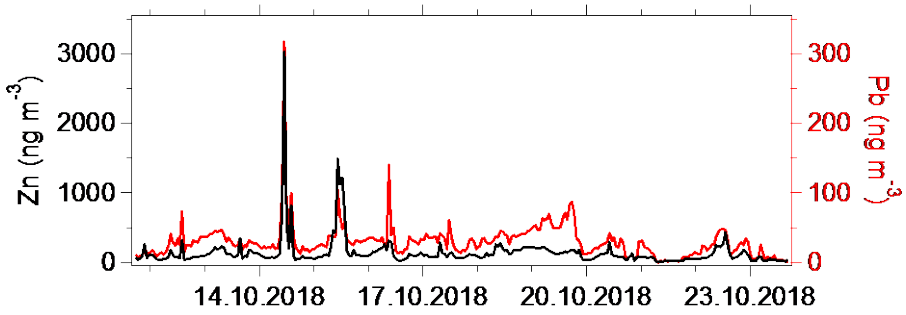


Figure S12: Time series of $PM_{2.5}$ Zn and Pb in Krakow.

Table S1: Xact 625i minimum detection limits (MDL) of elements with 30 min and 60 min time resolution. The percentage of data points below MDL is reported for both sizes in Delhi, Beijing and Krakow.

Element	Xact MDL		Data points below MDL (%)					
	60 min	30 min	Delhi		Beijing		Krakow	
	(ng m^{-3})	(ng m^{-3})	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Al	170	500	18.8	61.4	24.5	86.1	86.9	99.3
Si	30.9	88.9	0	3.52	0	2.43	12.06	55.67
P	9.0	26.0	100	100	100	100	100	100
S	5.5	15.7	0	0	0	0	0	0
Cl	3.0	8.6	0	0	0	0	0	0
K	2.0	5.8	0	0	0	0	0	0
Ca	0.52	1.5	0	0	0	0.24	0	0
Ti	0.28	0.79	0	0	0	0.24	0.35	7.09
V	0.21	0.60	4.9	45.4	12.6	85.9	84.8	94.7
Cr	0.20	0.58	0	10.8	0.49	16.3	10.6	17.0
Mn	0.25	0.71	0	0	0	0	5.3	11.0
Fe	0.30	0.85	0	0	0	0.49	0	0
Co	0.24	0.68	98.8	96.9	93.4	98.1	98.6	100
Ni	0.17	0.47	3.5	27.0	5.8	30.2	39.0	58.9
Cu	0.14	0.39	0	0	0	0	0.35	0.35
Zn	0.12	0.33	0	0	0	0.24	0	0
Ga	0.10	0.29	99.6	100	68.0	83.5	99.6	99.3
Ge	0.10	0.28	99.8	100	82.3	81.0	98.2	98.2
As	0.11	0.31	0.20	100	0.73	4.1	6.4	10.3
Se	0.14	0.40	6.4	7.0	40.3	44.5	59.2	59.6
Br	0.18	0.52	0	0	0	0.73	0	0.35
Rb	0.33	0.95	10.9	57.7	9.0	47.0	65.6	86.5
Sr	0.38	1.1	2.9	56.2	0	42.6	46.1	91.8
Y	0.48	1.4	95.1	97.8	86.4	98.5	98.2	99.3
Zr	0.57	1.6	7.0	45.6	5.6	47.4	40.8	71.6
Cd	4.4	12.4	92.8	94.7	99.8	99.3	99.3	99.6
In	5.4	15.4	93.2	91.6	97.3	98.1	100	99.3
Sn	7.1	20.1	50.2	54.4	70.1	79.1	64.9	69.9
Sb	9.0	25.5	74.6	76.7	89.6	95.1	89.0	89.7
Ba	0.67	1.9	5.1	36.8	0.5	24.6	16.0	53.9
Hg	0.21	0.60	100	100	100	100	100	100
Tl	0.20	0.57	94.7	99.2	99.0	99.4	100	100
Pb	0.22	0.63	0	0	0	0.49	1.77	0.71
Bi	0.23	0.64	99.8	99.8	94.2	95.1	100	100

Table S2: Means, medians and 25–75th percentiles of PM_{10el} and $PM_{2.5el}$ concentrations (ng m^{-3}) in Delhi, Beijing, Krakow and London (*BDL: below detection limit).

Element	PM_{10}				$PM_{2.5}$			
	mean	median	q25	q75	mean	median	q25	q75
Delhi								
Al	3089	2593	919	4609	742	199	BDL	1055
Si	12158	10988	7428	16101	1241	1182	687	1721
S	7664	6411	4203	10320	7098	6060	3919	9454
Cl	20254	13104	5100	25989	19057	12183	4515	25126
K	3056	2609	1807	3834	2098	1743	1099	2678
Ca	5373	4686	3074	7227	494	408	259	643
Ti	262	238	163	343	35.1	30.5	20.4	44.7
V	5.9	5.1	3.1	8.3	1.29	0.78	0.00	1.96
Cr	17.4	12.2	7.2	23.7	9.1	3.5	1.42	8.5
Mn	79.3	64.4	42.2	99.6	31.5	20.8	12.6	37.7
Fe	3345	2932	1993	4281	648	500	355	725
Ni	4.9	3.9	2.4	6.5	2.3	1.12	0.4	2.3
Cu	128	47.8	25.0	91.1	96.1	27.4	13.0	54.2
Zn	784	606	379	1015	580	445	258	760
As	13.6	11.7	7.3	17.1	11.5	10.0	6.1	15.2
Se	3.9	3.0	1.50	4.6	3.5	2.8	1.42	4.2
Br	124	77.0	39.4	160	111	66.3	34.5	147
Rb	7.2	6.2	2.9	10.2	1.41	0.58	BDL	2.2
Sr	25.6	22.5	13.8	35.4	1.47	0.80	BDL	2.3
Zr	13.5	9.9	5.3	18.1	2.6	1.89	0.57	3.6
Sn	29.7	19.9	12.2	34.8	26.8	18.0	9.7	32.2
Sb	23.5	14.1	3.7	26.5	18.4	12.8	2.2	25.0
Ba	58.7	42.7	20.3	77.6	11.8	4.8	0.16	15.0
Pb	475	216	106	415	421	181	88.8	363
Beijing								
Al	1524	1161	184	2478	68.4	BDL	BDL	BDL
Si	6060	5605	2866	7910	511	400	163	650
S	1224	708	445	1354	1084	578	376	1161
Cl	2089	684	203	3135	1841	479	134	2727
K	963	732	324	1533	546	265	100	906
Ca	3598	3239	1543	5234	414	342	174	592
Ti	141	128	67.9	195	18.8	15.6	7	26.3
V	1.98	1.54	0.65	2.7	0.11	BDL	BDL	BDL
Cr	8.2	7.2	3.1	11.6	2.4	1.73	0.41	3.9
Mn	65.0	55.8	25.2	94.5	29.0	20.3	6.4	44.2
Fe	2206	1946	981	3201	517	387	165	752
Ni	2.4	2.0	0.88	3.4	0.86	0.60	0.10	1.29
Cu	28.2	21.9	8.7	43.0	13.2	9.2	3.2	20.3
Zn	165	93.5	36.4	261	124	69.0	21.8	200
As	6.2	2.8	1.22	8.1	5.2	1.90	0.76	7.0
Se	1.7	0.36	BDL	2.5	1.67	0.25	BDL	2.4
Br	14.0	5.1	2.1	20.7	12.5	5.08	1.62	18.1
Rb	3.2	2.7	1.13	4.8	0.85	0.42	BDL	1.3
Sr	15.1	13.5	6.4	21.6	1.50	0.64	BDL	2.5
Zr	8.1	6.9	2.5	11.7	1.10	0.66	0.05	1.7
Sn	5.3	4.1	0.83	7.8	4.2	2.8	BDL	6.2
Sb	2.7	0.03	BDL	4.7	1.89	BDL	BDL	2.6
Ba	33.1	28.2	10.8	50.3	6.9	4.0	0.68	11.1
Pb	38.8	19.7	7.4	62.8	32.7	15.2	5.2	54.7

Element	PM_{10}				$PM_{2.5}$			
	mean	median	q25	q75	mean	median	q25	q75
Krakow								
Al	146	BDL	BDL	BDL	28	BDL	BDL	BDL
Si	1982	1461	385	2867	219	69.5	14.2	312
S	1780	1194	873	1931	1662	1099	801	1833
Cl	882	628	286	1103	688	431	195	857
K	653	641	440	885	534	506	344	718
Ca	1460	1059	459	1968	234	127	64.5	329
Ti	44.2	36.5	18.1	64.5	8.6	6.7	3.2	12.6
V	0.25	BDL	BDL	0.17	0.10	BDL	BDL	BDL
Cr	14.9	7.7	2.7	17.6	14.7	3.8	1.01	11.9
Mn	28.3	21.8	9.6	36.5	15.2	8.1	4.0	17.3
Fe	1833	1484	713	2437	722	521	252	879
Ni	1.73	0.73	0.24	1.72	2.1	0.36	BDL	0.94
Cu	29.4	22.0	12.0	40.7	14.0	10.9	5.9	19.2
Zn	168	129	76.9	191	140	91.4	60.9	150
As	3.3	3.1	1.95	4.4	2.8	2.5	1.19	3.6
Se	0.50	0.23	BDL	0.79	0.50	0.27	BDL	0.74
Br	12.2	10.6	6.2	15.3	11.7	9.8	5.8	15.0
Rb	0.79	0.50	BDL	1.30	0.34	BDL	BDL	0.55
Sr	2.4	1.39	BDL	3.66	0.31	BDL	BDL	0.16
Zr	4.3	2.3	0.77	5.61	1.04	0.66	BDL	1.71
Sn	17.4	15.5	7.9	24.6	14.3	12.1	4.3	22.7
Sb	10.8	8.7	1.19	16.7	10.0	6.4	BDL	17.1
Ba	14.3	10.5	2.1	20.3	3.4	1.59	BDL	4.9
Pb	32.7	30.9	18.2	41.5	29.5	25.8	15.7	36.7
London								
Al	96.1	82.2	59.5	121	45.8	42.7	29.3	54.8
Si	174	140	77	225	76.4	58.2	35.8	104
S	292	213	136	322	229	139	81.4	258
Cl	908	626	226	1391	362	162	57.2	483
K	52.1	47.8	30.0	69.0	29.7	25.5	15.6	38.9
Ca	154	114	72.2	195	61.8	45.5	26.9	79.1
Ti	4.8	3.4	1.87	6.2	2.1	1.52	0.75	2.8
V	1.18	0.83	0.52	1.42	0.56	0.43	0.25	0.72
Cr	1.97	1.37	0.72	2.5	0.81	0.62	0.31	1.03
Mn	4.9	3.8	2.3	5.8	2.5	1.96	0.98	3.0
Fe	293	216	130	362	129	92.2	51.6	161
Ni	0.62	0.35	0.18	0.70	0.21	0.16	0.08	0.28
Cu	9.8	7.2	4.0	12.2	4.9	3.1	1.84	6.0
Zn	8.2	6.0	2.7	11.3	5.4	3.5	1.69	7.9
Br	3.6	3.2	1.76	4.9	2.3	1.73	1.03	2.8
Sr	0.92	0.75	0.47	1.16	0.42	0.34	0.21	0.53
Zr	0.91	0.46	0.20	1.07	0.44	0.26	0.12	0.52
Sn	1.53	1.07	0.52	1.87	0.81	0.55	0.27	1.04
Sb	1.18	0.84	0.43	1.44	0.63	0.42	0.22	0.81
Ba	7.3	4.9	2.7	8.6	3.7	2.4	1.33	4.6
Pb	2.3	1.31	0.63	2.8	1.89	1.0	0.45	2.3

Table S3: Relative fractions (%) of elements in both sizes for all four sites.

Element	Delhi		Beijing		Krakow		London	
	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Si	22.6	3.9	36.4	9.9	22.1	5.1	9.1	8.4
S	14.2	22.2	7.3	21.0	19.9	38.5	15.2	25.0
Cl	37.6	59.6	12.5	35.7	9.8	16.0	47.3	39.7
K	5.7	6.6	5.8	10.6	7.3	12.4	2.7	3.3
Ca	10.0	1.55	21.6	8.0	16.3	5.4	8.0	6.8
Ti	0.49	0.11	0.85	0.36	0.49	0.20	0.25	0.23
Cr	0.03	0.03	0.05	0.05	0.17	0.34	0.10	0.09
Mn	0.15	0.10	0.39	0.56	0.32	0.35	0.26	0.28
Fe	6.2	2.0	13.2	10.0	20.5	16.7	15.2	14.1
Ni	0.01	0.01	0.01	0.02	0.02	0.05	0.03	0.02
Cu	0.24	0.30	0.17	0.26	0.33	0.32	0.51	0.53
Zn	1.45	1.81	0.99	2.4	1.88	3.2	0.43	0.59
Br	0.23	0.35	0.08	0.24	0.14	0.27	0.19	0.25
Sr	0.05	0	0.09	0.03	0.03	0.01	0.05	0.05
Zr	0.03	0.01	0.05	0.02	0.05	0.02	0.05	0.05
Sn	0.06	0.08	0.03	0.08	0.19	0.33	0.08	0.09
Ba	0.11	0.04	0.20	0.13	0.16	0.08	0.38	0.40
Pb	0.88	1.32	0.23	0.63	0.36	0.68	0.12	0.21