Supplementary materials for

A Long-lasting Winter Haze Episode in Xiangyang, Central China: Pollution Characteristics, Chemical Composition and Health Risk Assessment

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Table S1. The corresponding percent change in TSV (%) as possible number of clusters are combined.

Possible number of clusters	**Percent change in TSV (%)**
15	37.84
9	35.38
5	108.13
3	**33.06**
2	90.99

Table S2. The variables for human health risk assessment.

Variable	Description	Unit	Value			
R_{Ing}*	Ingestion rate	mg day^{-1}	200, 100 for children and adults			
R_{Inh}*	Inhalation rate	m^3 day^{-1}	20, 7.6 for children and adults			
ABS*	Dermal absorption factor	Unitless	0.030, 0.001, 0.01 for As, Cd and other metal(loid)s			
EF*	Exposure frequency	days $year^{-1}$	350 for both children and adults			
ED*	Exposure duration	years	6, 24 for children and adults			
BW*	Body weight	kg	15, 70 for children and adults			
AT*	Averaging time	days	Non-carcinogenic substances: 2190, 8760 for children and adults; Carcinogenic substances: 25500 for both children and adults			
PEF*	Particle emission factor	m^3 kg^{-1}	1.36×10^9			
SA*	Skin surface area in contact with air	cm^2	2800, 5700 for children and adults			
AF*	Adherence factor for air-borne particulates to skin	mg cm^{-2} day^{-1}	0.25, 1 for children and adults			
CF*	conversion factor	kg mg^{-1}	10^{-6}			
			Metal(loid)s	RfD_{Ing}	RfD_{Inh}	RfD_{Dermal}
RfD**	Reference dose	mg kg^{-1} day^{-1}	As	3.00E-04	3.01E-04	1.23E-04
			Cd	1.00E-03	1.00E-03	1.00E-05
			Cr (III)	3.00E-03	2.86E-05	6.00E-05
			Co	2.00E-02	5.71E-06	1.60E-02
			Cu	4.00E-02	4.02E-02	1.20E-02
			Mn	4.60E-02	1.43E-05	1.84E-03
			Ni	2.00E-02	2.06E-02	5.40E-03
			Zn	3.00E-01	3.00E-01	6.00E-02
			Pb	3.50E-03	3.52E-03	5.25E-04
			Ag	5.00E-03	—	9.00E-04
			Al	1.00E+00	1.43E-03	1.00E-01
			Ba	7.00E-02	1.43E-04	4.90E-03
			Mo	5.00E-03	—	1.90E-03
			Sb	4.00E-04	—	8.00E-06
			Sr	6.00E-01	—	1.20E-01
			U	6.00E-04	—	5.10E-04
			V	7.00E-03	—	7.00E-05

Variable	Description	Unit	Value			
			Metal(loid)s	SF_{Ing}	SF_{Inh}	SF_{Dermal}
SF**	Slope factor	mg kg^{-1} day^{-1}	As	1.50E+00	1.51E+01	3.66E+00
			Cd	—	6.30E+00	—
			Co	—	9.80E+00	—
			Cr (VI)	5.00E-01	4.20E+01	—
			Ni	—	8.40E-01	—
			Pb	2.80E-01	8.00E-05	—

Note. *The values were obtained from the Exposure Factors Handbook: 2011 Edition by USEPA, (2011). **The values were obtained from obtained from Ferreira-Baptista and De Miguel, (2005), Hu et al., (2012) and Li et al., (2013).

Table S3. The percentages of air-mass back-trajectory clusters and corresponding mass concentrations of $PM_{2.5}$ and species (μg m^{-3}) during the sampling period.

Cluster type (%)	$PM_{2.5}$	Cl^-	NO_3^-	SO_4^{2-}	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	WSIIs	SNA	OC	EC	TC	OM	SOC	POC	TE
1 (62)	165.49	6.30	51.70	25.16	1.09	21.43	0.20	1.27	0.55	107.70	98.29	20.59	6.65	27.23	32.94	10.02	10.57	10.30
2 (24)	102.68	3.21	27.69	16.30	0.76	12.93	0.10	0.73	0.06	61.78	56.92	12.28	3.99	16.27	19.65	5.93	6.35	11.60
3 (14)	234.61	6.02	84.64	35.71	1.20	33.29	0.21	1.59	0.70	163.38	153.64	27.84	7.84	35.68	44.54	15.38	12.46	10.53

Table S4. The comparation of reported No. of haze days, maximum and mean $PM_{2.5}$ concentrations (μg m^{-3}), and prevailing meteorological conditions in Xiangyang and other cities around the world.

Station (Country)	Site type	Sampling period	No. of haze days	Maximum	Mean ± Standard deviation	Prevailing meteorological conditions	References
Chengdu (China)	Near-road	2018 winter	—	—	113.2±60.3	Low T and WS	Qu et al., (2019)
Shanghai (China)	Suburban	2018 haze days	21	189.0	92.9±44.4	Lowest average WS (10.48 m s^{-1}) and RH (73.52%)	Wei et al., (2019)
Zhengzhou (China)	Urban	Jan. 11-23, 2018	18	349.4	188.2±52.4	RH: 55.8±1.1%, WS: 1.5±1.3 m s^{-1}, T: 2.2±3.7 ℃	Wang et al., (2019)
Hefei (China)	Industrial	Oct. 2016-Jan. 2017	—	100	81.0	—	Xue et al., (2019)
Guilin (China)	Urban	Dec. 10-15, 2016 Jan. 4-7, 2017	6	176	144.0±28.5	T: 15.3 ℃, RH:75%, WS: 0.96 m s^{-1}, WD: N and NW	Zhong et al., (2019)
Beijing (China)	Urban	Dec. 29, 2014.-Jan. 27, 2015	—	270	117.0	WD: NW	Shen et al., (2019)
Tianjin (China)	Urban		—	350	124.0		
Shijiazhuang (China)	Urban	Dec. 15, 2015-Jan. 14, 2016	56	588.7	234.0 ±139.5	Lowest boundary layer height	Xie et al., (2019)
Wuhan (China)	Urban	Jan. 9, 2013-Feb. 6, 2013	25	257	159.5±66.3	RH:85%, WS: 2 m s^{-1}, WD: SE and NE	Liu et al., (2016)
King Fahd (Saudi Arabia)	Urban	2013.01	—	180	71.9	WS: 2 m s^{-1}	Modaihsh et al., (2015)
Zonguldak (Turky)	Urban	2007 winter	—	83.3	37.3	T: 1.3 ℃. WS: 0.9 m s^{-1}, RH: 70%	Akyuz and Cabuk, (2009)
Delhi (India)	Near-road	2013.12-2014.01	—	—	293.1±36.7	—	Khanna et al., (2018)
Iasi (Romania)	Urban	Jan. 2016	—	—	23.4±11.7	—	Galon-Negru et al., (2018)
Xiangyang (China)	Urban	Jan. 13-24, 2018	12	347.7	169.3±57.0	T: 3.7 ℃, RH:81%, WS: 3.02 m s^{-1}, WD: NW and NE	**This study**

Note. T: Temperature (℃), WS: Wind speed (m s^{-1}), WD: Wind direction, RH: Relative humidity (%).

Table S5. Average daily exposure doses (mg kg^{-1} day^{-1}) of PM$_{2.5}$-bound metal(loid)s for the three different exposure pathways at the four pollution levels.

Pollution level	**Metal(loid)s**	**Children**				**Adults**			
		$ADED_{Ing}$	$ADED_{Inh}$	$ADED_{Dermal}$	$ADED$	$ADED_{Ing}$	$ADED_{Inh}$	$ADED_{Dermal}$	$ADED$
Mild pollution	**As**	7.57E-01	2.11E-05	7.95E-02	8.36E-01	1.00E-01	1.47E-05	1.72E-01	2.72E-01
	Cd	3.25E-04	9.07E-09	1.14E-06	3.26E-04	4.30E-05	6.33E-09	2.45E-06	4.55E-05
	Cr	4.76E-02	1.33E-06	1.66E-03	4.92E-02	5.31E-03	7.81E-07	3.03E-03	8.34E-03
	Co	2.28E+00	6.36E-05	7.97E-02	2.36E+00	3.02E-01	4.44E-05	1.72E-01	4.74E-01
	Cu	5.53E-02	1.55E-06	1.94E-03	5.72E-02	5.93E-03	8.71E-07	3.38E-03	9.30E-03
	Mn	2.42E-01	6.77E-06	8.48E-03	2.51E-01	2.60E-02	3.82E-06	1.48E-02	4.08E-02
	Ni	1.59E-02	4.44E-07	5.56E-04	1.64E-02	2.10E-03	3.09E-07	1.20E-03	3.30E-03
	Zn	2.30E+00	6.43E-05	8.06E-02	2.38E+00	2.47E-01	3.63E-05	1.41E-01	3.87E-01
	Pb	2.32E+00	6.48E-05	8.12E-02	2.40E+00	3.07E-01	4.52E-05	1.75E-01	4.83E-01
	Ag	1.43E-05	3.98E-10	4.99E-07	1.48E-05	1.53E-06	2.25E-10	8.71E-07	2.40E-06
	Al	1.33E+02	3.70E-03	4.64E+00	1.37E+02	1.42E+01	2.09E-03	8.10E+00	2.23E+01
	Ba	2.84E-01	7.92E-06	9.92E-03	2.93E-01	3.04E-02	4.47E-06	1.73E-02	4.77E-02
	Mo	4.95E-04	1.38E-08	1.73E-05	5.12E-04	5.31E-05	7.80E-09	3.02E-05	8.33E-05
	Sb	6.13E+02	1.71E-02	2.14E+01	6.34E+02	6.56E+01	9.65E-03	3.74E+01	1.03E+02
	Sr	2.66E-03	7.42E-08	9.29E-05	2.75E-03	2.85E-04	4.18E-08	1.62E-04	4.47E-04
	U	1.41E-06	3.95E-11	4.95E-08	1.46E-06	1.51E-07	2.23E-11	8.63E-08	2.38E-07
	V	4.22E-03	1.18E-07	1.48E-04	4.37E-03	4.52E-04	6.65E-08	2.58E-04	7.10E-04
Moderate pollution	**As**	1.31E-02	3.67E-07	1.38E-03	1.45E-02	1.74E-03	2.56E-07	2.97E-03	4.71E-03
	Cd	7.32E-04	2.04E-08	2.56E-06	7.34E-04	9.70E-05	1.43E-08	5.53E-06	1.03E-04
	Cr	4.46E-03	1.25E-07	1.56E-04	4.62E-03	4.98E-04	7.32E-08	2.84E-04	7.82E-04
	Co	3.29E-02	9.19E-07	1.15E-03	3.40E-02	4.36E-03	6.41E-07	2.48E-03	6.84E-03
	Cu	8.57E-03	2.39E-07	3.00E-04	8.87E-03	9.18E-04	1.35E-07	5.23E-04	1.44E-03
	Mn	1.61E-02	4.49E-07	5.63E-04	1.66E-02	1.72E-03	2.53E-07	9.82E-04	2.70E-03
	Ni	3.24E-03	9.06E-08	1.13E-04	3.36E-03	4.30E-04	6.32E-08	2.45E-04	6.75E-04
	Zn	5.87E-02	1.64E-06	2.05E-03	6.07E-02	6.28E-03	9.24E-07	3.58E-03	9.87E-03
	Pb	3.30E-02	9.22E-07	1.15E-03	3.42E-02	4.37E-03	6.43E-07	2.49E-03	6.87E-03
	Ag	1.02E-04	2.84E-09	3.56E-06	1.05E-04	1.09E-05	1.60E-09	6.21E-06	1.71E-05
	Al	2.89E-01	8.08E-06	1.01E-02	2.99E-01	3.10E-02	4.56E-06	1.77E-02	4.86E-02
	Ba	8.77E-03	2.45E-07	3.07E-04	9.08E-03	9.40E-04	1.38E-07	5.36E-04	1.48E-03
	Mo	4.63E-04	1.29E-08	1.62E-05	4.79E-04	4.96E-05	7.29E-09	2.83E-05	7.79E-05
	Sb	3.51E-01	9.81E-06	1.23E-02	3.63E-01	3.76E-02	5.53E-06	2.14E-02	5.91E-02
	Sr	2.27E-03	6.34E-08	7.94E-05	2.35E-03	2.43E-04	3.58E-08	1.39E-04	3.82E-04

Pollution level	**Metal(loid)s**	**Children**				**Adults**			
		$ADED_{Ing}$	$ADED_{Inh}$	$ADED_{Dermal}$	$ADED$	$ADED_{Ing}$	$ADED_{Inh}$	$ADED_{Dermal}$	$ADED$
	U	4.18E-05	1.17E-09	1.46E-06	4.32E-05	4.47E-06	6.58E-10	2.55E-06	7.02E-06
	V	2.03E-03	5.66E-08	7.09E-05	2.10E-03	2.17E-04	3.19E-08	1.24E-04	3.41E-04
Heavy pollution	**As**	6.67E-03	1.86E-07	7.00E-04	7.37E-03	8.84E-04	1.30E-07	1.51E-03	2.40E-03
	Cd	7.90E-04	2.21E-08	2.76E-06	7.93E-04	1.05E-04	1.54E-08	5.97E-06	1.11E-04
	Cr	4.95E-03	1.38E-07	1.73E-04	5.12E-03	5.53E-04	8.13E-08	3.15E-04	8.68E-04
	Co	2.45E-02	6.86E-07	8.59E-04	2.54E-02	3.25E-03	4.78E-07	1.85E-03	5.11E-03
	Cu	7.53E-03	2.10E-07	2.63E-04	7.79E-03	8.06E-04	1.19E-07	4.60E-04	1.27E-03
	Mn	1.51E-02	4.22E-07	5.29E-04	1.56E-02	1.62E-03	2.38E-07	9.23E-04	2.54E-03
	Ni	3.70E-03	1.04E-07	1.30E-04	3.83E-03	4.91E-04	7.22E-08	2.80E-04	7.71E-04
	Zn	6.65E-02	1.86E-06	2.33E-03	6.89E-02	7.13E-03	1.05E-06	4.06E-03	1.12E-02
	Pb	5.64E-02	1.58E-06	1.97E-03	5.84E-02	7.47E-03	1.10E-06	4.26E-03	1.17E-02
	Ag	9.14E-05	2.56E-09	3.20E-06	9.47E-05	9.80E-06	1.44E-09	5.58E-06	1.54E-05
	Al	2.89E-01	8.06E-06	1.01E-02	2.99E-01	3.09E-02	4.55E-06	1.76E-02	4.85E-02
	Ba	1.27E-02	3.55E-07	4.45E-04	1.32E-02	1.36E-03	2.00E-07	7.77E-04	2.14E-03
	Mo	6.63E-04	1.85E-08	2.32E-05	6.87E-04	7.11E-05	1.05E-08	4.05E-05	1.12E-04
	Sb	2.32E-01	6.47E-06	8.11E-03	2.40E-01	2.48E-02	3.65E-06	1.41E-02	3.90E-02
	Sr	2.36E-03	6.59E-08	8.26E-05	2.44E-03	2.53E-04	3.72E-08	1.44E-04	3.97E-04
	U	2.98E-05	8.32E-10	1.04E-06	3.08E-05	3.19E-06	4.69E-10	1.82E-06	5.01E-06
	V	1.25E-03	3.50E-08	4.38E-05	1.30E-03	1.34E-04	1.97E-08	7.64E-05	2.11E-04
Severe pollution	**As**	5.10E-03	1.43E-07	5.36E-04	5.64E-03	6.76E-04	9.95E-08	1.16E-03	1.83E-03
	Cd	7.95E-04	2.22E-08	2.78E-06	7.98E-04	1.05E-04	1.55E-08	6.01E-06	1.11E-04
	Cr	8.07E-03	2.26E-07	2.82E-04	8.35E-03	9.01E-04	1.33E-07	5.14E-04	1.42E-03
	Co	1.25E-02	3.48E-07	4.36E-04	1.29E-02	1.65E-03	2.43E-07	9.42E-04	2.59E-03
	Cu	6.62E-03	1.85E-07	2.32E-04	6.85E-03	7.09E-04	1.04E-07	4.04E-04	1.11E-03
	Mn	1.24E-02	3.48E-07	4.35E-04	1.29E-02	1.33E-03	1.96E-07	7.60E-04	2.09E-03
	Ni	4.43E-03	1.24E-07	1.55E-04	4.58E-03	5.87E-04	8.63E-08	3.34E-04	9.21E-04
	Zn	5.68E-02	1.59E-06	1.99E-03	5.88E-02	6.09E-03	8.95E-07	3.47E-03	9.56E-03
	Pb	3.00E-02	8.39E-07	1.05E-03	3.11E-02	3.98E-03	5.85E-07	2.27E-03	6.25E-03
	Ag	6.89E-05	1.92E-09	2.41E-06	7.13E-05	7.38E-06	1.09E-09	4.21E-06	1.16E-05
	Al	1.89E-01	5.27E-06	6.60E-03	1.95E-01	2.02E-02	2.97E-06	1.15E-02	3.17E-02
	Ba	5.60E-03	1.56E-07	1.96E-04	5.79E-03	6.00E-04	8.82E-08	3.42E-04	9.42E-04
	Mo	4.91E-04	1.37E-08	1.72E-05	5.08E-04	5.26E-05	7.73E-09	3.00E-05	8.25E-05
	Sb	1.47E-01	4.11E-06	5.15E-03	1.52E-01	1.58E-02	2.32E-06	8.98E-03	2.47E-02
	Sr	1.45E-03	4.05E-08	5.07E-05	1.50E-03	1.55E-04	2.28E-08	8.84E-05	2.44E-04
	U	2.35E-05	6.56E-10	8.22E-07	2.43E-05	2.52E-06	3.70E-10	1.43E-06	3.95E-06
	V	8.79E-04	2.46E-08	3.08E-05	9.10E-04	9.42E-05	1.39E-08	5.37E-05	1.48E-04

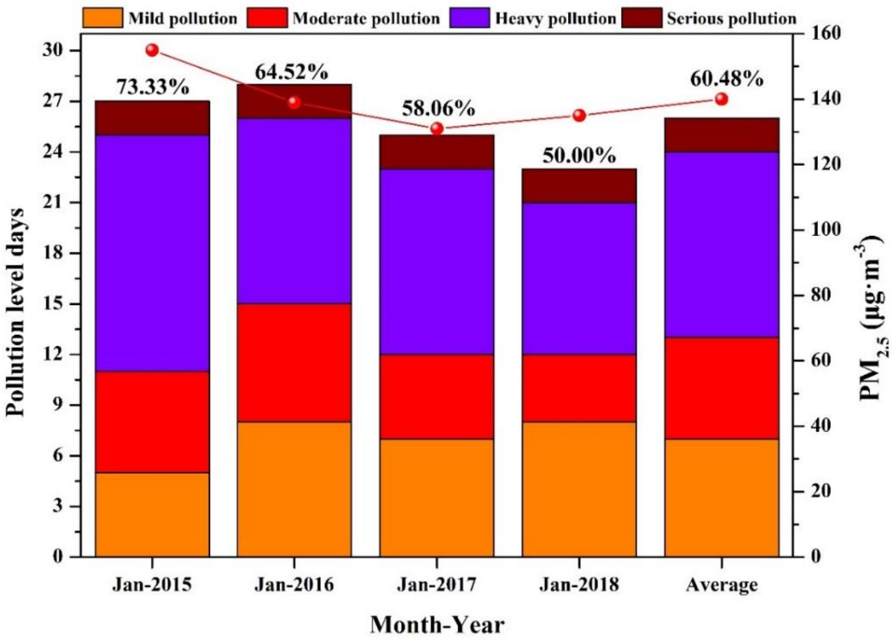

Fig. S1. The pollution level days and $PM_{2.5}$ concentrations at the four pollution levels in January from 2015-2018.

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