Health risk assessment of $PM_{2.5}$ bound components in Beijing, China during 2013-2015

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Supplementary Material

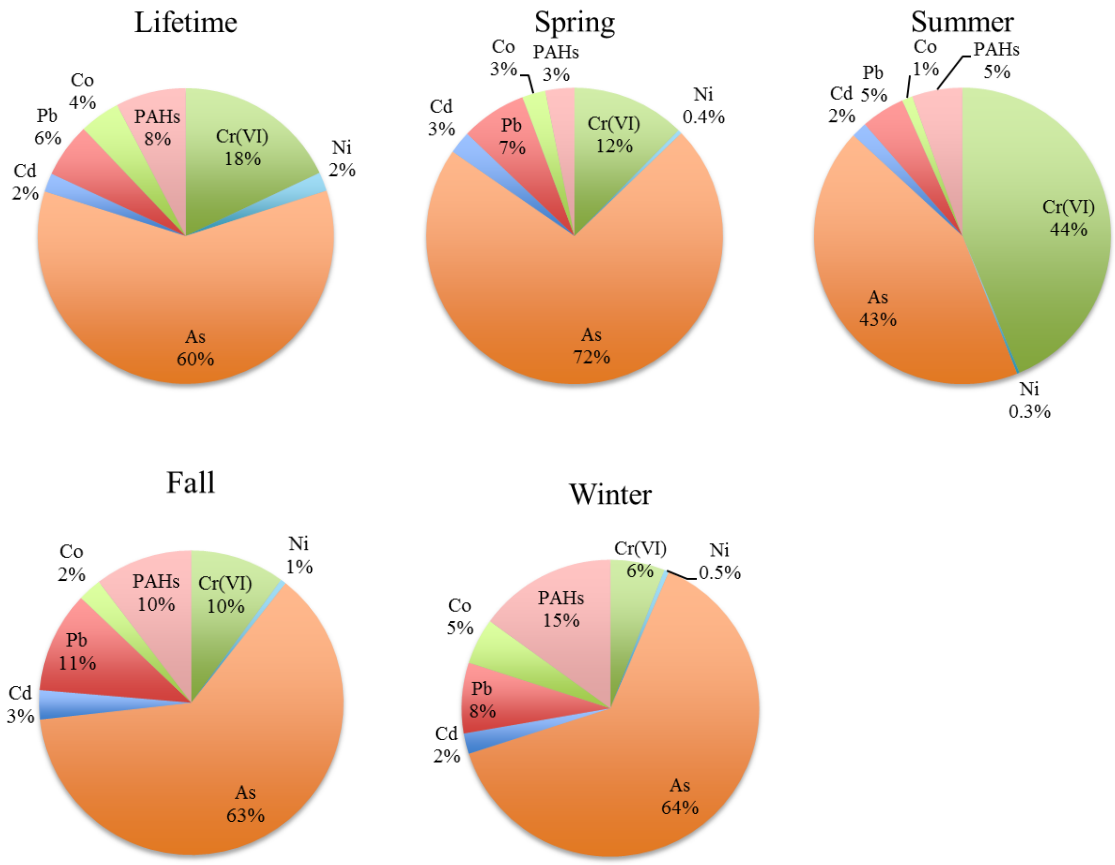

Figure S1. Lifetime cancer risk from exposure to ambient PM2.5-bound elements and PAHs, by element and in each of the four seasons.

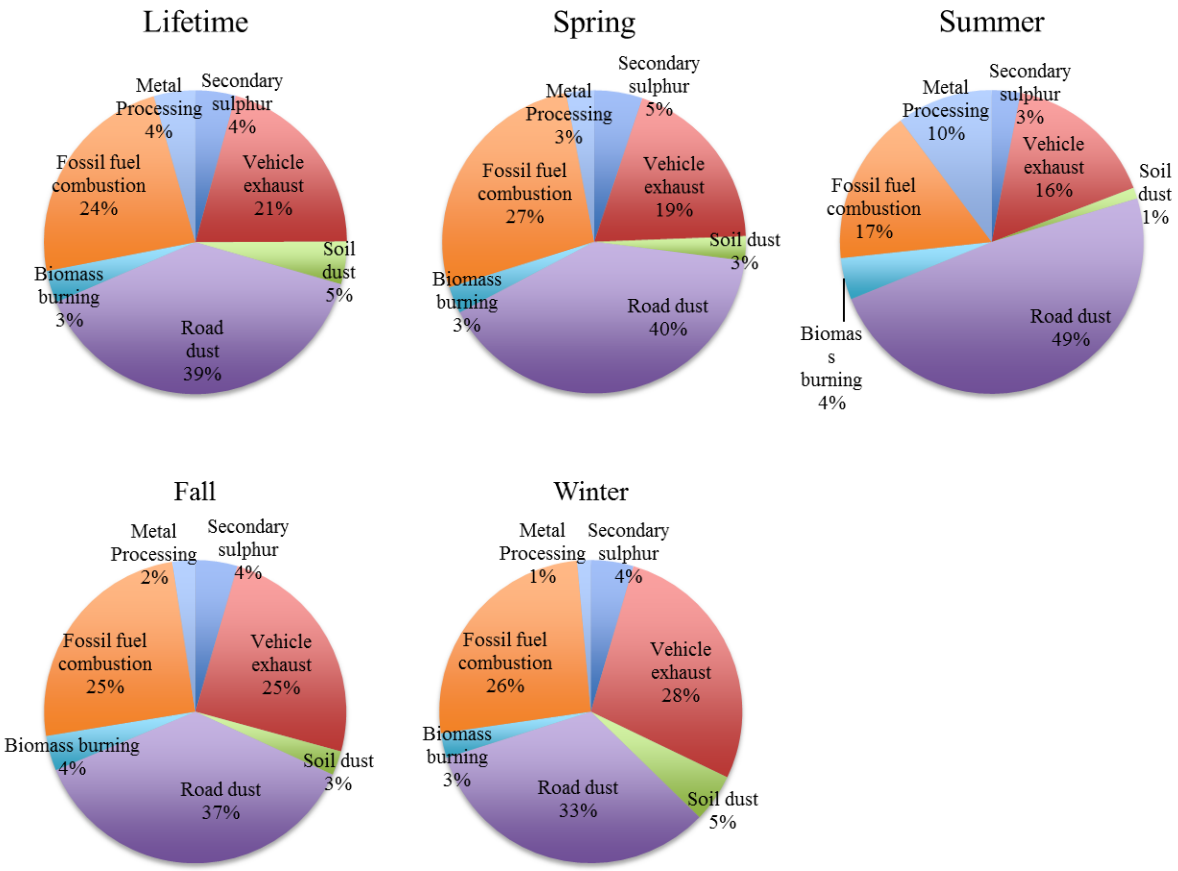

Figure S2. Lifetime cancer risks from exposure to ambient PM2.5-bound elements and PAHs, by source and in each of the four seasons.

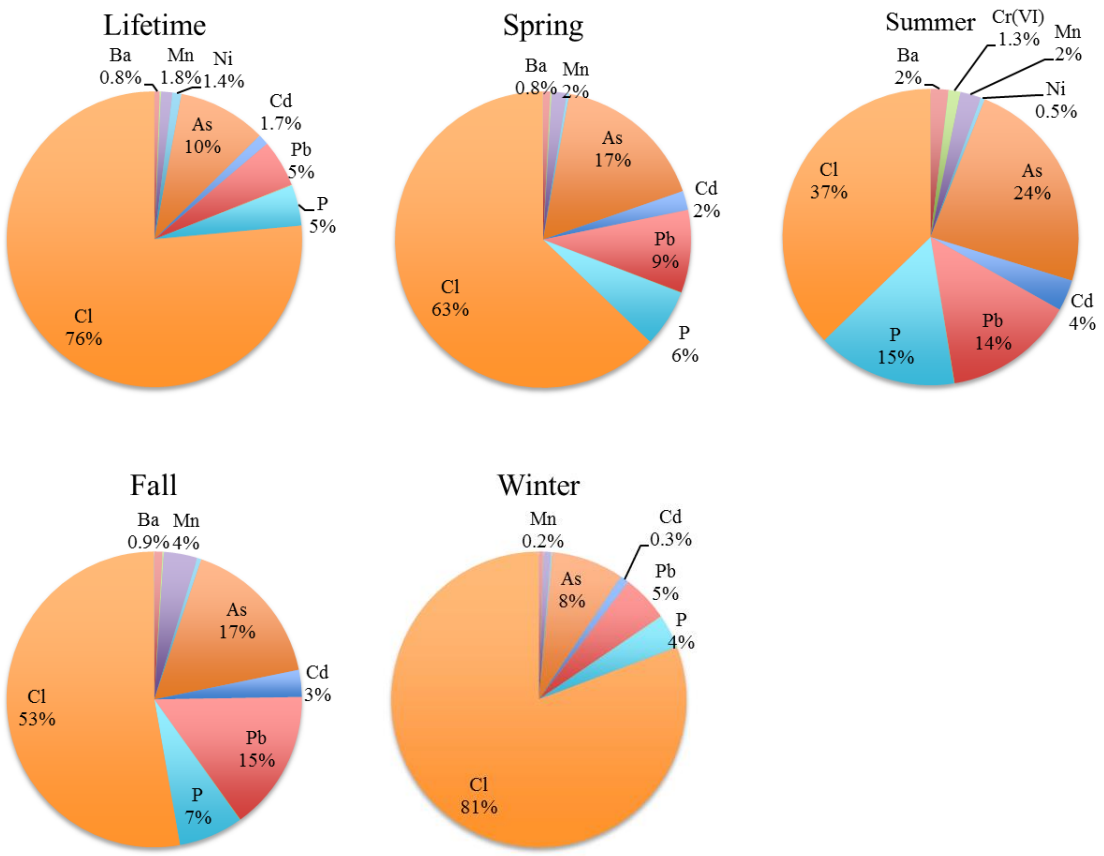

Figure S3. Lifetime noncancer HQ from exposure to ambient PM2.5-bound elements, by element and in each of the four seasons.

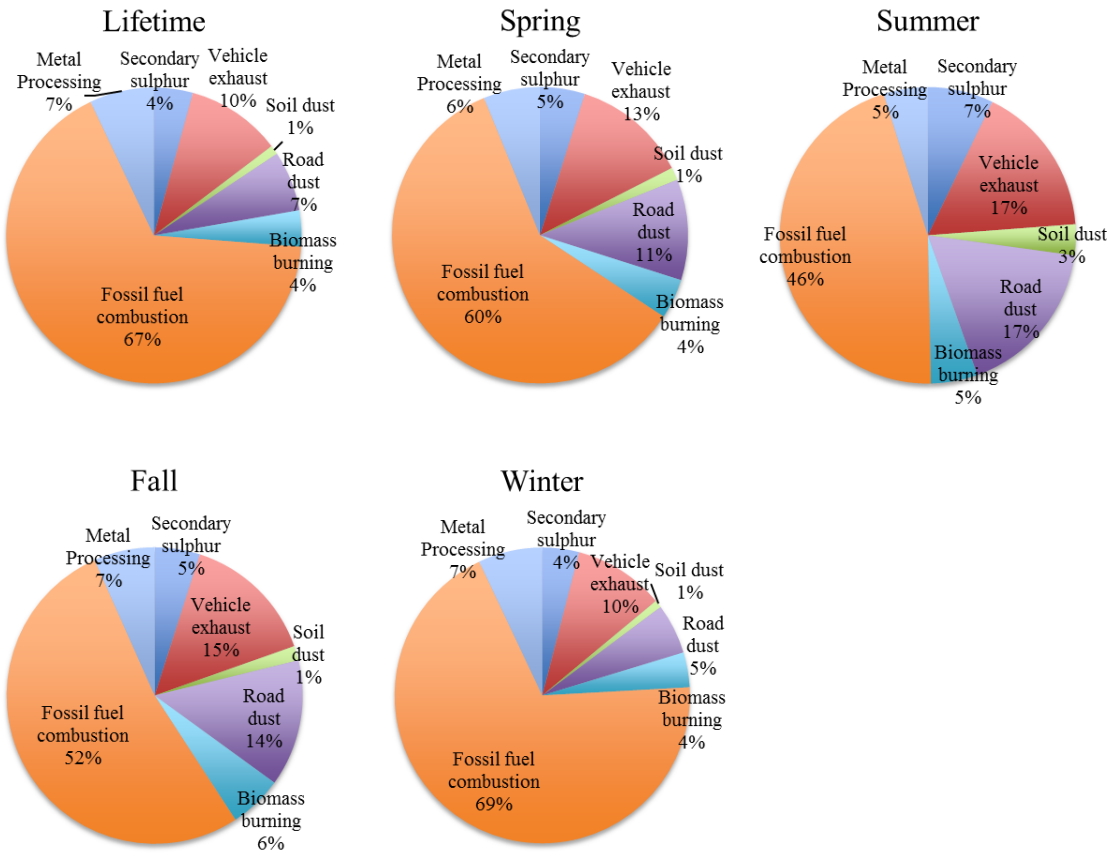

Figure S4. Lifetime noncancer HQ from exposure to ambient PM2.5-bound elements, by source and in each of the four seasons.

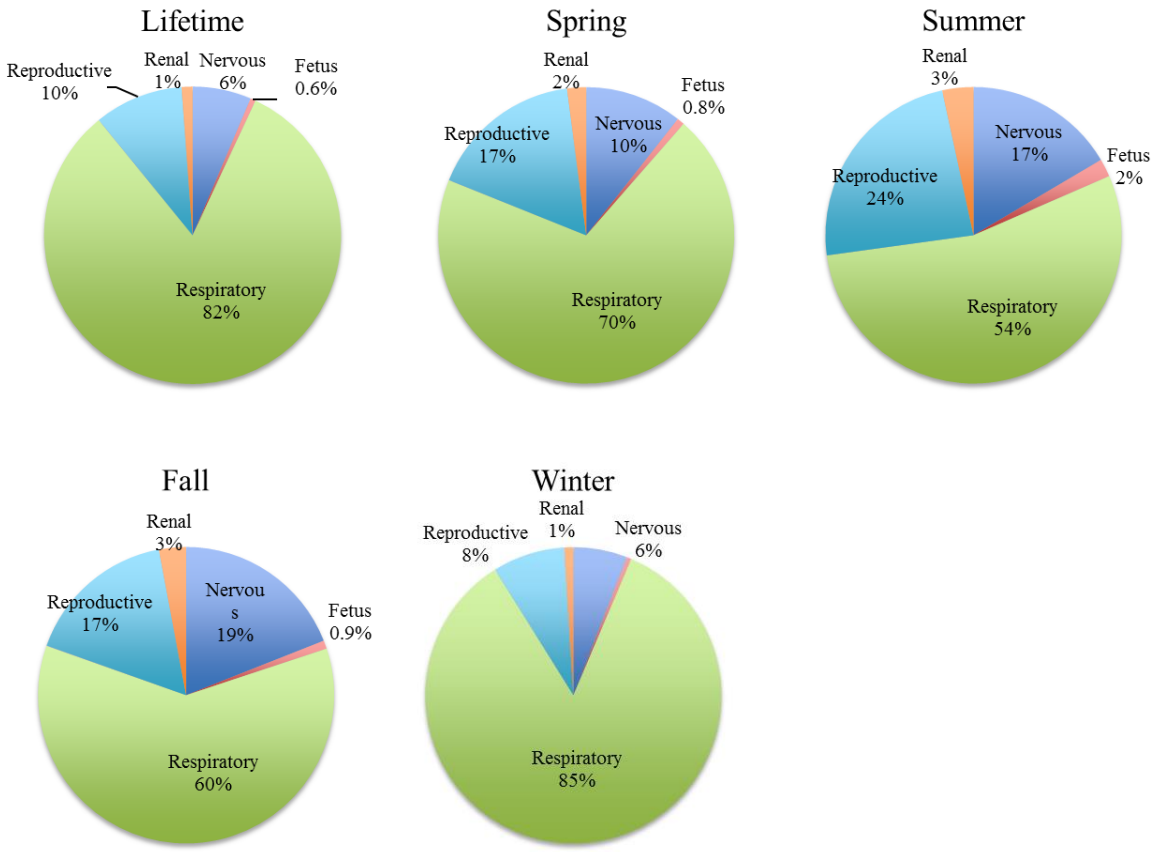

Figure S5. Lifetime noncancer HQ from exposure to ambient PM2.5-bound elements, by target organ and in each of the four seasons.

Table S1. Information about the 12 government air quality monitoring stations in Beijing (station type from: Yao et al. (2015); longitude and latitude from SHQY, (2019)).

Station name	Station type	Longitude (°E)	Latitude (°N)
Aotizhongxin	Urban	116.407	40.003
Dongsi	Urban	116.434	39.952
Guanyuan	Urban	116.361	39.943
Nongzhanguan	Urban	116.473	39.972
Tiantan	Urban	116.434	39.875
Wanshouxigong	Urban	116.366	39.867
Gucheng	Urban	116.225	39.928
Haidianquwanliu	Urban	116.315	39.993
Changpingzhen	Suburban	116.230	40.195
Dingling	Suburban	116.170	40.287
Huairouzhen	Suburban	116.644	40.394
Shunyixincheng	Suburban	116.720	40.144

Table S2. Concentrations of elemental $PM_{2.5}$ ($\mu g/m^3$) in Beijing, a) annual and b) seasonal concentration from previous studies.

a) Annual

#	Source	Sampling site	$PM_{2.5}$ mass	As	Ba	Cd	Cl	Co	Cr	Mn	Ni	P	Pb	Se
1	Cui et al., 2008	NFRR	131	0.029		0.0026	4.270	0.001	0.003	0.120	0.005		0.180	0.005
2	Du et al., 2010	QHY	110.5							0.100			0.193	
3	Song et al., 2006	MT, Airport, PKU, DS, YLD	96.1	0.030			1.690		0.020	0.070	0.020		0.300	0.010
4	Sun et al., 2006	BNU	36.73	0.010				0.0007	0.01	0.040	0.020		0.040	
5	Yu et al., 2012	CUG	89.61	0.016		0.003							0.148	
6	Yu et al., 2013	BNU	55.5	0.038	0.088		2.204		0.022	0.062	0.028	0.028	0.117	0.038
7	Zhao et al., 2013	BJ	123.45	0.030	0.020				0.020	0.070	0.010	0.090	0.140	
7	Zhao et al., 2013	SDZ	71.79	0.010	0.010				0.040	0.040	0.010	0.060	0.070	
8	Duan et al., 2006	CGZ	96.5	0.060			1.640						0.170	0.090
8	Duan et al., 2006	THU	106.9	0.060			2.090						0.210	0.120
9	Tao et al., 2014	PKU	135.0	0.012		0.003		0.001	0.011		0.004		0.143	0.003
10	Yang et al., 2014	NFRR	137.55	0.028		0.004			0.032	0.079	0.005		0.355	

b) Seasonal (Ba and P are not available)

#	Source	Sampling site	Seasons	$PM_{2.5}$ mass	As	Cd	Cl	Co	Cr	Mn	Ni	Pb	Se
10	Yang et al., 2014	NFRR	Spring	91.16	0.029	0.004			0.025	0.069	0.005	0.288	
8	Duan et al., 2006	CGZ	Spring	76.41	0.060		1.130					0.170	0.060
9	Tao et al., 2014	PKU	Spring	135.0	0.011	0.003		0.001	0.009		0.004	0.133	0.004
10	Yang et al., 2014	NFRR	Summer	84.47	0.008	0.002			0.094	0.037	0.003	0.158	
8	Duan et al., 2006	CGZ	Summer	88.99	0.040		0.320					0.120	0.010
9	Tao et al., 2014	PKU	Summer	135.00	0.019	0.003			0.008		0.002	0.123	0.004
10	Yang et al., 2014	NFRR	Fall	78.50	0.028	0.005			0.012	0.120	0.007	0.513	
8	Duan et al., 2006	CGZ	Fall	79.80	0.050		0.880					0.160	0.130
9	Tao et al., 2014	PKU	Fall	135.0	0.008	0.003		0.001	0.017		0.0038	0.147	0.003
10	Yang et al., 2014	NFRR	Winter	143.4	0.045	0.005			0.010	0.091	0.007	0.454	
8	Duan et al., 2006	CGZ	Winter	122.09	0.070		3.930					0.210	0.120
9	Tao et al., 2014	PKU	Winter	135.0	0.007	0.002		0.002	0.010		0.0058	0.163	0.003

Table S3. Concentrations of PAHs (ng/m^3) and $PM_{2.5}$ mass ($\mu g/m^3$) in Beijing from previous studies, a) annual and b) seasonal.

a) Annual

Source	**Wang et al., 2008**	**Liu et al., 2008**	**Hou et al., 2006**	**Yu et al., 2008**	**Cui et al., 2008**	**Duan et al., 2009**
Sampling sites	20 sampling sites in Beijing	6 sampling sites in Beijing	Beijing Normal University	China University of Petroleum	North forth ring road	Beijing
$PM_{2.5}$ mass	378	103	26	95.5	166	133
Ace	0.53	13.5	-	0.61	-	0.1
Acy	0.25	13.3	-	0.46	0.83	0.03
Ant	1.15	0.39	-	1.43	0.5	1.15
BaA	12.3	2.03	2.42	4.52	8.15	12.4
BaP	17.8	2.04	2.41	5.73	3.66	11.5
BbF	36.7	5.25	3.68	9.71	8.14	16
BghiP	25.2	16.2	2.7	15.7	7.82	14.1
BkF	53.1	1.95	1.49	6.37	8.32	12.1
Chr	8.27	2.18	3.08	8.76	31.1	16.6
DBA	6.27	27.3	0.9	7.86	1.5	6.52
Fl	3.84	5.25	-	2.03	0.33	0.44
Flu	186	7.61	5.3	7.26	26.1	18.9
InP	27.6	3.22	2.16	4.6	2.83	9.59
Nap	2.2	-	-	0.49	2.16	0.16
Phe	11.6	3.87	-	7.87	71.5	7.05
Pyr	16.2	8.69	3.65	7.08	25.9	17.1

b) Seasonal

Source	**Yu et al., 2008**	**Duan et al., 2009**	**Yu et al., 2008**	**Duan et al., 2009**	**Yu et al., 2008**	**Duan et al., 2009**	**Yu et al., 2008**	**Duan et al., 2009**
Sampling site	China University of Petroleum	Beijing	China University of Petroleum	Beijing	China University of Petroleum	Beijing	China University of Petroleum	Beijing
Season	Spring	Spring	Summer	Summer	Fall	Fall	Winter	Winter
$PM_{2.5}$ mass	165.81	111.3	52.1	35	69.4	27	94.7	165
Ace	0.46	0.03	0.11	0.01	0.67	0.04	1.18	0.19
Acy	0.33	0.08	0.09	0.01	0.53	0.01	0.89	0.02
Ant	0.99	0.6	0.39	0.05	1.48	0.15	2.84	2.11
BaA	3.06	3.35	1.37	1	5.06	2.57	8.59	24.96
BaP	5.14	3.03	2.48	1.37	5.88	3.06	9.4	22.43
BbF	7.42	5.44	6.36	4.28	9.26	5.2	15.79	30.52
BghiP	12.28	5.99	7.47	5.07	15.55	5.44	27.48	22.99
BkF	4.77	4.5	2.52	3.27	6.94	4.5	11.25	21.82
Chr	6.21	5.48	3.28	2.25	10.97	4.94	14.57	31.83
DBA	5.86	1.55	3.09	0.69	8.17	0.81	14.32	13.43
Fl	1.05	0.2	0.23	0.04	2.08	0.15	4.77	0.84
Flu	4.92	4.67	2.75	1.58	7.09	2.67	14.26	39.49
InP	3.26	4.24	2.09	4.36	4.12	4.27	8.94	17.49
Nap	0.46	0.11	0.1	0.08	0.61	0.17	0.08	0.19
Phe	5.87	2	2.96	0.6	9.73	1.26	12.91	14.19
Pyr	4.99	3.82	3.06	1.45	8.24	2.54	12.04	35.84

Table S4. Annual and seasonal percentages (%) of elements in $PM_{2.5}$ mass in Beijing, derived using data in Table S2.

Elements	Annual	Spring	Summer	Fall	Winter
As	0.032	0.040	0.023	0.035	0.031
Ba	0.063	0.063	0.063	0.063	0.063
Cd	0.003	0.003	0.002	0.004	0.003
Cl	2.530	1.480	0.360	1.100	3.220
Co	0.001	0.001	2.9E-6	0.001	0.001
Cr	0.003	0.002	0.008	0.002	0.001
Mn	0.081	0.076	0.044	0.153	0.064
Ni	0.020	0.004	0.003	0.006	0.005
P	0.069	0.069	0.069	0.069	0.069
Pb	0.171	0.212	0.138	0.321	0.204
Se	0.048	0.041	0.007	0.083	0.050

Table S5. Annual and seasonal percentages (%) of PAHs in $PM_{2.5}$ mass in Beijing, derived using data in Table S3.

PAHs	Annual	Spring	Summer	Fall	Winter
Ace	3.5E-03	1.5E-04	1.2E-04	5.6E-04	6.8E-04
Acy	2.8E-03	1.4E-04	1.0E-04	4.0E-04	4.8E-04
Ant	6.7E-04	5.7E-04	4.4E-04	1.3E-03	2.1E-03
BaA	5.6E-03	2.4E-03	2.7E-03	8.4E-03	1.2E-02
BaP	5.5E-03	2.9E-03	4.3E-03	9.9E-03	1.2E-02
BbF	9.4E-03	4.7E-03	1.2E-02	1.6E-02	1.8E-02
BghiP	1.1E-02	6.4E-03	1.4E-02	2.1E-02	2.1E-02
BkF	7.1E-03	3.5E-03	7.0E-03	1.3E-02	1.3E-02
Chr	9.4E-03	4.3E-03	6.3E-03	1.7E-02	1.7E-02
DBA	7.6E-03	2.5E-03	3.9E-03	7.4E-03	1.2E-02
Fl	1.7E-03	4.1E-04	2.8E-04	1.8E-03	2.8E-03
Flu	1.9E-02	3.6E-03	4.9E-03	1.0E-02	1.9E-02
InP	5.4E-03	2.9E-03	8.2E-03	1.1E-02	1.0E-02
Nap	6.3E-04	1.9E-04	2.1E-04	7.5E-04	9.9E-05
Phe	1.3E-02	2.7E-03	3.7E-03	9.3E-03	1.1E-02
Pyr	1.0E-02	3.2E-03	5.0E-03	1.1E-02	1.7E-02

Table S6. Inhalation unit risk (UR) for the six carcinogenic PM components considered in this study.

Chemical name	UR $(\mu g/m^3)^{-1}$	Source
As (Arsenic)	4.30E-3	USEPA, 2019
Cd (Cadmium)	1.80E-3	USEPA, 2019
Co (Cobalt)	9.00E-3	ATSDR, 2011
Cr (Chromium) (VI)	1.20E-2	USEPA, 2019
Ni (Nickel)	2.40E-4	USEPA, 2019
Pb (Lead)	8.00E-5	OEHHA, 2000

Table S7. The 16 priority USEPA PAHs considered in this study and corresponding toxic equivalency factors (Nisbet and LaGoy, 1992).

Name	Abbreviation	TEF	Name	Abbreviation	TEF
Acenaphthene	Ace	0.001	Chrysene	Chr	0.01
Acenaphthylene	Acy	0.001	Dibenz[a,h]anthracene	DBA	1
Anthracene	An	0.01	Fluoranthene	Flu	0.001
Benz[a]anthracene	BaA	0.1	Fluorene	Fl	0.001
Benzo[a]pyrene	BaP	1	Indeno[1,2,3,-cd]pyrene	InP	0.1
Benzo[b]fluoranthene	BbF	0.1	Naphthalene	Nap	0.001
Benzo[g,h,i]perylene	BghiP	0.01	Phenanthrene	Phe	0.001
Benzo[k]fluoranthene	BkF	0.1	Pyrene	Pyr	0.001

Table S8. Reference concentration (RfC, noncancer) for the 11 PM components considered in this study.

Chemical name	RfC (mg/m^3)	Target organ	Source
As (Arsenic)	1.50E-5	Reproductive	OEHHA, 2000
Ba (Barium)	5.00E-4	Fetus	USEPA, 1997
Cd (Cadmium)	1.00E-5	Renal	ATSDR, 2011
Cl (Chlorine)	1.50E-4	Respiratory	ATSDR, 2011
Co (Cobalt)	1.00E-4	Respiratory	ATSDR, 2011
Cr (Chromium) (VI)	1.00E-4	Respiratory	USEPA, 2019
Mn (Manganese)	5.00E-5	Nervous	ATSDR, 2011
Ni (Nickel)	9.00E-5	Respiratory	ATSDR, 2011
P (Phosphorus)	7.00E-5	Respiratory	OEHHA, 2000
Pb (Lead)	1.50E-4	Nervous	USEPA, 2016
Se (Selenium)	2.00E-2	Alimentary	OEHHA, 2000

Table S9. Source profiles (percentages of $PM_{2.5}$ bound elements in each source) (Yu et al., 2008).

Element	Secondary sulphur	Vehicle exhaust	Soil dust	Road dust	Biomass burning	Fossil fuel combustion	Metal Processing
As	7	19	0	39	0	35	0
Ba	3	92	0	5	0	0	0
Cd	0	0	0	0	0	0	0
Cl	3	7	0	0	3	79	8
Co	0	0	100	0	0	0	0
Cr	0	4	0	66	7	0	23
Mn	5	34	0	0	2	0	59
Ni	0	4	0	28	27	31	10
P	26	16	21	3	0	34	0
Pb	0	27	0	42	25	6	0
Se	0	0	19	21	4	49	7

Table S10. Normalized proportions of the six elements and total PAHs to PM2.5 mass by summer values.

Elements and total PAHs	Spring	Fall	Winter
Cr(VI)	0.3	0.2	0.1
Co	2.3	2.3	4.0
As	1.7	1.5	1.4
Cd	1.5	1.9	1.2
Ni	1.6	2.2	1.7
Pb	1.5	2.3	1.5
Total PAHs	0.5	1.9	2.3

Table S11. Normalized proportions of the 11 elements to PM2.5 mass by summer values.

Elements and total PAHs	Spring	Fall	Winter
Se	5.8	11.7	7.2
Ba	1.0	1.0	1.0
Cl	4.1	3.1	9.0
Pb	1.5	2.3	1.5
Co	2.3	2.3	4.0
Cr(VI)	0.3	0.2	0.1
Ni	1.6	2.2	1.7
P	1.0	1.0	1.0
Mn	1.7	3.5	1.4
As	1.7	1.5	1.4
Cd	1.5	1.9	1.2

Table S12. HQ values by source by season.

Source	Spring	Summer	Fall	Winter
Fossil fuel combustion	7.31	1.92	5.65	19.71
Vehicle exhaust	1.55	0.70	1.58	2.85
Metal Processing	0.76	0.20	0.72	2.01
Road dust	1.35	0.73	1.49	1.57
Secondary sulphur	0.60	0.30	0.53	1.15
Biomass burning	0.54	0.22	0.62	1.09
Soil dust	0.17	0.14	0.17	0.24

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