Supplemental Materials

Title of manuscript:

Chemical characteristics, sources apportionment and risk assessment of $PM_{2.5}$ in different functional areas of an emerging megacity in China

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Materials and Methods

Chemical analysis. WSII: The half of $PM_{2.5}$ filter was cut into pieces and ultrasonically extracted with 20 mL of Milli-Q water for 30 min, followed by filtering through a 0.45 mm polytetrafluoroethylene syringe filter before analysis. The cation concentrations were determined by an IonPacASll-HC4 mm anion separation column and an IonPacAGll-HC4 mm protective column. The eluent was 20 mM methane sulfonate and the eluent was 0.8 mL/min. The anions were measured by an IonPacCS12A cation separation column and an IonPacCG12A guard column, with a solution of 8.0 mM Na_2CO_3 + 1.0 mM $NaHCO_3$ as an eluent at 1.0 mL/min. The regression coefficients (R^2) of the calibration curves were over 0.9996 for all ions, except NH_4^+ (0.9988), which showed a quadratic response. The method detection limits (MDLs) were 0.001, 0.001, 0.015, 0.031, 0.005, 0.011, 0.006, 0.002, and 0.017 mg/L for F^-, Cl^-, NO_3^-, SO_4^{2-}, Na^+, NH_4^+, K^+, Mg^{2+} and Ca^{2+}, respectively.

OC/EC: In the first step, temperature was increased to approximately 840 °C to volatilize OC from the sample. In the second step, temperature was increased to approximately 870 °C, and EC was measured in an oxidizing atmosphere of 2% oxygen with 98% helium. The two step products were completely oxidized to carbon dioxide and reduced to methane, which was detected by a flame ion detector. The MDLs of OC and EC were 0.2 μg/cm^2.

Elements: This spectrometer was equipped with an X-ray tube with close coupling among the tube, sample, and detector, which ensured a high efficiency with optimal excitation of the elements in the sample. Before analysis, various high-quality self-prepared standards were used for instrument calibration. Detailed operation steps of calibration were performed by referring to published methods (Chow and Watson, 1994). The MDLs ranged from 0.002 μg/cm^3 (Mg) to 0.026 μg/cm^3 (Cd). Details on MDLs are summarized in Table 1. Blank filters were also routinely analyzed with each batch of samples to detect sample contamination and provide quality assurance on the elemental concentrations.

Table 1. MDLs of elements.

element	μg/cm^2	element	μg/cm^2
Na	0.003	Ga	0.005
Mg	0.002	As	0.008
Al	0.004	Se	0.006
Si	0.005	Sr	0.006
P	0.002	Cd	0.034
S	0.006	Sn	0.016
Cl	0.007	Sb	0.020
K	0.005	Ba	0.022
Ca	0.014	Pb	0.015
Ti	0.010	Cr	0.018
V	0.008	Mn	0.017
Ni	0.006	Fe	0.028
Cu	0.005	Co	0.009
Zn	0.003		

Potential source contribution function (PSCF) model. PSCF is a statistical method that can be interpreted as the conditional probability that concentrations larger than a given criterion are related to the passage of air parcels through the grid cell during transport to the receptor site (Hopke et al., 1995). The study region was divided into latitude i × longitude j small equal grid cells. The PSCF value for the grid cells are calculated by counting the trajectory segment endpoints that terminate within each cell was defined as:

$$PSCF = \frac{m_{ij}}{n_{ij}} \quad (1)$$

Where n_{ij} represented the number of times that the trajectories passed through fell in the (i, j) cell, and m_{ij} was the number of times in the same cell that were related to the samples that were greater than the criterion value.

Based on the NAAQS (GB3095-2012 guideline value (24 h) of Grade II), the criterion values of $PM_{2.5}$ was set to 75 μg/m3. In terms of the average during the sampling period. When nij is smaller than three times the grid average number of the end points per cell (nave), a weighting function W(nij) was used to reduce uncertainty in cells (Dimitriou et al., 2015). The weighting function was defined by:

$$WPSCF_{IJ} = \frac{m_{ij}}{n_{ij}} * W(n_{ij}) \quad (2)$$

$$W(n_{ij}) = \begin{cases} 1.00, 3n_{ave} < n_{ij} \\ 0.70, 1.5\, n_{ave} < n_{ij} \leqslant 3n_{ave} \\ 0.40,\ n_{ave} < n_{ij} \leq 1.5n_{ave} \\ 0.20,\ n_{ij} \leq n_{ave} \end{cases} \quad (3)$$

Positive matrix factorization (PMF) model. The two matrices (factor contributions (G) and factor profiles (F)), as described in the following:

$$X = G * F + E, \tag{4}$$

where *X*, the data matrix, is the n*m matrix of the *m* measured chemical species in *n* samples; *F* is a p*m-matrix with rows that represent the emission profiles of *p* factors; and *G*, an n*p-matrix with columns that represent the scores of *p* factors. Matrix E is the residual matrix.

Factor contributions and profiles were derived by the PMF model by minimizing the objective function Q, i.e.,

$$Q = \sum_{i=1}^{n} \sum_{j=1}^{m} \left[\frac{e_{ij}}{u_{ij}} \right]^2, \tag{5}$$

where e_{ij} is the residual of the *j*th chemical component in the *i*th sample, and u_{ij} is the uncertainty of the *j*th chemical component in the *i*th sample.

According to the previous studies (Jiang et al., 2018), uncertainty is calculated as follows (Equation 6):

$$u_{ij} = \begin{cases} 0.2 * c_{ij} + MDL/3 & u_{ij} \leq MDL \\ 0.1 * c_{ij} + MDL/3 & u_{ij} > MDL, \end{cases} \tag{6}$$

where u_{ij} is the uncertainty of the jth chemical component in the ith sample, c_{ij} is the concentration of the jth chemical component in the ith sample. The missing data is instead by species median, and the outiers are excluded from the PMF analysis. More other details were described in the PMF 5.0 User Guide (US EPA, 2014).

Health risk assessment.

Exposure assessment. The upper limit of the 95% confidence interval for the mean 95% UCL was used to represent the corresponding exposure concentration. The 95% UCL concentration (C_{UCL}) had been calculated by the following formula:

$$C_{95\%}=\exp\left\{X+0.5\times S^2+\frac{s\times H}{\sqrt{n-1}}\right\} \quad (7)$$

where X is the arithmetic mean, s is the standard deviation, H is the H-statistic and n is the number of samples.

According to the human health evaluation manual (Part A) (US EPA, 1989), supplemental guidance for dermal risk assessment (Part E) and supplemental guidance for inhalation risk assessment (Part F) (USEPA, 2011),the chemical daily intake ($CD_{Iingest}$, mg/(kg day)), dermal absorption dose (DAD_{dermal}, mg/(kg day)), exposure concentration (EC_{inhale}, $\mu g/m^3$) of the toxic species of the toxic species were calculated according to the three following equations (Sun et al., 2014; Nie et al., 2018). The equations were as follows:

$$EC_{inhale}=\frac{(C\times ET\times EF\times ED)}{AT_1} \quad (8)$$

$$CDI_{ingest}=\frac{C\times IngR}{BW}\times\frac{EF\times ED}{AT_2}\times CF \quad (9)$$

$$DAD_{dermal}=\frac{C\times SA\times AF\times ABS}{BW}\times\frac{EF\times ED}{AT_2}\times CF \quad (10)$$

where C is the 95% UCL concentration ($\mu g/m^3$ besides in $CD_{Iingest}$ and DAD_{dermal}, mg/kg); ET is the exposure time, 6 h/day for adults and children; EF is the exposure frequency, 350 days/year; ED is the exposure duration, 6 and 24 years for children and adults, respectively; and AT1 is the average time, calculated by ED year × 365 days/year × 24 h/day for non-carcinogens and 74 years × 365 days/year × 24 h/day for carcinogens; IngR is the ingestion rate, 200 and 100 mg/day for children and adults, respectively; BW is the body weight, 15 and 59 kg for children and adults, respectively; AT_2 is the average time, calculated by ED year × 365 days/year for non-carcinogens and 74 years ×365 days/year for carcinogens; and CF is the conversion factor, 10^{-6} kg/mg._SA is the surface area, 2800 and 5700 cm^2 for children and adults, respectively; AF is the adherence factor, 0.2 and 0.07 mg/(cm2 d) for children and adults; ABS is the dermal adherence factor, ABS = 0.03 for element As, ABS = 0.001 for element Cd and ABS = 0.01 for all evaluated elements except for As and Cd. (Hu et al., 2012).

Risk assessment. After the $CD_{Iingest}$, EC_{inhale} and D_{dermal} were calculated for evaluated elements, The hazard quotient (HQ) and the carcinogenic risks (CR) were quantified for non-carcinogenic and carcinogenic health risks, HI corresponds to the sum of the individual HQ calculated for each element, which were calculated by the following equation:

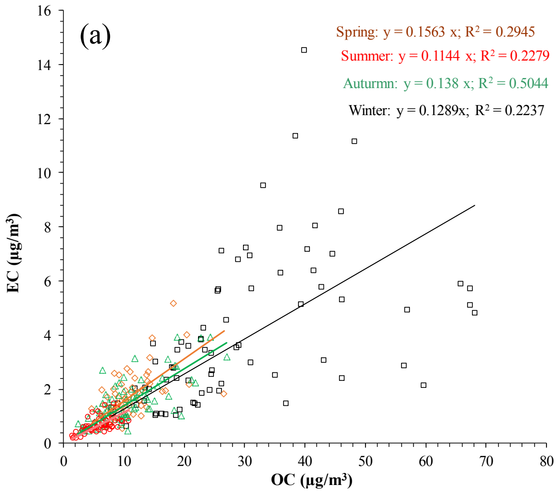
$$CR = \mathrm{IUR} \times \mathrm{EC} = \mathrm{CDI} \times SF_O = DAD \times \frac{SF_O}{GIABS} \quad (11)$$

$$HQ = \frac{\mathrm{EC}}{(\mathrm{Rf}C_i \times 1000\mu\mathrm{g/mg})} = \frac{CDI}{RfD_O} = \frac{DAD}{RfD_O \times \mathrm{GIABS}} \quad (12)$$

$$HI = \sum HQ_i \quad (13)$$

where IUR is the inhalation unit risk, $(\mu g/m^3)^{-1}$; SF_O is the slope factor, $(mg/ (kg\ day))^{-1}$; GIABS is the gastrointestinal absorption factor;

RfC_i is the inhalation reference concentrations, mg/m^3; RfDo is the oral reference dose, mg/(kg day) (USEPA, 2017); and HI is the hazard index, the sum of HQ. When CR is higher than 1.0×10^{-4}, the potential risk of cancer exists seriously. While when CR is between 1.0×10^{-6} and1.0×10^{-4}, the risk can be accepted. When CR is below1.0×10^{-6}, less risk exists or the risk can be ignored (Zhang et al., 2018). If the value of HI or HQ is less than one, it is believed that there is no significant risk of non-carcinogenic effects. If HI or HQ exceeds one, then there is a chance that non-carcinogenic effects may occur, with a probability which tends to increase as the value of HI increases (USEPA, 2001).



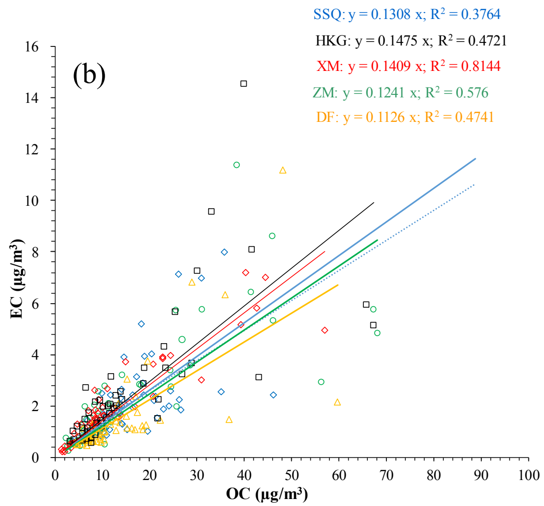


Fig. S1 Correlations between OC and EC during different seasons (a) and at different sampling sites (b) in Zhengzhou.

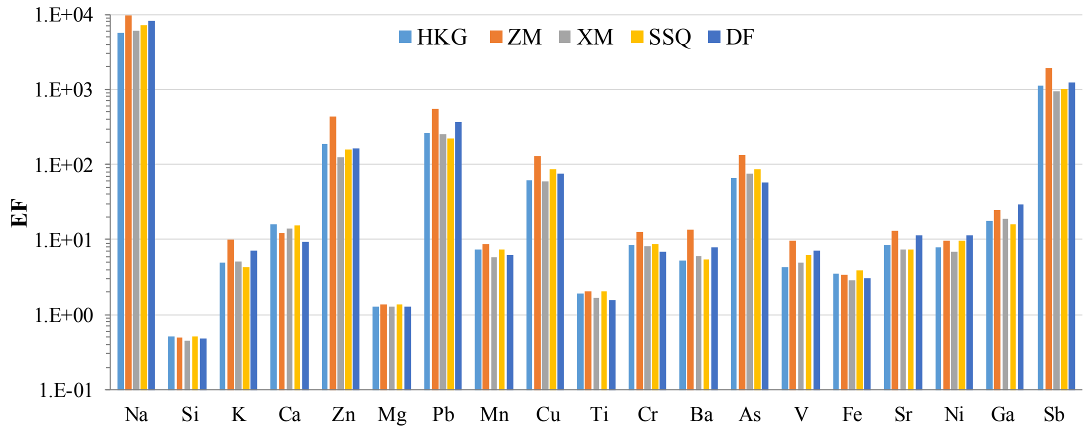


Fig. S2 EF of elements in $PM_{2.5}$ in five sampling sites.

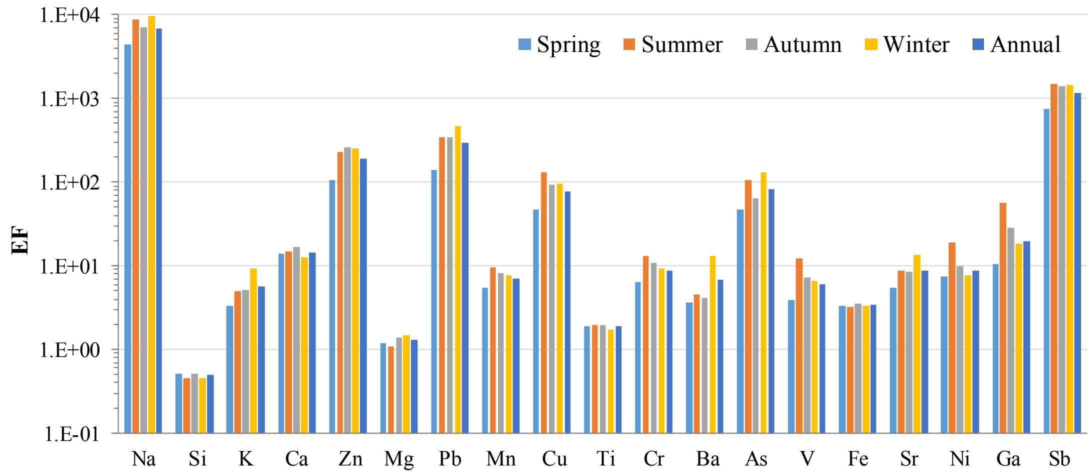


Fig. S3 EF of elements in $PM_{2.5}$ during different seasons.

Table S1

Seasonal distribution of $PM_{2.5}$, WSIIs, and carbonaceous species found in five sites, all sites mean and heavy pollution days (December 18-20, 2016) in Zhengzhou.

	HKG					ZM				
	Winter	Spring	Summer	Autumn	Annual	Winter	Spring	Summer	Autumn	Annual
$PM_{2.5}$ (μg/m^3)	229 ± 109	112 ± 44	50 ± 11	105 ± 34	131 ± 91	244 ± 139	84 ± 29	48 ± 18	50 ± 11	112 ± 112
OC (μg/m^3)	33.9 ± 16.4	10.2 ± 2.5	5.9 ± 1.8	12.4 ± 6.4	16.6 ± 14.4	36.7 ± 16.2	9.1 ± 2.4	5.4 ± 1.3	6.3 ± 3.3	15.3 ± 16.1
EC (μg/m^3)	5.5 ± 3.5	1.7 ± 0.5	0.8 ± 0.2	2.1 ± 0.8	2.7 ± 2.6	4.9 ± 2.5	1.8 ± 0.7	0.7 ± 0.3	0.9 ± 0.4	2.2 ± 2.2
SOC (μg/m^3)	14.8 ± 13.7	3.1 ± 1.7	2.8 ± 2.2	7.4 ± 5.5	7.4 ± 9.2	14.9 ± 12.5	3.5 ± 1.8	2.0 ± 1.0	3.4 ± 2.6	6.4 ± 8.6
Na^+ (μg/m^3)	0.6 ± 0.2	0.3 ± 0.1	0.1 ± 0.0	0.3 ± 0.2	0.4 ± 0.2	0.5 ± 0.2	0.3 ± 0.2	0.1 ± 0.0	0.2 ± 0.1	0.3 ± 0.2
NH_4^+ (μg/m^3)	24.5 ± 16.7	7.6 ± 4.1	6.3 ± 2.1	10.7 ± 5.9	12.9 ± 12.0	25.5 ± 17.7	9.2 ± 5.1	6.4 ± 1.7	6.0 ± 2.2	12.3 ± 12.7
K^+ (μg/m^3)	2.6 ± 1.6	0.7 ± 0.1	0.4 ± 0.1	1.0 ± 0.4	1.3 ± 1.3	3.5 ± 2.4	0.7 ± 0.2	0.4 ± 0.1	0.5 ± 0.2	1.4 ± 1.8
Mg^{2+} (μg/m^3)	0.1 ± 0.1	0.2 ± 0.1	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.0
Ca^{2+} (μg/m^3)	1.6 ± 1.4	3.0 ± 1.8	0.7 ± 0.3	1.9 ± 1.1	1.8 ± 1.5	0.7 ± 0.4	1.0 ± 0.6	0.4 ± 0.1	0.8 ± 0.4	0.7 ± 0.5
F^- (μg/m^3)	0.3 ± 0.2	0.1 ± 0.1	0.0 ± 0.1	0.1 ± 0.1	0.2 ± 0.2	0.3 ± 0.2	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.2
Cl^- (μg/m^3)	7.0 ± 3.2	0.8 ± 0.4	0.2 ± 0.1	2.7 ± 1.9	2.9 ± 3.3	7.8 ± 3.2	1.2 ± 0.7	0.3 ± 0.3	1.5 ± 0.8	2.9 ± 3.5
NO_3^- (μg/m^3)	46.7 ± 35.5	11.3 ± 6.9	5.0 ± 2.8	21.3 ± 14.3	22.6 ± 25.7	45.4 ± 32.8	13.5 ± 12.1	4.1 ± 2.2	9.6 ± 3.6	19.4 ± 24.6
SO_4^{2-} (μg/m^3)	35.5 ± 30.4	12.5 ± 4.6	10.8 ± 2.7	15.3 ± 7.4	19.3 ± 19.3	35.5 ± 31.4	11.3 ± 5.7	11.8 ± 3.8	6.9 ± 2.5	17.0 ± 20.4
OC/EC	7.4 ± 4.1	6.2 ± 1.1	8.1 ± 3.4	6.0 ± 2.1	6.9 ± 2.9	8.5 ± 4.2	5.8 ± 2.0	8.3 ± 2.3	7.8 ± 4.2	7.6 ± 3.5
SOC/OC (%)	40.0 ± 23.0	29.3 ± 14.7	41.4 ± 25.8	54.2 ± 20.3	41.2 ± 22.3	36.2 ± 20.3	38.6 ± 20.7	38.0 ± 17.1	49.6 ± 19.1	40.7 ± 19.7
SOC/$PM_{2.5}$ (%)	5.8 ± 3.3	2.8 ± 1.5	6.0 ± 5.1	6.5 ± 3.4	5.2 ± 3.7	5.8 ± 3.2	4.8 ± 3.5	4.9 ± 3.4	6.9 ± 5.2	5.6 ± 3.9
OC/$PM_{2.5}$ (%)	14.7 ± 2.5	9.7 ± 2.0	12.6 ± 5.5	11.5 ± 3.3	12.1 ± 3.8	15.8 ± 3.1	11.5 ± 3.2	12.6 ± 4.6	12.5 ± 6.0	13.2 ± 4.6
EC/$PM_{2.5}$ (%)	2.7 ± 1.7	1.6 ± 0.6	1.6 ± 0.6	2.1 ± 0.7	2.0 ± 1.1	2.3 ± 1.2	2.1 ± 0.5	1.6 ± 0.7	1.7 ± 0.6	2.0 ± 0.9

SIAs/$PM_{2.5}$ (%)	42.2 ± 13.1	34.8 ± 21.9	44.4 ± 11.1	43.6 ± 13.8	41.1 ± 15.7	41.4 ± 10.9	38.7 ± 14.8	48.2 ± 9.3	44.8 ± 13.6	43.1 ± 12.6
WSIIs/$PM_{2.5}$ (%)	47.9 ± 11.9	39.4 ± 21.8	47.6 ± 10.5	49.6 ± 14.0	46.1 ± 15.5	47.3 ± 9.4	42.8 ± 14.3	51.2 ± 9.6	51.2 ± 13.9	48.0 ± 12.2
SIAs/WSIIs (%)	86.9 ± 5.8	83.2 ± 10.9	92.8 ± 3.6	86.9 ± 6.1	87.1 ± 7.8	86.6 ± 6.2	88.2 ± 7.2	94.1 ± 1.5	87.0 ± 3.7	88.7 ± 5.9

	XM					SSQ				
	Winter	Spring	Summer	Autumn	Annual	Winter	Spring	Summer	Autumn	Annual
$PM_{2.5}$ (μg/m^3)	204 ± 99	97 ± 22	31 ± 13	94 ± 51	111 ± 85	255 ± 166	111 ± 36	57 ± 15	113 ± 27	137 ± 113
OC (μg/m^3)	26.6 ± 15.0	9.1 ± 2.9	3.3 ± 1.9	10.6 ± 6.1	13.0 ± 12.2	42.9 ± 22.1	12.6 ± 4.8	7.9 ± 2.0	15.9 ± 3.6	19.5 ± 15.1
EC (μg/m^3)	3.8 ± 2.0	1.6 ± 0.6	0.5 ± 0.3	1.9 ± 1.0	2.0 ± 1.6	3.2 ± 2.2	2.3 ± 1.2	0.9 ± 0.3	2.1 ± 0.8	2.1 ± 1.6
SOC (μg/m^3)	8.4 ± 10.1	3.9 ± 2.5	0.9 ± 0.5	3.3 ± 2.9	4.4 ± 6.1	21.8 ± 23.1	6.8 ± 4.9	3.3 ± 1.9	6.7 ± 3.6	9.9 ± 13.9
Na^+ (μg/m^3)	0.7 ± 0.5	0.4 ± 0.3	0.1 ± 0.1	0.4 ± 0.2	0.4 ± 0.4	1.0 ± 0.8	0.3 ± 0.1	0.1 ± 0.1	0.3 ± 0.1	0.4 ± 0.5
NH_4^+ (μg/m^3)	19.8 ± 14.3	8.4 ± 5.2	4.1 ± 1.4	11.5 ± 7.6	11.4 ± 10.4	26.7 ± 18.4	11.1 ± 5.4	9.6 ± 3.9	13.8 ± 4.2	15.5 ± 12
K^+ (μg/m^3)	2.9 ± 2.9	0.7 ± 0.2	0.2 ± 0.1	1.1 ± 0.6	1.3 ± 1.8	3.2 ± 3.2	0.7 ± 0.3	0.4 ± 0.1	0.9 ± 0.3	1.3 ± 2.0
Mg^{2+} (μg/m^3)	0.1 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.0	0.2 ± 0.1	0.0 ± 0.0	0.1 ± 0.0	0.1 ± 0.1
Ca^{2+} (μg/m^3)	1.8 ± 1.0	2.3 ± 1.3	0.4 ± 0.6	1.9 ± 1.0	1.7 ± 1.2	3.5 ± 3.5	2.5 ± 1.3	0.6 ± 0.2	1.5 ± 0.7	2.1 ± 2.2
F^- (μg/m^3)	0.6 ± 0.4	0.2 ± 0.2	0.0 ± 0.1	0.3 ± 0.2	0.3 ± 0.3	0.3 ± 0.4	0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.0	0.1 ± 0.2
Cl^- (μg/m^3)	6.3 ± 4.4	0.9 ± 0.6	0.1 ± 0.1	2.0 ± 1.1	2.5 ± 3.4	6.8 ± 4.5	0.7 ± 0.5	0.2 ± 0.2	2.0 ± 1.0	2.5 ± 3.5
NO_3^- (μg/m^3)	44.0 ± 38.2	12.9 ± 8.4	3.1 ± 2.1	20.6 ± 17.3	21.2 ± 26.5	44.5 ± 35.4	12.3 ± 10.5	5.0 ± 5.4	20.1 ± 7.8	21.0 ± 24.1
SO_4^{2-} (μg/m^3)	31.3 ± 25.5	12.6 ± 5.2	8.2 ± 3.0	14.6 ± 7.3	17.2 ± 16.4	35.9 ± 31.1	12.5 ± 6.2	12.6 ± 5.4	12.6 ± 5.1	18.6 ± 19.1
OC/EC	7.2 ± 2.0	6. 1± 2.0	6.9 ± 1.5	5.7 ± 1.3	6.5 ± 1.8	13.7 ± 10.1	7.5 ± 3.0	8.9 ± 2.3	8.2 ± 3.6	9.6 ± 6.1
SOC/OC (%)	29.9 ± 24.2	41.4 ± 19.3	27.1 ± 16.1	28.1 ± 16.5	31.7 ± 19.8	57.3 ± 26.7	45.3 ± 22.2	41.4 ± 17.5	43.7 ± 19.6	47.1 ± 22.2
SOC/$PM_{2.5}$ (%)	3.6 ± 2.7	4.1 ± 2.2	2.8 ± 1.6	3.3 ± 2.5	3.5 ± 2.3	7.6 ± 3.6	6.0 ± 3.0	5.5 ± 2.3	5.8 ± 2.6	6.3 ± 3.0
OC/$PM_{2.5}$ (%)	12.7 ± 3.3	9.4 ± 1.9	10.3 ± 2.0	11.4 ± 3.1	11.0 ± 2.9	16.8 ± 5.5	11.3 ± 2.9	13.8 ± 1.5	14.1 ± 2.1	14.2 ± 3.2
EC/$PM_{2.5}$ (%)	1.9 ± 0.7	1.7 ± 0.5	1.6 ± 0.5	2.1 ± 0.7	1.8 ± 0.6	1.5 ± 1.0	2.1 ± 0.8	1.6 ± 0.5	1.9 ± 0.6	1.8 ± 0.8
SIAs/$PM_{2.5}$ (%)	42.6 ± 17.8	36.2 ± 18.2	51.0 ± 13.2	48.3 ± 11.3	44.3 ± 16.1	39.3 ± 9.2	34.1 ± 17.0	46.3 ± 14.0	41.2 ± 13.1	40.0 ± 13.9
WSIIs/$PM_{2.5}$ (%)	48.7 ± 16.8	41 ± 17.8	53.3 ± 13.1	54.7 ± 10.9	49.3 ± 15.6	45.7 ± 9.4	38.1 ± 16.8	48.8 ± 13.8	45.6 ± 12.8	44.4 ± 13.7
SIAs/WSIIs (%)	84.7 ± 9.6	84.3 ± 10.9	95.5 ± 2.3	87.5 ± 4.5	87.7 ± 8.8	85.7 ± 8.9	86.2 ± 8.4	94.4 ± 2.1	89.6 ± 4.2	88.8 ± 7.3

	DF					All sites					HE
	Winter	Spring	Summer	Autumn	Annual	Winter	Spring	Summer	Autumn	Annual	2016.12.18-20
$PM_{2.5}$ (μg/m^3)	178 ± 105	75 ± 21	50 ± 19	78 ± 30	104 ± 82	221 ± 126	98 ± 34	47 ± 16	88 ± 39	119 ± 98	440 ± 121
OC (μg/m^3)	23.7 ± 14.0	7.1 ± 2.8	5.7 ± 2.5	9.5 ± 4.0	12.3 ± 10.9	30.8 ± 17.2	10.8 ± 3.9	5.8 ± 2.2	10.9 ± 5.5	15.4 ± 13.9	57.6 ± 16.8
EC (μg/m^3)	2.8 ± 2.8	1.0 ± 0.3	0.6 ± 0.4	1.0 ± 0.4	1.5 ± 1.9	4.0 ± 2.7	1.7 ± 0.8	0.7 ± 0.3	1.6 ± 0.9	2.1 ± 2.0	3.7 ± 1.5
SOC (μg/m^3)	5.8 ± 7.6	2.6 ± 1.9	2.1 ± 1.9	5.0 ± 2.9	4.2 ± 4.9	13.0 ± 15.0	4.2 ± 3.2	2.2 ± 1.7	5.1 ± 3.9	6.5 ± 9.4	37.6 ± 17.8
Na^+ (μg/m^3)	0.6 ± 0.3	0.2 ± 0.1	0.1 ± 0.1	0.3 ± 0.2	0.3 ± 0.3	0.7 ± 0.5	0.3 ± 0.2	0.1 ± 0.1	0.3 ± 0.2	0.4 ± 0.3	0.8 ± 0.2
NH_4^+ (μg/m^3)	20.7 ± 12.9	10.9 ± 5.7	9.8 ± 4.5	10.1 ± 5.0	13.7 ± 9.6	23.4 ± 15.9	9.4 ± 5.1	7.3 ± 3.4	10.4 ± 5.7	13.2 ± 11.4	52.7 ± 11.8
K^+ (μg/m^3)	3.7 ± 4.2	0.7 ± 0.2	0.3 ± 0.2	0.7 ± 0.2	1.6 ± 2.8	3.2 ± 3.0	0.7 ± 0.2	0.3 ± 0.1	0.8 ± 0.4	1.4 ± 2.0	3.2 ± 0.6
Mg^{2+} (μg/m^3)	0.1 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.0
Ca^{2+} (μg/m^3)	1.5 ± 1.0	1.0 ± 0.8	0.2 ± 0.3	1.5 ± 1.7	1.1 ± 1.2	1.8 ± 2.0	2.0 ± 1.4	0.5 ± 0.4	1.5 ± 1.1	1.5 ± 1.5	0.7 ± 0.4
F^- (μg/m^3)	0.4 ± 0.4	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	0.2 ± 0.3	0.4 ± 0.3	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.2 ± 0.2	0.2 ± 0.2
Cl^- (μg/m^3)	5.4 ± 4.9	0.6 ± 0.5	0.2 ± 0.3	0.9 ± 0.6	2.2 ± 3.6	6.6 ± 4.1	0.9 ± 0.6	0.2 ± 0.2	1.8 ± 1.3	2.6 ± 3.5	11.0 ± 3.8
NO_3^- (μg/m^3)	34.0 ± 25.4	14.4 ± 12.8	4.6 ± 8.9	11.3 ± 8.0	17.8 ± 19.8	42.7 ± 32.9	12.8 ± 9.9	4.4 ± 3.4	16.4 ± 12.0	20.4 ± 24.2	105.4 ± 19.9
SO_4^{2-} (μg/m^3)	24.1 ± 15.0	16.2 ± 6.9	11.8 ± 5.4	10.8 ± 4.9	16.3 ± 11.1	32.2 ± 26.8	12.7 ± 5.7	11.1 ± 4.1	11.9 ± 6.3	17.7 ± 17.6	82.0 ± 24.4
OC/EC	12.1 ± 7.2	10. 8± 2.9	11.1 ± 2.3	10.2 ± 2.5	11.2 ± 4.6	9.9 ± 6.6	7.0 ± 2.7	8.7 ± 2.7	7.6 ± 3.3	8.3 ± 4.4	18.3 ± 9.5
SOC/OC (%)	24.4 ± 20.9	24.5 ± 17.0	29.2 ± 16.8	45.0 ± 17.3	31.2 ± 19.7	37.2 ± 25.1	37.1 ± 20.0	35.3 ± 18.8	44.0 ± 20.1	38.6 ± 21.5	63.3 ± 14.4
SOC/$PM_{2.5}$ (%)	3.2 ± 2.8	3.3 ± 2.3	3.9 ± 2.2	6.0 ± 2.3	4.2 ± 2.6	5.1 ± 3.5	4.3 ± 2.8	4.6 ± 3.2	5.7 ± 3.6	5.0 ± 3.3	8.3 ± 2.1
OC/$PM_{2.5}$ (%)	13.3 ± 4.8	9.3 ± 3.0	10.9 ± 3.2	12.0 ± 4.1	11.7 ± 4.3	14.0 ± 2.5	11.3 ± 2.5	12.4 ± 3.3	12.4 ± 3.4	12.6 ± 3.1	13.1 ± 1.0
EC/$PM_{2.5}$ (%)	1.6 ± 0.9	1.3 ± 0.3	1.3 ± 0.5	1.4 ± 0.4	1.4 ± 0.6	2.0 ± 1.2	1.8 ± 0.6	1.5 ± 0.5	1.8 ± 0.7	1.8 ± 0.8	0.9 ± 0.4
SIAs/$PM_{2.5}$ (%)	42.7 ± 9.7	53.0 ± 22.6	53.1 ± 14.7	41.0 ± 15.1	46.3 ± 15.9	41.7 ± 12.2	38.1 ± 19.0	48.7 ± 13.2	43.8 ± 13.3	42.9 ± 14.9	55.8 ± 8.7
WSIIs/$PM_{2.5}$ (%)	49.6 ± 10.3	56.5 ± 21.8	54.9 ± 14.6	45.8 ± 15.3	50.9 ± 15.6	47.9 ± 11.6	42.3 ± 18.6	51.2 ± 13.0	49.4 ± 13.5	47.7 ± 14.6	59.5 ± 9.1
SIAs/WSIIs (%)	85.9 ± 8.5	90.1 ± 11.8	96.5 ± 2.1	88.4 ± 7.5	89.7 ± 8.6	86 ± 7.8	86.1 ± 9.7	94.7 ± 2.5	87.9 ± 5.3	88.4 ± 7.7	93.8 ± 1.2

Table S2

Ratios of NO_3^-/SO_4^{2-} in $PM_{2.5}$ in five sampling sites during different seasons.

	HKG	ZM	XM	SSQ	DF	All sites
Winter	1.4 ± 0.3	1.4 ± 0.3	1.3 ± 0.4	1.3 ± 0.3	1.3 ± 0.3	1.3 ± 0.3
Spring	0.9 ± 0.6	1.1 ± 0.6	1.0 ± 0.4	1.0 ± 0.6	0.8 ± 0.5	1.0 ± 0.5
Summer	0.4 ± 0.2	0.3 ± 0.1	0.4 ± 0.2	0.4 ± 0.3	0.4 ± 0.5	0.4 ± 0.2
Auturmn	1.4 ± 0.3	1.4 ± 0.2	1.3 ± 0.5	1.7 ± 0.5	1.0 ± 0.3	1.3 ± 0.5
Annual	1.1 ± 0.5	1.1 ± 0.5	1.1 ± 0.6	1.1 ± 0.6	0.9 ± 0.5	1.0 ± 0.6

Table S3

Concentrations (ng/m^3) of elements in $PM_{2.5}$ over four seasons in five sites, all sites mean and heavy pollution days (December 18-20, 2016) in Zhengzhou. (CE: crustal elements, TE: total elements)

	HKG					ZM				
	Winter	Spring	Summer	Autumn	Annual	Winter	Spring	Summer	Autumn	Annual
Na	129 ± 38	158 ± 76	39 ± 14.7	105 ± 61	112 ± 67	118 ± 45	76 ± 24	45 ± 28	86 ± 44	84 ± 44
Mg	215 ± 156	507 ± 359	63 ± 33	228 ± 162	264 ± 264	145 ± 94	152 ± 84	61 ± 64	132 ± 108	126 ± 95
Al	804 ± 595	2566 ± 1893	288 ± 158	902 ± 617	1184 ± 1343	482 ± 321	719 ± 405	301 ± 285	562 ± 461	523 ± 395
Si	1738 ± 1459	6273 ± 4562	617 ± 411	2264 ± 1562	2830 ± 3295	849 ± 422	1813 ± 999	739 ± 735	1440 ± 1140	1218 ± 949
K	2277 ± 1217	2019 ± 1208	413 ± 126	1257 ± 428	1572 ± 1138	3001 ± 2219	951 ± 271	446 ± 152	1015 ± 329	1437 ± 1544
Ca	3193 ± 3547	10502 ± 9514	1130 ± 697	4171 ± 2583	4935 ± 6279	1273 ± 902	2014 ± 1145	1010 ± 893	2236 ± 1520	1653 ± 1229
Ti	93 ± 79	343 ± 280	38 ± 16.6	111 ± 69	152 ± 189	60 ± 57	95 ± 51	44 ± 73	86 ± 61	72 ± 62
V	7.6 ± 3.8	12.5 ± 10.7	3.6 ± 3.1	4.8 ± 3.3	7.3 ± 6.9	9.1 ± 7.5	2.6 ± 3.2	4.2 ± 2.9	11.6 ± 4.1	7.1 ± 6.1
Ni	3.6 ± 2.4	6.8 ± 4.9	2.0 ± 2.6	2.3 ± 2.0	3.8 ± 3.7	1.3 ± 2.3	3.7 ± 1.5	1.1 ± 1.2	2.3 ± 1.8	2.1 ± 2.0
Cu	22 ± 9.2	22 ± 9.1	15.5 ± 19.5	27 ± 14.6	22 ± 13.4	33 ± 19.5	17.6 ± 8.2	8.4 ± 7.3	20 ± 10.3	21 ± 15.4
Zn	245 ± 116	169 ± 57	69 ± 30	310 ± 190	207 ± 144	307 ± 165	143 ± 71	77 ± 37	265 ± 319	207 ± 206
Ga	4.5 ± 2.7	5.5 ± 3.1	3.2 ± 1.3	7.3 ± 2.7	5.2 ± 2.9	4.2 ± 3.6	3.2 ± 1.4	3.1 ± 1.7	2.4 ± 1.4	3.2 ± 2.3
As	27 ± 19.7	12.4 ± 6.6	4.0 ± 3.7	7.9 ± 3.0	13.6 ± 14.0	22 ± 16.6	12.6 ± 5.6	6.5 ± 11.9	6.6 ± 5.8	12.3 ± 12.6
Se	14.2 ± 11.3	7.2 ± 1.9	2.8 ± 3.0	7.8 ± 4.4	8.4 ± 7.6	16.0 ± 8.0	10.3 ± 3.8	3.0 ± 3.0	6.9 ± 2.6	9.5 ± 6.9
Sr	23 ± 23	40 ± 37	9.2 ± 4.8	18.2 ± 9.6	23 ± 25	33 ± 42	6.2 ± 5.4	9.1 ± 3.1	12.8 ± 5.7	16.0 ± 25
Sb	32 ± 12.1	38 ± 30	9.8 ± 5.8	28 ± 9.0	28 ± 19.7	29 ± 15.7	16.3 ± 6.4	15.2 ± 4.5	23 ± 8.6	21 ± 11.5
Ba	70 ± 79	71 ± 50	6.3 ± 10.4	22 ± 15.6	45 ± 56	118 ± 167	34 ± 11.6	5.0 ± 8.1	29 ± 16.9	50 ± 97
Pb	153 ± 49	78 ± 25	26 ± 11.5	104 ± 51	95 ± 59	157 ± 65	54 ± 28	35 ± 10.6	83 ± 35	86 ± 62

Cr	6.8 ± 4.6	14.0 ± 9.6	6.5 ± 2.6	11.4 ± 4.7	9.8 ± 6.7	7.6 ± 4.1	9.2 ± 4.5	2.9 ± 2.5	5.6 ± 5.0	6.5 ± 4.7
Mn	65 ± 31	120 ± 90	49 ± 73	67 ± 31	76 ± 65	50 ± 23	40 ± 16.3	21 ± 8.5	45 ± 23	40 ± 21
Fe	1198 ± 801	4004 ± 3384	405 ± 240	1460 ± 940	1837 ± 2241	702 ± 271	996 ± 540	453 ± 389	870 ± 621	766 ± 502
CE	9.6 ± 6.3	26.3 ± 20.9	3.0 ± 1.5	10.5 ± 6.2	12.9 ± 14.2	6.6 ± 3.0	6.8 ± 3.4	3.1 ± 2.6	6.4 ± 4.1	5.8 ± 3.6
TE	10.3 ± 6.3	27 ± 21.2	3.2 ± 1.6	11.1 ± 6.4	13.4 ± 14.3	3.2 ± 1.6	8.9 ± 5.3	6.7 ± 4.3	12.4 ± 6.2	7.7 ± 5.7
CE/TE	90.9 ± 4.6	96.4 ± 2.0	92.8 ± 2.5	93.3 ± 3.0	93.4 ± 3.8	87.9 ± 3.8	93.7 ± 2.6	92.2 ± 2.7	90.9 ± 5.7	91.0 ± 4.4
CE/$PM_{2.5}$	5.5 ± 5.7	20.3 ± 10.1	6.8 ± 5.5	10.7 ± 6.0	11 ± 9.1	7.4 ± 3.2	7.2 ± 3.5	3.3 ± 2.6	6.9 ± 4.3	6.4 ± 3.7
TE/$PM_{2.5}$	5.9 ± 5.7	20.8 ± 10.1	7.3 ± 5.7	11.3 ± 6.2	11.5 ± 9.2	3.6 ± 1.7	9.3 ± 5.4	7.2 ± 4.4	13.5 ± 6.3	8.4 ± 5.9

	XM					SSQ				
	Winter	Spring	Summer	Autumn	Annual	Winter	Spring	Summer	Autumn	Annual
Na	177 ± 201	107 ± 66	35 ± 10.4	86 ± 38	105 ± 121	250 ± 243	148 ± 77	54 ± 24	107 ± 71	143 ± 150
Mg	306 ± 256	337 ± 285	40 ± 40	211 ± 126	232 ± 231	416 ± 420	389 ± 301	79 ± 71	230 ± 207	286 ± 308
Al	1233 ± 979	1619 ± 1383	273 ± 265	923 ± 453	1043 ± 1002	1645 ± 1651	1832 ± 1616	374 ± 302	856 ± 802	1205 ± 1354
Si	2472 ± 2467	3595 ± 3262	435 ± 350	1879 ± 1035	2162 ± 2380	3952 ± 3879	4522 ± 4072	802 ± 656	2154 ± 1996	2929 ± 3312
K	2633 ± 2163	1369 ± 796	284 ± 112	1162 ± 551	1424 ± 1468	2382 ± 1454	1656 ± 1056	414 ± 181	1147 ± 487	1434 ± 1169
Ca	3651 ± 2737	5794 ± 4413	915 ± 770	4167 ± 2368	3731 ± 3320	6370 ± 5087	6398 ± 4146	1653 ± 1305	4538 ± 2955	4846 ± 4084
Ti	129 ± 124	188 ± 178	28 ± 23	106 ± 54	116 ± 125	223 ± 212	232 ± 219	50 ± 38	131 ± 97	163 ± 175
V	8.2 ± 6.8	12.3 ± 5.6	2.6 ± 2.1	5.8 ± 3.0	7.4 ± 5.9	15.1 ± 7.4	8.1 ± 7.9	8.8 ± 2.6	11.1 ± 4.6	10.8 ± 6.6
Ni	2.2 ± 1.7	3.8 ± 1.9	3.3 ± 1.8	2.7 ± 1.6	3.0 ± 1.8	6.0 ± 2.6	5.8 ± 2.7	2.2 ± 1.1	4.8 ± 2.6	4.8 ± 2.7
Cu	23 ± 23	13.2 ± 3.3	8.5 ± 6.0	27 ± 11.1	18.6 ± 15.2	44 ± 28	40 ± 19.3	15.1 ± 6.3	25 ± 13.5	32 ± 22
Zn	144 ± 103	118 ± 43	52 ± 22	153 ± 122	119 ± 91	249 ± 159	193 ± 57	80 ± 36	173 ± 74	177 ± 111
Ga	3.9 ± 3.2	3.9 ± 2.4	4.0 ± 2.5	7.4 ± 4.2	4.8 ± 3.4	5.4 ± 4.4	4.7 ± 2.0	3.8 ± 1.5	5.1 ± 2.5	4.8 ± 2.9
As	23 ± 10.8	12.2 ± 5.1	2.3 ± 2.1	14.7 ± 6.9	13.6 ± 10.1	33 ± 23	16.7 ± 6.4	9.4 ± 5.8	10.7 ± 5.7	17.8 ± 15.7
Se	10.8 ± 8.5	6.8 ± 2.8	3.6 ± 2.2	5.6 ± 5.4	6.9 ± 6.0	14.2 ± 10.1	4.8 ± 2.9	3.8 ± 2.7	7.3 ± 2.5	7.6 ± 6.8
Sr	31 ± 36	21 ± 16.7	3.6 ± 2.4	14.1 ± 6.9	18.2 ± 22	42 ± 46	18.9 ± 19.3	3.4 ± 4.7	17.2 ± 12.4	21 ± 29
Sb	31 ± 21	21 ± 14.9	3.5 ± 4.1	25 ± 13.2	21 ± 17.8	41 ± 17.5	27 ± 15.5	10.1 ± 6.6	24 ± 10.6	26 ± 17.0
Ba	116 ± 152	27 ± 28	4.4 ± 7.0	21 ± 10.8	45 ± 91	89 ± 155	43 ± 38	18.9 ± 12.3	32 ± 21	47 ± 84
Pb	126 ± 74	67 ± 24	26 ± 12.4	88 ± 61	79 ± 62	162 ± 97	64 ± 22	22 ± 13.1	73 ± 23	82 ± 72
Cr	9.9 ± 4.8	6.0 ± 5.1	6.4 ± 4.7	10.9 ± 5.1	8.4 ± 5.3	16.9 ± 5.5	12.0 ± 7.7	1.2 ± 1.6	9.8 ± 4.6	10.2 ± 7.7
Mn	67 ± 34	68 ± 52	15.4 ± 6.3	55 ± 33	53 ± 41	116 ± 55	94 ± 73	21 ± 12.0	76 ± 34	79 ± 59
Fe	1520 ± 1491	2111 ± 2080	272 ± 153	1134 ± 700	1300 ± 1472	2921 ± 2576	2798 ± 2824	575 ± 326	1566 ± 1246	2013 ± 2213
CE	12.0 ± 8.2	15.1 ± 12.2	2.3 ± 1.7	9.6 ± 5.0	10.1 ± 9.0	18.0 ± 14.7	17.9 ± 14.0	4.0 ± 2.8	10.7 ± 7.7	13.0 ± 12.3

TE	7.7 ± 6.6	14.8 ± 9.9	6.9 ± 2.3	11.3 ± 5.1	10.2 ± 7.2	9.6 ± 9.6	15.4 ± 8.3	7.3 ± 4.8	9.6 ± 5.8	10.6 ± 7.8
CE/TE	93.2 ± 4.3	96.0 ± 2.6	91.9 ± 3.5	95.2 ± 1.8	94.1 ± 3.5	91.8 ± 6.6	95.6 ± 2.4	92.7 ± 4.0	94.5 ± 2.6	93.7 ± 4.4
CE/$PM_{2.5}$	12.7 ± 8.4	15.5 ± 12.4	2.4 ± 1.7	10.1 ± 5.2	10.5 ± 9.2	19.0 ± 15.1	18.5 ± 14.2	4.2 ± 2.9	11.2 ± 7.9	13.5 ± 12.6
TE/$PM_{2.5}$	8.0 ± 6.7	15.2 ± 10.0	7.4 ± 2.2	11.8 ± 5.2	10.7 ± 7.3	10.1 ± 9.8	15.9 ± 8.3	7.7 ± 4.9	10.1 ± 5.8	11.1 ± 8.0

			DF			All sites			HE		
	Winter	Spring	Summer	Autumn	Annual	Winter	Spring	Summer	Autumn	Annual	2016.12.18-20
Na	132 ± 110	73 ± 37	26 ± 24	79 ± 87	83 ± 88	160 ± 155	116 ± 69	40 ± 21	92 ± 62	106 ± 104	121 ± 32
Mg	209 ± 142	138 ± 129	11.4 ± 69	146 ± 235	134 ± 170	256 ± 252	318 ± 289	51 ± 54	189 ± 175	209 ± 234	68 ± 36
Al	877 ± 495	720 ± 620	102 ± 291	667 ± 935	612 ± 671	1001 ± 985	1552 ± 1486	269 ± 247	778 ± 676	913 ± 1056	271 ± 180
Si	1835 ± 1194	1703 ± 1520	270 ± 639	1586 ± 2385	1378 ± 1631	2149 ± 2380	3730 ± 3624	575 ± 536	1857 ± 1683	2103 ± 2571	697 ± 357
K	2255 ± 1837	879 ± 269	259 ± 200	895 ± 663	1196 ± 1356	2512 ± 1808	1416 ± 924	363 ± 151	1093 ± 504	1413 ± 1343	2169 ± 352
Ca	1937 ± 1077	1585 ± 1632	341 ± 1294	1800 ± 2374	1469 ± 1621	3225 ± 3445	5539 ± 5972	1016 ± 940	3371 ± 2598	3329 ± 3991	1301 ± 1040
Ti	82 ± 45	83 ± 75	15.9 ± 39	74 ± 111	64 ± 74	116 ± 129	196 ± 205	35 ± 40	102 ± 82	114 ± 140	55 ± 27
V	7.0 ± 5.6	8.0 ± 4.6	3.9 ± 2.5	6.4 ± 4.7	6.3 ± 4.6	9.4 ± 6.9	8.7 ± 7.8	4.7 ± 3.3	8.1 ± 4.8	7.9 ± 6.2	6.1 ± 5.0
Ni	2.9 ± 2.4	3.0 ± 1.6	1.9 ± 1.3	3.6 ± 2.7	2.9 ± 2.2	3.1 ± 2.8	4.7 ± 3.1	2.1 ± 1.8	3.2 ± 2.4	3.3 ± 2.7	2.4 ± 2.4
Cu	23 ± 18.0	13.7 ± 3.1	5.8 ± 15.1	9.7 ± 6.9	13.9 ± 13.2	29 ± 22	22 ± 14.9	10.6 ± 10.2	22 ± 13.0	22 ± 17.1	31 ± 12.8
Zn	203 ± 296	111 ± 64	3.6 ± 3.8	27 ± 25	93 ± 190	230 ± 189	151 ± 65	56 ± 40	185 ± 200	162 ± 160	372 ± 138
Ga	5.1 ± 3.7	1.7 ± 2.0	4.3 ± 1.6	5.2 ± 1.6	4.4 ± 2.8	4.6 ± 3.6	4.0 ± 2.5	3.7 ± 1.8	5.4 ± 3.2	4.5 ± 2.9	7.4 ± 3.9
As	11.7 ± 14.1	6.9 ± 5.0	1.4 ± 5.6	2.6 ± 2.5	6.0 ± 9.4	23 ± 18.3	12.7 ± 6.3	4.8 ± 6.8	8.5 ± 6.4	12.8 ± 13.1	41 ± 14.8
Se	6.8 ± 6.4	5.0 ± 2.5	2.0 ± 2.8	3.2 ± 2.7	4.4 ± 4.5	12.3 ± 9.3	6.9 ± 3.4	3.0 ± 2.6	6.2 ± 3.9	7.4 ± 6.6	28 ± 6.8
Sr	29 ± 31	12.9 ± 8.0	3.1 ± 5.2	15.6 ± 14.3	16.7 ± 22	32 ± 36	20 ± 23	5.5 ± 4.4	15.5 ± 10.2	19.0 ± 25	10.2 ± 7.3
Sb	23 ± 16.4	19.9 ± 4.6	4.7 ± 6.5	15.8 ± 12.2	16.2 ± 13.5	31 ± 17.5	25 ± 18.6	8.6 ± 6.6	23 ± 11.3	23 ± 16.5	27 ± 9.3
Ba	78 ± 120	26 ± 19.2	7.5 ± 11.9	10.8 ± 19.6	35 ± 76	94 ± 136	41 ± 36	8.7 ± 10.5	23 ± 18.4	44 ± 82	25 ± 13.6
Pb	106 ± 67	60 ± 18.6	30 ± 13.3	56 ± 14.3	67 ± 50	140 ± 74	65 ± 25	28 ± 12.5	80 ± 42	82 ± 62	226 ± 64
Cr	5.2 ± 5.3	6.0 ± 5.4	1.0 ± 2.5	4.4 ± 4.9	4.1 ± 4.8	9.2 ± 6.3	9.7 ± 7.3	3.4 ± 3.6	8.3 ± 5.5	7.9 ± 6.3	9.2 ± 4.8
Mn	45 ± 20	42 ± 27	9.4 ± 16.9	35 ± 37	33 ± 28	68 ± 42	75 ± 66	22 ± 33	56 ± 34	56 ± 49	82 ± 22
Fe	1049 ± 585	991 ± 947	190 ± 346	970 ± 1424	816 ± 943	1460 ± 1556	2272 ± 2503	381 ± 292	1197 ± 1041	1348 ± 1691	925 ± 337
CE	8.3 ± 3.7	6.1 ± 5.2	1.2 ± 2.8	6.2 ± 8.1	5.7 ± 5.7	10.8 ± 8.9	15.1 ± 14.7	2.7 ± 2.2	8.6 ± 6.5	9.5 ± 10.2	5.6 ± 1.9
TE	6.5 ± 5.6	8.8 ± 7.4	2.5 ± 4.6	7.5 ± 6.6	6.2 ± 5.9	6.5 ± 6.5	14.0 ± 9.2	6.0 ± 4.2	10.3 ± 6.0	9.2 ± 7.4	1.3 ± 0.5

CE/TE	93.3 ± 3.8	93.0 ± 3.2	91.8 ± 3.9	94.6 ± 2.6	93.3 ± 3.4	91.4 ± 5.0	95.1 ± 2.7	92.3 ± 3.2	93.7 ± 3.7	93.1 ± 4.1	85.3 ± 4.0
CE/$PM_{2.5}$	8.9 ± 4.1	6.5 ± 5.2	1.3 ± 2.9	6.4 ± 8.3	6.1 ± 5.9	11.6 ±9 .2	15.6 ± 14.9	2.9 ± 2.2	9.1 ± 6.7	10.0 ± 10.4	6.5 ± 2.0
TE/$PM_{2.5}$	7.0 ± 6.0	9.2 ± 7.4	2.7 ± 4.7	7.8 ± 6.7	6.6 ± 6.1	6.9 ± 6.7	14.5 ± 9.3	6.4 ± 4.3	10.9 ± 6.2	9.6 ± 7.5	1.5 ± 0.5

Table S4

Carcinogenic risk of toxic elements in $PM_{2.5}$ for children in different sources at the five sites in Zhengzhou

		HKG			ZM			XM		
		CR_{inh}	CR_{ing}	CR_{der}	CR_{inh}	CR_{ing}	CR_{der}	CR_{inh}	CR_{ing}	CR_{der}
As	dust	8.24E-08	1.08E-05	9.08E-07	7.35E-08	1.47E-05	1.23E-06	7.65E-08	1.22E-05	1.02E-06
	vehicular traffic									
	coal combustion	1.18E-06	1.54E-04	1.30E-05	1.05E-06	2.10E-04	1.76E-05	1.09E-06	1.74E-04	1.46E-05
	secondary aerosol									
	industrial	2.04E-07	2.68E-05	2.25E-06	1.82E-07	3.63E-05	3.05E-06	1.90E-07	3.02E-05	2.53E-06
	biomass combustion									
	All sources	1.47E-06	1.92E-04	1.61E-05	1.31E-06	2.61E-04	2.19E-05	1.36E-06	2.16E-04	1.82E-05
Pb	dust	6.29E-10	1.83E-07	5.13E-09	5.78E-10	2.35E-07	6.59E-09	5.40E-10	1.81E-07	5.07E-09
	vehicular traffic	9.15E-09	2.66E-06	7.45E-08	8.40E-09	3.42E-06	9.57E-08	7.84E-09	2.63E-06	7.37E-08
	coal combustion	1.08E-08	3.13E-06	8.77E-08	9.88E-09	4.02E-06	1.13E-07	9.23E-09	3.10E-06	8.67E-08
	secondary aerosol	3.04E-09	8.85E-07	2.48E-08	2.79E-09	1.14E-06	3.18E-08	2.61E-09	8.75E-07	2.45E-08
	industrial	2.56E-09	7.46E-07	2.09E-08	2.35E-09	9.58E-07	2.68E-08	2.20E-09	7.38E-07	2.07E-08
	biomass combustion									
	All sources	2.61E-08	7.61E-06	2.13E-07	2.40E-08	9.77E-06	2.74E-07	2.24E-08	7.52E-06	2.11E-07
Ni	dust	1.99E-10	6.82E-07	4.77E-07	1.08E-10	5.91E-07	4.14E-07	1.42E-10	9.73E-07	6.81E-07
	vehicular traffic	9.10E-09	3.11E-05	2.18E-05	4.94E-09	2.70E-05	1.89E-05	6.49E-09	4.44E-05	3.11E-05
	coal combustion									
	secondary aerosol									
	industrial	1.33E-08	4.54E-05	3.18E-05	7.20E-09	3.93E-05	2.75E-05	9.46E-09	6.48E-05	4.53E-05
	biomass combustion									

All sources	2.26E-08	7.72E-05	5.40E-05	1.22E-08	6.69E-05	4.69E-05	1.61E-08	1.10E-04	7.71E-05

		SSQ			DF			All sites		
		CR_{inh}	CR_{ing}	CR_{der}	CR_{inh}	CR_{ing}	CR_{der}	CR_{inh}	CR_{ing}	CR_{der}
As	dust	1.03E-07	1.47E-05	1.23E-06	4.07E-08	5.45E-06	4.58E-07	6.74E-08	1.07E-05	9.02E-07
	vehicular traffic									
	coal combustion	1.47E-06	2.10E-04	1.76E-05	5.82E-07	7.79E-05	6.55E-06	9.64E-07	1.54E-04	1.29E-05
	secondary aerosol									
	industrial	2.55E-07	3.63E-05	3.05E-06	1.01E-07	1.35E-05	1.13E-06	1.67E-07	2.66E-05	2.24E-06
	biomass combustion									
	All sources	1.83E-06	2.61E-04	2.19E-05	7.24E-07	9.69E-05	8.14E-06	1.20E-06	1.91E-04	1.60E-05
Pb	dust	5.67E-10	1.37E-07	3.84E-09	4.55E-10	1.60E-07	4.48E-09	5.02E-10	1.70E-07	4.75E-09
	vehicular traffic	8.23E-09	1.99E-06	5.58E-08	6.62E-09	2.33E-06	6.51E-08	7.30E-09	2.46E-06	6.90E-08
	coal combustion	9.69E-09	2.35E-06	6.57E-08	7.79E-09	2.74E-06	7.66E-08	8.59E-09	2.90E-06	8.12E-08
	secondary aerosol	2.74E-09	6.63E-07	1.86E-08	2.20E-09	7.73E-07	2.17E-08	2.43E-09	8.19E-07	2.29E-08
	industrial	2.31E-09	5.59E-07	1.56E-08	1.85E-09	6.52E-07	1.83E-08	2.05E-09	6.91E-07	1.93E-08
	biomass combustion									
	All sources	2.35E-08	5.70E-06	1.60E-07	1.89E-08	6.65E-06	1.86E-07	2.09E-08	7.04E-06	1.97E-07
Ni	dust	2.26E-10	7.25E-07	5.08E-07	1.45E-10	6.40E-07	4.48E-07	1.49E-10	6.50E-07	4.55E-07
	vehicular traffic	1.03E-08	3.31E-05	2.32E-05	6.61E-09	2.92E-05	2.05E-05	6.82E-09	2.97E-05	2.08E-05
	coal combustion									
	secondary aerosol									
	industrial	1.50E-08	4.83E-05	3.38E-05	9.63E-09	4.26E-05	2.98E-05	9.94E-09	4.32E-05	3.03E-05
	biomass combustion									
	All sources	2.56E-08	8.21E-05	5.75E-05	1.64E-08	7.24E-05	5.07E-05	1.69E-08	7.36E-05	5.15E-05

Table S5

Carcinogenic risk of toxic elements in $PM_{2.5}$ for adult in different sources at the five sites in Zhengzhou

		HKG			ZM			XM		
		CR_{inh}	CR_{ing}	CR_{der}	CR_{inh}	CR_{ing}	CR_{der}	CR_{inh}	CR_{ing}	CR_{der}
As	dust	3.30E-07	5.49E-06	6.58E-07	2.94E-07	7.46E-06	8.93E-07	3.06E-07	6.19E-06	7.41E-07
	vehicular traffic									
	coal combustion	4.71E-06	7.85E-05	9.40E-06	4.20E-06	1.07E-04	1.28E-05	4.38E-06	8.85E-05	1.06E-05
	secondary aerosol									
	industrial	8.17E-07	1.36E-05	1.63E-06	7.28E-07	1.85E-05	2.21E-06	7.59E-07	1.53E-05	1.84E-06
	biomass combustion									
	All sources	5.86E-06	9.77E-05	1.17E-05	5.22E-06	1.33E-04	1.59E-05	5.44E-06	1.10E-04	1.32E-05
Pb	dust	2.52E-09	9.32E-08	3.72E-09	2.31E-09	1.20E-07	4.77E-09	2.16E-09	9.21E-08	3.68E-09
	vehicular traffic	3.66E-08	1.35E-06	5.40E-08	3.36E-08	1.74E-06	6.94E-08	3.14E-08	1.34E-06	5.34E-08
	coal combustion	4.30E-08	1.59E-06	6.36E-08	3.95E-08	2.05E-06	8.16E-08	3.69E-08	1.57E-06	6.28E-08
	secondary aerosol	1.22E-08	4.50E-07	1.80E-08	1.12E-08	5.78E-07	2.31E-08	1.04E-08	4.45E-07	1.78E-08
	industrial	1.03E-08	3.79E-07	1.51E-08	9.42E-09	4.87E-07	1.94E-08	8.79E-09	3.75E-07	1.50E-08
	biomass combustion									
	All sources	1.05E-07	3.87E-06	1.54E-07	9.60E-08	4.97E-06	1.98E-07	8.97E-08	3.83E-06	1.53E-07
Ni	dust	7.97E-10	3.47E-07	3.46E-07	4.33E-10	3.01E-07	3.00E-07	5.68E-10	4.95E-07	4.94E-07
	vehicular traffic	3.64E-08	1.58E-05	1.58E-05	1.98E-08	1.37E-05	1.37E-05	2.60E-08	2.26E-05	2.25E-05
	coal combustion									
	secondary aerosol									
	industrial	5.30E-08	2.31E-05	2.30E-05	2.88E-08	2.00E-05	2.00E-05	3.78E-08	3.29E-05	3.28E-05
	biomass combustion									

All sources	9.02E-08	3.93E-05	3.92E-05	4.90E-08	3.40E-05	3.40E-05	6.43E-08	5.60E-05	5.59E-05

		SSQ			DF			All sites		
		CR_{inh}	CR_{ing}	CR_{der}	CR_{inh}	CR_{ing}	CR_{der}	CR_{inh}	CR_{ing}	CR_{der}
As	dust	4.12E-07	7.46E-06	8.93E-07	1.63E-07	2.77E-06	3.32E-07	2.70E-07	5.46E-06	6.54E-07
	vehicular traffic									
	coal combustion	5.89E-06	1.07E-04	1.28E-05	2.33E-06	3.96E-05	4.74E-06	3.86E-06	7.81E-05	9.35E-06
	secondary aerosol									
	industrial	1.02E-06	1.85E-05	2.21E-06	4.04E-07	6.87E-06	8.22E-07	6.68E-07	1.35E-05	1.62E-06
	biomass combustion									
	All sources	7.32E-06	1.33E-04	1.59E-05	2.90E-06	4.93E-05	5.90E-06	4.79E-06	9.71E-05	1.16E-05
Pb	dust	2.27E-09	6.98E-08	2.78E-09	1.82E-09	8.14E-08	3.25E-09	2.01E-09	8.62E-08	3.44E-09
	vehicular traffic	3.29E-08	1.01E-06	4.04E-08	2.65E-08	1.18E-06	4.72E-08	2.92E-08	1.25E-06	5.00E-08
	coal combustion	3.87E-08	1.19E-06	4.76E-08	3.11E-08	1.39E-06	5.55E-08	3.44E-08	1.47E-06	5.88E-08
	secondary aerosol	1.09E-08	3.37E-07	1.34E-08	8.80E-09	3.93E-07	1.57E-08	9.71E-09	4.17E-07	1.66E-08
	industrial	9.23E-09	2.84E-07	1.13E-08	7.42E-09	3.32E-07	1.32E-08	8.18E-09	3.51E-07	1.40E-08
	biomass combustion									
	All sources	9.41E-08	2.90E-06	1.16E-07	7.57E-08	3.38E-06	1.35E-07	8.35E-08	3.58E-06	1.43E-07
Ni	dust	9.04E-10	3.69E-07	3.68E-07	5.79E-10	3.25E-07	3.24E-07	5.97E-10	3.30E-07	3.30E-07
	vehicular traffic	4.13E-08	1.68E-05	1.68E-05	2.64E-08	1.49E-05	1.48E-05	2.73E-08	1.51E-05	1.51E-05
	coal combustion									
	secondary aerosol									
	industrial	6.02E-08	2.45E-05	2.45E-05	3.85E-08	2.16E-05	2.16E-05	3.98E-08	2.20E-05	2.19E-05
	biomass combustion									
	All sources	1.02E-07	4.18E-05	4.17E-05	6.56E-08	3.68E-05	3.67E-05	6.76E-08	3.74E-05	3.73E-05

Table S6

Non-carcinogenic risk of toxic elements in $PM_{2.5}$ for children in different sources at the five sites in Zhengzhou

		HKG						
		dust	vehicular traffic	coal combustion	secondary aerosol	industrial	biomass combustion	All sources
V	HQ_{inh}	6.00E-03	1.21E-02	1.99E-03		2.23E-03		2.23E-02
	HQ_{ing}	5.52E-02	1.11E-01	1.83E-02		2.05E-02		2.05E-01
	HQ_{der}	5.94E-02	1.20E-01	1.97E-02		2.21E-02		2.21E-01
Cu	HQ_{inh}							
	HQ_{ing}	6.71E-03	4.48E-02	1.69E-02		1.71E-02		8.55E-02
	HQ_{der}	1.88E-04	1.25E-03	4.73E-04		4.79E-04		2.39E-03
As	HQ_{inh}	1.58E-02		2.25E-01		3.91E-02		2.80E-01
	HQ_{ing}	2.96E-01		4.23E+00		7.34E-01		5.26E+00
	HQ_{der}	2.49E-02		3.56E-01		6.16E-02		4.42E-01
Mn	HQ_{inh}	2.06E-01	1.27E-01	2.06E-02	3.82E-02	2.92E-02	3.40E-02	4.55E-01
	HQ_{ing}	2.23E-01	1.38E-01	2.23E-02	4.14E-02	3.17E-02	3.68E-02	4.92E-01
	HQ_{der}	1.56E-01	9.63E-02	1.56E-02	2.90E-02	2.22E-02	2.58E-02	3.45E-01
Zn	HQ_{inh}							
	HQ_{ing}	4.47E-03	5.27E-02	7.63E-03	8.56E-03	1.88E-02	1.71E-03	9.39E-02
	HQ_{der}	1.25E-04	1.48E-03	2.14E-04	2.40E-04	5.26E-04	4.79E-05	2.63E-03
Pb	HQ_{inh}							
	HQ_{ing}	7.60E-02	1.10E+00	1.30E+00	3.67E-01	3.09E-01		3.15E+00
	HQ_{der}	2.13E-03	3.09E-02	3.64E-02	1.03E-02	8.66E-03		8.83E-02
Ni	HQ_{inh}	2.05E-04	9.35E-03			1.36E-02		2.32E-02
	HQ_{ing}	4.50E-04	2.05E-02			2.99E-02		5.09E-02
	HQ_{der}	3.15E-04	1.44E-02			2.09E-02		3.56E-02
HI	inh	2.27E-01	1.48E-01	2.48E-01	3.82E-02	8.42E-02	3.40E-02	7.80E-01
	ing	6.61E-01	1.47E+00	5.60E+00	4.17E-01	1.16E+00	3.86E-02	9.35E+00
	der	2.43E-01	2.64E-01	4.28E-01	3.95E-02	1.37E-01	2.58E-02	1.14E+00

		ZM						
		dust	vehicular traffic	coal combustion	secondary aerosol	industrial	biomass combustion	All sources
V	HQ_{inh}	5.63E-03	1.13E-02	1.87E-03		2.09E-03		2.09E-02
	HQ_{ing}	8.81E-02	1.78E-01	2.92E-02		3.28E-02		3.28E-01
	HQ_{der}	9.49E-02	1.91E-01	3.14E-02		3.53E-02		3.53E-01
Cu	HQ_{inh}							
	HQ_{ing}	7.07E-03	4.72E-02	1.78E-02		1.80E-02		9.01E-02
	HQ_{der}	1.98E-04	1.32E-03	4.98E-04		5.04E-04		2.52E-03
As	HQ_{inh}	1.41E-02		2.01E-01		3.48E-02		2.50E-01
	HQ_{ing}	4.02E-01		5.75E+00		9.96E-01		7.15E+00
	HQ_{der}	3.38E-02		4.83E-01		8.37E-02		6.00E-01
Mn	HQ_{inh}	9.89E-02	6.11E-02	9.90E-03	1.84E-02	1.41E-02	1.64E-02	2.19E-01
	HQ_{ing}	1.43E-01	8.87E-02	1.44E-02	2.67E-02	2.04E-02	2.38E-02	3.17E-01
	HQ_{der}	1.00E-01	6.21E-02	1.00E-02	1.87E-02	1.43E-02	1.66E-02	2.22E-01
Zn	HQ_{inh}							
	HQ_{ing}	6.82E-03	8.04E-02	1.16E-02	1.31E-02	2.86E-02	2.61E-03	1.43E-01
	HQ_{der}	1.91E-04	2.25E-03	3.26E-04	3.66E-04	8.02E-04	7.32E-05	4.01E-03
Pb	HQ_{inh}							
	HQ_{ing}	9.76E-02	1.42E+00	1.67E+00	4.71E-01	3.97E-01		4.05E+00
	HQ_{der}	2.73E-03	3.97E-02	4.67E-02	1.32E-02	1.11E-02		1.13E-01
Ni	HQ_{inh}	1.11E-04	5.08E-03			7.40E-03		1.26E-02
	HQ_{ing}	3.90E-04	1.78E-02			2.60E-02		4.41E-02
	HQ_{der}	2.73E-04	1.25E-02			1.82E-02		3.09E-02
HI	inh	1.19E-01	7.76E-02	2.13E-01	1.84E-02	5.84E-02	1.64E-02	5.02E-01
	ing	7.46E-01	1.83E+00	7.49E+00	5.11E-01	1.52E+00	2.64E-02	1.21E+01
	der	2.32E-01	3.09E-01	5.72E-01	3.22E-02	1.64E-01	1.67E-02	1.33E+00

		XM						
		dust	vehicular traffic	coal combustion	secondary aerosol	industrial	biomass combustion	All sources
V	HQ_{inh}	5.81E-03	1.17E-02	1.92E-03		2.16E-03		2.16E-02
	HQ_{ing}	6.77E-02	1.36E-01	2.24E-02		2.52E-02		2.52E-01
	HQ_{der}	7.29E-02	1.47E-01	2.42E-02		2.71E-02		2.71E-01
Cu	HQ_{inh}							
	HQ_{ing}	6.41E-03	4.28E-02	1.61E-02		1.63E-02		8.17E-02
	HQ_{der}	1.80E-04	1.20E-03	4.52E-04		4.57E-04		2.29E-03
As	HQ_{inh}	1.46E-02		2.09E-01		3.63E-02		2.60E-01
	HQ_{ing}	3.34E-01		4.77E+00		8.27E-01		5.93E+00
	HQ_{der}	2.80E-02		4.01E-01		6.95E-02		4.98E-01
Mn	HQ_{inh}	1.39E-01	8.57E-02	1.39E-02	2.58E-02	1.97E-02	2.30E-02	3.07E-01
	HQ_{ing}	1.49E-01	9.22E-02	1.49E-02	2.77E-02	2.12E-02	2.47E-02	3.30E-01
	HQ_{der}	1.04E-01	6.46E-02	1.05E-02	1.94E-02	1.49E-02	1.73E-02	2.31E-01
Zn	HQ_{inh}							
	HQ_{ing}	2.99E-03	3.52E-02	5.10E-03	5.72E-03	1.25E-02	1.14E-03	6.27E-02
	HQ_{der}	8.36E-05	9.86E-04	1.43E-04	1.60E-04	3.51E-04	3.20E-05	1.76E-03
Pb	HQ_{inh}							
	HQ_{ing}	7.51E-02	1.09E+00	1.28E+00	3.63E-01	3.06E-01		3.12E+00
	HQ_{der}	2.10E-03	3.06E-02	3.60E-02	1.02E-02	8.56E-03		8.73E-02
Ni	HQ_{inh}	1.46E-04	6.67E-03			9.72E-03		1.65E-02
	HQ_{ing}	6.42E-04	2.93E-02			4.27E-02		7.27E-02
	HQ_{der}	4.49E-04	2.05E-02			2.99E-02		5.09E-02
HI	inh	1.59E-01	1.04E-01	2.25E-01	2.58E-02	6.79E-02	2.30E-02	6.05E-01
	ing	6.36E-01	1.43E+00	6.11E+00	3.96E-01	1.25E+00	2.58E-02	9.85E+00
	der	2.08E-01	2.65E-01	4.72E-01	2.97E-02	1.51E-01	1.73E-02	1.14E+00

		SSQ						
		dust	vehicular traffic	coal combustion	secondary aerosol	industrial	biomass combustion	All sources
V	HQ_{inh}	8.11E-03	1.63E-02	2.69E-03		3.01E-03		3.01E-02
	HQ_{ing}	8.27E-02	1.67E-01	2.74E-02		3.08E-02		3.08E-01
	HQ_{der}	8.91E-02	1.80E-01	2.95E-02		3.31E-02		3.31E-01
Cu	HQ_{inh}							
	HQ_{ing}	7.76E-03	5.18E-02	1.95E-02		1.98E-02		9.89E-02
	HQ_{der}	2.17E-04	1.45E-03	5.47E-04		5.54E-04		2.77E-03
As	HQ_{inh}	1.97E-02		2.81E-01		4.88E-02		3.50E-01
	HQ_{ing}	4.02E-01		5.75E+00		9.96E-01		7.14E+00
	HQ_{der}	3.38E-02		4.83E-01		8.37E-02		6.00E-01
Mn	HQ_{inh}	2.05E-01	1.27E-01	2.05E-02	3.81E-02	2.91E-02	3.39E-02	4.53E-01
	HQ_{ing}	1.71E-01	1.06E-01	1.71E-02	3.17E-02	2.43E-02	2.83E-02	3.78E-01
	HQ_{der}	1.20E-01	7.39E-02	1.20E-02	2.22E-02	1.70E-02	1.98E-02	2.64E-01
Zn	HQ_{inh}							
	HQ_{ing}	3.27E-03	3.86E-02	5.58E-03	6.26E-03	1.37E-02	1.25E-03	6.87E-02
	HQ_{der}	9.16E-05	1.08E-03	1.56E-04	1.75E-04	3.85E-04	3.51E-05	1.92E-03
Pb	HQ_{inh}							
	HQ_{ing}	5.69E-02	8.26E-01	9.72E-01	2.75E-01	2.32E-01		2.36E+00
	HQ_{der}	1.59E-03	2.31E-02	2.72E-02	7.69E-03	6.49E-03		6.61E-02
Ni	HQ_{inh}	2.32E-04	1.06E-02			1.55E-02		2.63E-02
	HQ_{ing}	4.78E-04	2.18E-02			3.18E-02		5.42E-02
	HQ_{der}	3.35E-04	1.53E-02			2.23E-02		3.79E-02
HI	inh	2.33E-01	1.53E-01	3.05E-01	3.81E-02	9.64E-02	3.39E-02	8.59E-01
	ing	7.24E-01	1.21E+00	6.79E+00	3.13E-01	1.35E+00	2.95E-02	1.04E+01
	der	2.45E-01	2.94E-01	5.52E-01	3.01E-02	1.63E-01	1.98E-02	1.30E+00

		DF						
		dust	vehicular traffic	coal combustion	secondary aerosol	industrial	biomass combustion	All sources
V	HQ_{inh}	4.87E-03	9.82E-03	1.61E-03		1.81E-03		1.81E-02
	HQ_{ing}	6.22E-02	1.25E-01	2.06E-02		2.31E-02		2.31E-01
	HQ_{der}	6.70E-02	1.35E-01	2.22E-02		2.49E-02		2.49E-01
Cu	HQ_{inh}							
	HQ_{ing}	3.89E-03	2.60E-02	9.79E-03		9.91E-03		4.96E-02
	HQ_{der}	1.09E-04	7.27E-04	2.74E-04		2.78E-04		1.39E-03
As	HQ_{inh}	7.79E-03		1.11E-01		1.93E-02		1.38E-01
	HQ_{ing}	1.49E-01		2.14E+00		3.70E-01		2.66E+00
	HQ_{der}	1.26E-02		1.79E-01		3.11E-02		2.23E-01
Mn	HQ_{inh}	8.93E-02	5.52E-02	8.94E-03	1.66E-02	1.27E-02	1.48E-02	1.98E-01
	HQ_{ing}	1.06E-01	6.57E-02	1.06E-02	1.98E-02	1.51E-02	1.76E-02	2.35E-01
	HQ_{der}	7.44E-02	4.60E-02	7.45E-03	1.38E-02	1.06E-02	1.23E-02	1.65E-01
Zn	HQ_{inh}							
	HQ_{ing}	2.62E-03	3.09E-02	4.47E-03	5.02E-03	1.10E-02	1.00E-03	5.50E-02
	HQ_{der}	7.33E-05	8.65E-04	1.25E-04	1.40E-04	3.08E-04	2.81E-05	1.54E-03
Pb	HQ_{inh}							
	HQ_{ing}	6.64E-02	9.64E-01	1.13E+00	3.21E-01	2.70E-01		2.76E+00
	HQ_{der}	1.86E-03	2.70E-02	3.18E-02	8.98E-03	7.57E-03		7.72E-02
Ni	HQ_{inh}	1.49E-04	6.79E-03			9.90E-03		1.68E-02
	HQ_{ing}	4.22E-04	1.93E-02			2.81E-02		4.78E-02
	HQ_{der}	2.95E-04	1.35E-02			1.97E-02		3.34E-02
HI	inh	1.02E-01	7.18E-02	1.22E-01	1.66E-02	4.37E-02	1.48E-02	3.71E-01
	ing	3.91E-01	1.23E+00	3.32E+00	3.45E-01	7.28E-01	1.86E-02	6.03E+00
	der	1.56E-01	2.23E-01	2.41E-01	2.30E-02	9.44E-02	1.23E-02	7.51E-01

		All sites						
		dust	vehicular traffic	coal combustion	secondary aerosol	industrial	biomass combustion	All sources
V	HQ_{inh}	5.55E-03	1.12E-02	1.84E-03		2.06E-03		2.06E-02
	HQ_{ing}	6.51E-02	1.31E-01	2.16E-02		2.42E-02		2.42E-01
	HQ_{der}	7.01E-02	1.41E-01	2.32E-02		2.61E-02		2.61E-01
Cu	HQ_{inh}							
	HQ_{ing}	5.90E-03	3.94E-02	1.48E-02		1.50E-02		7.51E-02
	HQ_{der}	1.65E-04	1.10E-03	4.15E-04		4.21E-04		2.10E-03
As	HQ_{inh}	1.29E-02		1.84E-01		3.19E-02		2.29E-01
	HQ_{ing}	2.94E-01		4.21E+00		7.29E-01		5.23E+00
	HQ_{der}	2.47E-02		3.54E-01		6.13E-02		4.40E-01
Mn	HQ_{inh}	1.35E-01	8.35E-02	1.35E-02	2.51E-02	1.92E-02	2.23E-02	2.99E-01
	HQ_{ing}	1.45E-01	8.97E-02	1.45E-02	2.70E-02	2.06E-02	2.40E-02	3.21E-01
	HQ_{der}	1.02E-01	6.28E-02	1.02E-02	1.89E-02	1.45E-02	1.68E-02	2.25E-01
Zn	HQ_{inh}							
	HQ_{ing}	3.68E-03	4.34E-02	6.28E-03	7.04E-03	1.54E-02	1.41E-03	7.72E-02
	HQ_{der}	1.03E-04	1.21E-03	1.76E-04	1.97E-04	4.32E-04	3.94E-05	2.16E-03
Pb	HQ_{inh}							
	HQ_{ing}	7.03E-02	1.02E+00	1.20E+00	3.40E-01	2.86E-01		2.92E+00
	HQ_{der}	1.97E-03	2.86E-02	3.37E-02	9.51E-03	8.02E-03		8.17E-02
Ni	HQ_{inh}	1.54E-04	7.01E-03			1.02E-02		1.74E-02
	HQ_{ing}	4.29E-04	1.96E-02			2.85E-02		4.85E-02
	HQ_{der}	3.00E-04	1.37E-02			2.00E-02		3.40E-02
HI	inh	1.54E-01	1.02E-01	2.00E-01	2.51E-02	6.34E-02	2.23E-02	5.66E-01
	ing	5.85E-01	1.34E+00	5.47E+00	3.74E-01	1.12E+00	2.54E-02	8.92E+00
	der	1.99E-01	2.49E-01	4.21E-01	2.86E-02	1.31E-01	1.69E-02	1.04E+00

Table S7

Non-carcinogenic risk of toxic elements in $PM_{2.5}$ for adult in different sources at the five sites in Zhengzhou

		HKG						
		dust	vehicular traffic	coal combustion	secondary aerosol	industrial	biomass combustion	All sources
V	HQ_{inh}	6.00E-03	1.21E-02	1.99E-03		2.23E-03		2.23E-02
	HQ_{ing}	7.01E-03	1.41E-02	2.32E-03		2.61E-03		2.61E-02
	HQ_{der}	1.08E-02	2.17E-02	3.57E-03		4.00E-03		4.00E-02
Cu	HQ_{inh}							
	HQ_{ing}	8.54E-04	5.70E-03	2.15E-03		2.17E-03		1.09E-02
	HQ_{der}	3.41E-05	2.27E-04	8.56E-05		8.67E-05		4.34E-04
As	HQ_{inh}	1.58E-02		2.25E-01		3.91E-02		2.80E-01
	HQ_{ing}	3.76E-02		5.38E-01		9.33E-02		6.69E-01
	HQ_{der}	4.51E-03		6.44E-02		1.12E-02		8.01E-02
Mn	HQ_{inh}	2.06E-01	1.27E-01	2.06E-02	3.82E-02	2.92E-02	3.40E-02	4.55E-01
	HQ_{ing}	2.83E-02	1.75E-02	2.83E-03	5.26E-03	4.02E-03	4.68E-03	6.26E-02
	HQ_{der}	2.82E-02	1.74E-02	2.82E-03	5.25E-03	4.01E-03	4.67E-03	6.24E-02
Zn	HQ_{inh}							
	HQ_{ing}	5.68E-04	6.70E-03	9.70E-04	1.09E-03	2.39E-03	2.18E-04	1.19E-02
	HQ_{der}	2.27E-05	2.67E-04	3.87E-05	4.34E-05	9.52E-05	8.69E-06	4.76E-04
Pb	HQ_{inh}							
	HQ_{ing}	9.66E-03	1.40E-01	1.65E-01	4.66E-02	3.93E-02		4.01E-01
	HQ_{der}	3.85E-04	5.60E-03	6.59E-03	1.86E-03	1.57E-03		1.60E-02
Ni	HQ_{inh}	2.05E-04	9.35E-03			1.36E-02		2.32E-02
	HQ_{ing}	5.72E-05	2.61E-03			3.80E-03		6.47E-03
	HQ_{der}	5.70E-05	2.60E-03			3.79E-03		6.46E-03
HI	inh	2.27E-01	1.48E-01	2.48E-01	3.82E-02	8.42E-02	3.40E-02	7.80E-01
	ing	8.41E-02	1.87E-01	7.12E-01	5.30E-02	1.48E-01	4.90E-03	1.19E+00
	der	4.40E-02	4.78E-02	7.75E-02	7.15E-03	2.47E-02	4.68E-03	2.06E-01

		ZM						
		dust	vehicular traffic	coal combustion	secondary aerosol	industrial	biomass combustion	All sources
V	HQ_{inh}	5.63E-03	1.13E-02	1.87E-03		2.09E-03		2.09E-02
	HQ_{ing}	1.12E-02	2.26E-02	3.71E-03		4.16E-03		4.16E-02
	HQ_{der}	1.72E-02	3.46E-02	5.69E-03		6.39E-03		6.39E-02
Cu	HQ_{inh}							
	HQ_{ing}	8.99E-04	6.00E-03	2.26E-03		2.29E-03		1.15E-02
	HQ_{der}	3.59E-05	2.39E-04	9.02E-05		9.14E-05		4.57E-04
As	HQ_{inh}	1.41E-02		2.01E-01		3.48E-02		2.50E-01
	HQ_{ing}	5.11E-02		7.31E-01		1.27E-01		9.08E-01
	HQ_{der}	6.12E-03		8.75E-02		1.52E-02		1.09E-01
Mn	HQ_{inh}	9.89E-02	6.11E-02	9.90E-03	1.84E-02	1.41E-02	1.64E-02	2.19E-01
	HQ_{ing}	1.82E-02	1.13E-02	1.82E-03	3.39E-03	2.59E-03	3.02E-03	4.03E-02
	HQ_{der}	1.82E-02	1.12E-02	1.82E-03	3.38E-03	2.59E-03	3.01E-03	4.02E-02
Zn	HQ_{inh}							
	HQ_{ing}	8.67E-04	1.02E-02	1.48E-03	1.66E-03	3.64E-03	3.32E-04	1.82E-02
	HQ_{der}	3.46E-05	4.08E-04	5.90E-05	6.62E-05	1.45E-04	1.33E-05	7.26E-04
Pb	HQ_{inh}							
	HQ_{ing}	1.24E-02	1.80E-01	2.12E-01	5.99E-02	5.05E-02		5.15E-01
	HQ_{der}	4.95E-04	7.19E-03	8.46E-03	2.39E-03	2.02E-03		2.06E-02
Ni	HQ_{inh}	1.11E-04	5.08E-03			7.40E-03		1.26E-02
	HQ_{ing}	4.96E-05	2.26E-03			3.30E-03		5.61E-03
	HQ_{der}	4.94E-05	2.26E-03			3.29E-03		5.60E-03
HI	inh	1.19E-01	7.76E-02	2.13E-01	1.84E-02	5.84E-02	1.64E-02	5.02E-01
	ing	9.48E-02	2.33E-01	9.52E-01	6.50E-02	1.93E-01	3.35E-03	1.54E+00
	der	4.21E-02	5.60E-02	1.04E-01	5.84E-03	2.97E-02	3.02E-03	2.40E-01

		XM						
		dust	vehicular traffic	coal combustion	secondary aerosol	industrial	biomass combustion	All sources
V	HQ_{inh}	5.81E-03	1.17E-02	1.92E-03		2.16E-03		2.16E-02
	HQ_{ing}	8.61E-03	1.73E-02	2.85E-03		3.20E-03		3.20E-02
	HQ_{der}	1.32E-02	2.66E-02	4.38E-03		4.91E-03		4.91E-02
Cu	HQ_{inh}							
	HQ_{ing}	8.15E-04	5.44E-03	2.05E-03		2.08E-03		1.04E-02
	HQ_{der}	3.25E-05	2.17E-04	8.18E-05		8.28E-05		4.14E-04
As	HQ_{inh}	1.46E-02		2.09E-01		3.63E-02		2.60E-01
	HQ_{ing}	4.24E-02		6.07E-01		1.05E-01		7.54E-01
	HQ_{der}	5.08E-03		7.26E-02		1.26E-02		9.03E-02
Mn	HQ_{inh}	1.39E-01	8.57E-02	1.39E-02	2.58E-02	1.97E-02	2.30E-02	3.07E-01
	HQ_{ing}	1.90E-02	1.17E-02	1.90E-03	3.53E-03	2.70E-03	3.14E-03	4.20E-02
	HQ_{der}	1.89E-02	1.17E-02	1.89E-03	3.52E-03	2.69E-03	3.13E-03	4.18E-02
Zn	HQ_{inh}							
	HQ_{ing}	3.79E-04	4.48E-03	6.48E-04	7.27E-04	1.59E-03	1.45E-04	7.97E-03
	HQ_{der}	1.51E-05	1.79E-04	2.58E-05	2.90E-05	6.36E-05	5.80E-06	3.18E-04
Pb	HQ_{inh}							
	HQ_{ing}	9.55E-03	1.39E-01	1.63E-01	4.61E-02	3.89E-02		3.96E-01
	HQ_{der}	3.81E-04	5.53E-03	6.51E-03	1.84E-03	1.55E-03		1.58E-02
Ni	HQ_{inh}	1.46E-04	6.67E-03			9.72E-03		1.65E-02
	HQ_{ing}	8.16E-05	3.73E-03			5.43E-03		9.24E-03
	HQ_{der}	8.14E-05	3.72E-03			5.42E-03		9.21E-03
HI	inh	1.59E-01	1.04E-01	2.25E-01	2.58E-02	6.79E-02	2.30E-02	6.05E-01
	ing	8.08E-02	1.81E-01	7.77E-01	5.04E-02	1.59E-01	3.29E-03	1.25E+00
	der	3.77E-02	4.80E-02	8.55E-02	5.39E-03	2.73E-02	3.14E-03	2.07E-01

		SSQ						
		dust	vehicular traffic	coal combustion	secondary aerosol	industrial	biomass combustion	All sources
V	HQ_{inh}	8.11E-03	1.63E-02	2.69E-03		3.01E-03		3.01E-02
	HQ_{ing}	1.05E-02	2.12E-02	3.48E-03		3.91E-03		3.91E-02
	HQ_{der}	1.61E-02	3.25E-02	5.35E-03		6.00E-03		6.00E-02
Cu	HQ_{inh}							
	HQ_{ing}	9.87E-04	6.59E-03	2.48E-03		2.51E-03		1.26E-02
	HQ_{der}	3.94E-05	2.63E-04	9.90E-05		1.00E-04		5.02E-04
As	HQ_{inh}	1.97E-02		2.81E-01		4.88E-02		3.50E-01
	HQ_{ing}	5.11E-02		7.30E-01		1.27E-01		9.08E-01
	HQ_{der}	6.12E-03		8.74E-02		1.52E-02		1.09E-01
Mn	HQ_{inh}	2.05E-01	1.27E-01	2.05E-02	3.81E-02	2.91E-02	3.39E-02	4.53E-01
	HQ_{ing}	2.17E-02	1.34E-02	2.17E-03	4.03E-03	3.09E-03	3.59E-03	4.80E-02
	HQ_{der}	2.16E-02	1.34E-02	2.17E-03	4.02E-03	3.08E-03	3.58E-03	4.79E-02
Zn	HQ_{inh}							
	HQ_{ing}	4.16E-04	4.90E-03	7.10E-04	7.96E-04	1.75E-03	1.59E-04	8.73E-03
	HQ_{der}	1.66E-05	1.96E-04	2.83E-05	3.18E-05	6.97E-05	6.36E-06	3.48E-04
Pb	HQ_{inh}							
	HQ_{ing}	7.23E-03	1.05E-01	1.24E-01	3.49E-02	2.94E-02		3.00E-01
	HQ_{der}	2.89E-04	4.19E-03	4.93E-03	1.39E-03	1.17E-03		1.20E-02
Ni	HQ_{inh}	2.32E-04	1.06E-02			1.55E-02		2.63E-02
	HQ_{ing}	6.08E-05	2.78E-03			4.05E-03		6.88E-03
	HQ_{der}	6.07E-05	2.77E-03			4.04E-03		6.87E-03
HI	inh	2.33E-01	1.53E-01	3.05E-01	3.81E-02	9.64E-02	3.39E-02	8.59E-01
	ing	9.20E-02	1.54E-01	8.63E-01	3.98E-02	1.71E-01	3.75E-03	1.32E+00
	der	4.43E-02	5.33E-02	1.00E-01	5.45E-03	2.96E-02	3.59E-03	2.36E-01

		DF						
		dust	vehicular traffic	coal combustion	secondary aerosol	industrial	biomass combustion	All sources
V	HQ_{inh}	4.87E-03	9.82E-03	1.61E-03		1.81E-03		1.81E-02
	HQ_{ing}	7.91E-03	1.59E-02	2.62E-03		2.94E-03		2.94E-02
	HQ_{der}	1.21E-02	2.45E-02	4.02E-03		4.51E-03		4.51E-02
Cu	HQ_{inh}							
	HQ_{ing}	4.95E-04	3.30E-03	1.24E-03		1.26E-03		6.30E-03
	HQ_{der}	1.97E-05	1.32E-04	4.96E-05		5.03E-05		2.51E-04
As	HQ_{inh}	7.79E-03		1.11E-01		1.93E-02		1.38E-01
	HQ_{ing}	1.90E-02		2.72E-01		4.71E-02		3.38E-01
	HQ_{der}	2.27E-03		3.25E-02		5.63E-03		4.04E-02
Mn	HQ_{inh}	8.93E-02	5.52E-02	8.94E-03	1.66E-02	1.27E-02	1.48E-02	1.98E-01
	HQ_{ing}	1.35E-02	8.35E-03	1.35E-03	2.51E-03	1.92E-03	2.24E-03	2.99E-02
	HQ_{der}	1.35E-02	8.33E-03	1.35E-03	2.51E-03	1.92E-03	2.23E-03	2.98E-02
Zn	HQ_{inh}							
	HQ_{ing}	3.33E-04	3.93E-03	5.68E-04	6.38E-04	1.40E-03	1.28E-04	6.99E-03
	HQ_{der}	1.33E-05	1.57E-04	2.27E-05	2.54E-05	5.58E-05	5.09E-06	2.79E-04
Pb	HQ_{inh}							
	HQ_{ing}	8.44E-03	1.23E-01	1.44E-01	4.08E-02	3.44E-02		3.50E-01
	HQ_{der}	3.37E-04	4.89E-03	5.76E-03	1.63E-03	1.37E-03		1.40E-02
Ni	HQ_{inh}	1.49E-04	6.79E-03			9.90E-03		1.68E-02
	HQ_{ing}	5.36E-05	2.45E-03			3.57E-03		6.07E-03
	HQ_{der}	5.35E-05	2.44E-03			3.56E-03		6.06E-03
HI	inh	1.02E-01	7.18E-02	1.22E-01	1.66E-02	4.37E-02	1.48E-02	3.71E-01
	ing	4.97E-02	1.57E-01	4.22E-01	4.39E-02	9.25E-02	2.36E-03	7.67E-01
	der	2.83E-02	4.04E-02	4.37E-02	4.16E-03	1.71E-02	2.24E-03	1.36E-01

		All sites						
		dust	vehicular traffic	coal combustion	secondary aerosol	industrial	biomass combustion	All sources
V	HQ_{inh}	5.55E-03	1.12E-02	1.84E-03		2.06E-03		2.06E-02
	HQ_{ing}	8.27E-03	1.67E-02	2.74E-03		3.08E-03		3.08E-02
	HQ_{der}	1.27E-02	2.56E-02	4.21E-03		4.72E-03		4.72E-02
Cu	HQ_{inh}							
	HQ_{ing}	7.50E-04	5.00E-03	1.89E-03		1.91E-03		9.55E-03
	HQ_{der}	2.99E-05	2.00E-04	7.52E-05		7.62E-05		3.81E-04
As	HQ_{inh}	1.29E-02		1.84E-01		3.19E-02		2.29E-01
	HQ_{ing}	3.74E-02		5.35E-01		9.27E-02		6.65E-01
	HQ_{der}	4.48E-03		6.40E-02		1.11E-02		7.96E-02
Mn	HQ_{inh}	1.35E-01	8.35E-02	1.35E-02	2.51E-02	1.92E-02	2.23E-02	2.99E-01
	HQ_{ing}	1.84E-02	1.14E-02	1.85E-03	3.43E-03	2.62E-03	3.05E-03	4.08E-02
	HQ_{der}	1.84E-02	1.14E-02	1.84E-03	3.42E-03	2.62E-03	3.05E-03	4.07E-02
Zn	HQ_{inh}							
	HQ_{ing}	4.67E-04	5.51E-03	7.98E-04	8.95E-04	1.96E-03	1.79E-04	9.82E-03
	HQ_{der}	1.86E-05	2.20E-04	3.18E-05	3.57E-05	7.83E-05	7.15E-06	3.92E-04
Pb	HQ_{inh}							
	HQ_{ing}	8.94E-03	1.30E-01	1.53E-01	4.32E-02	3.64E-02		3.71E-01
	HQ_{der}	3.57E-04	5.18E-03	6.10E-03	1.72E-03	1.45E-03		1.48E-02
Ni	HQ_{inh}	1.54E-04	7.01E-03			1.02E-02		1.74E-02
	HQ_{ing}	5.45E-05	2.49E-03			3.63E-03		6.17E-03
	HQ_{der}	5.43E-05	2.48E-03			3.62E-03		6.15E-03
HI	inh	1.54E-01	1.02E-01	2.00E-01	2.51E-02	6.34E-02	2.23E-02	5.66E-01
	ing	7.44E-02	1.71E-01	6.95E-01	4.75E-02	1.42E-01	3.23E-03	1.13E+00
	der	3.60E-02	4.50E-02	7.63E-02	5.18E-03	2.37E-02	3.05E-03	1.89E-01

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