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Submitted to: RSC Advances

Title: Atmospheric Emissions of Toxic Elements (As, Cd, Hg, and Pb) from Brick Making Plants in China

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Table S1

Provincial coal consumption for brick making plants in China (10⁴t).

	2008	2009	2010	2011	2012	2013
Anhui	19.39	37.96	80.34	71.51	74.46	95.36
Beijing	5.01	6.49	4.63	1.46	0.54	0.18
Chongqing	12.98	28.70	40.39	20.73	24.35	31.05
Fujian	5.54	8.90	15.17	9.12	17.35	30.54
Gansu	0.77	20.24	0.94	0.28	5.47	4.82
Guangdong	13.79	18.53	19.59	16.83	19.41	30.26
Guangxi	24.39	41.02	61.68	58.07	58.64	66.04
Guizhou	5.98	8.04	10.50	11.59	23.84	35.48
Hebei	68.42	78.00	79.97	76.59	37.17	35.07
Heilongjiang	2.76	6.06	17.82	30.43	39.17	31.55
Henan	269.74	433.51	500.22	549.15	466.70	683.33
Hubei	52.50	101.04	135.72	117.16	178.81	226.64
Hunan	51.25	68.83	68.98	89.26	109.59	124.92
Inner Mongolia	10.21	12.47	15.06	18.77	17.77	21.22
Jiangsu	18.87	19.64	22.48	11.35	10.70	10.22
Jiangxi	12.69	18.01	21.41	16.00	13.57	12.93
Jilin	13.77	40.75	41.33	36.52	37.88	38.70
Liaoning	37.25	79.05	55.91	54.37	53.90	51.99
Ningxia	0.00	0.34	0.79	1.41	1.07	0.90
Qinghai	0.96	0.88	1.03	0.50	0.63	0.53
Shanghai	0.09	0.00	0.17	0.00	0.55	1.12
Shaanxi	2.90	14.23	25.12	30.25	39.28	63.32
Shandong	93.54	158.34	170.13	160.53	157.03	154.36
Shanxi	6.80	10.33	9.43	5.18	11.14	11.73
Sichuan	37.90	90.68	106.86	161.44	131.78	147.19
Tianjin	6.21	6.59	16.25	5.90	3.94	4.07
Xinjiang	4.46	5.34	5.75	1.24	1.73	3.54
Yunnan	1.66	1.70	2.44	2.35	6.55	6.48
Zhejiang	20.58	27.41	22.64	7.67	6.81	7.94
Total	800.72	1343.95	1553.53	1565.64	1549.83	1931.49

Notes: For the little brick output and no available data from references, the coal consumption in Hainan, Hong Kong, Macao, Taiwan and Xizang are not included in this table.

Table S2
 Provincial production of bricks in China (10⁹ piece).

	2008	2009	2010	2011	2012	2013
Anhui	35.25	69.03	160.68	143.01	165.47	211.92
Beijing	9.11	11.80	9.27	2.92	1.21	0.41
Chongqing	23.59	52.17	80.78	41.46	54.12	69.00
Fujian	10.06	16.18	30.34	18.24	38.55	67.86
Gansu	1.41	36.80	1.87	0.56	12.16	10.72
Guangdong	25.07	33.69	39.19	33.66	43.12	67.24
Guangxi	44.35	74.59	123.36	116.14	130.32	146.75
Guizhou	10.88	14.61	21.01	23.17	52.99	78.85
Hebei	124.41	141.81	159.94	153.18	82.61	77.93
Heilongjiang	5.03	11.02	35.64	60.86	87.05	70.10
Henan	490.43	788.21	1000.43	1098.31	1037.10	1518.51
Hubei	95.45	183.71	271.44	234.32	397.36	503.65
Hunan	93.18	125.14	137.96	178.52	243.54	277.60
Inner Mongolia	18.56	22.68	30.13	37.54	39.48	47.15
Jiangsu	34.31	35.71	44.96	22.69	23.77	22.71
Jiangxi	23.06	32.75	42.82	32.01	30.16	28.73
Jilin	25.03	74.09	82.66	73.03	84.18	86.01
Liaoning	67.72	143.73	111.82	108.74	119.79	115.53
Ningxia	0.00	0.61	1.58	2.82	2.37	2.01
Qinghai	1.75	1.60	2.05	1.01	1.39	1.17
Shaanxi	5.27	25.88	50.25	60.50	87.28	140.70
Shandong	170.08	287.90	340.26	321.05	348.96	343.02
Shanghai	0.17	0.00	0.35	0.00	1.23	2.49
Shanxi	12.37	18.78	18.87	10.35	24.76	26.07
Sichuan	68.91	164.88	213.72	322.88	292.83	327.09
Tianjin	11.29	11.98	32.50	11.80	8.76	9.04
Xinjiang	8.10	9.71	11.50	2.47	3.85	7.86
Yunnan	3.02	3.09	4.87	4.70	14.55	14.40
Zhejiang	37.42	49.84	45.28	15.34	15.12	17.65
Total	1455.85	2443.55	3107.06	3131.28	3444.06	4292.19

Notes: For the little brick output and no available data from references, the production of bricks in Hainan, Hong Kong, Macao, Taiwan and Xizang are not included in this table.

Table S3

Provincial coal ash consumption in brick plants in China (10⁴ t).

	2008	2009	2010	2011	2012	2013
Anhui	37.95	76.21	181.82	165.78	196.38	257.36
Beijing	9.80	13.03	10.49	3.38	1.44	0.50
Chongqing	25.40	57.60	61.54	48.06	64.22	83.79
Fujian	10.83	17.87	24.24	21.14	45.75	82.41
Gansu	1.52	40.63	2.12	0.64	14.43	13.02
Guangdong	26.99	37.20	37.30	39.01	51.18	81.66
Guangxi	47.74	82.35	109.60	134.63	154.66	178.21
Guizhou	11.71	16.13	23.77	26.86	62.88	95.75
Hebei	133.91	156.54	180.98	177.56	198.04	194.96
Heilongjiang	5.41	12.17	40.33	70.54	103.31	85.13
Henan	527.90	870.18	1132.09	1273.16	1230.84	1844.07
Hubei	102.74	202.81	222.81	271.62	471.58	611.63
Hunan	100.29	138.16	156.12	206.94	289.03	337.12
Inner Mongolia	19.98	25.03	34.09	43.52	46.85	57.26
Jiangsu	36.94	39.42	40.88	66.32	68.21	67.58
Jiangxi	24.83	36.15	38.46	37.10	35.79	34.89
Jilin	26.94	81.80	93.54	84.66	99.90	104.45
Liaoning	72.90	85.87	126.53	126.06	142.16	140.30
Ningxia	0.00	0.68	1.79	3.27	2.81	2.44
Qinghai	1.89	1.76	1.33	1.17	1.65	1.42
Shanghai	0.18	0.19	0.39	0.85	1.46	3.03
Shaanxi	5.67	28.57	56.86	70.13	103.59	170.87
Shandong	183.07	317.84	385.04	372.17	414.14	416.56
Shanxi	13.31	20.73	21.35	12.00	29.38	31.66
Sichuan	74.18	182.02	241.85	374.28	347.54	397.22
Tianjin	12.15	13.22	13.45	13.67	10.39	10.98
Xinjiang	8.72	10.72	8.01	8.87	9.57	9.55
Yunnan	3.25	3.41	5.51	5.44	17.27	17.49
Zhejiang	20.27	25.03	21.34	27.78	27.95	21.44
Total	1546.45	2593.32	3273.62	3686.62	4242.41	5352.75

Notes: For the little brick output and no available data from references, the coal fly ash consumption in Hainan, Hong Kong, Macao, Taiwan and Xizang are not included in this table.

Table S4

Provincial coal gangue consumption in brick plants in China (10⁴ t).

	2008	2009	2010	2011	2012	2013
Anhui	13.75	27.61	55.88	60.07	71.15	93.24
Beijing	3.55	4.72	3.80	1.23	0.52	0.18
Chongqing	9.20	20.87	23.22	17.41	23.27	30.36
Fujian	3.93	6.47	6.44	7.66	16.57	29.86
Gansu	0.55	0.72	0.77	3.23	5.23	4.72
Guangxi	17.30	29.84	50.58	48.78	56.04	64.57
Guizhou	4.24	5.84	8.61	9.73	22.78	34.69
Hebei	28.52	26.72	35.57	34.33	35.52	34.29
Heilongjiang	1.96	4.41	14.61	25.56	37.43	30.84
Henan	191.27	315.28	410.18	461.29	445.96	668.14
Hubei	37.23	73.48	81.29	98.41	170.86	221.61
Hunan	36.34	50.06	56.56	74.98	104.72	122.14
Inner Mongolia	7.24	9.07	12.35	15.77	16.98	20.75
Jiangsu	3.38	4.28	8.43	9.53	10.22	9.99
Jiangxi	9.00	13.10	13.56	13.44	12.97	12.64
Jilin	9.76	29.64	30.89	30.67	36.20	37.84
Liaoning	26.41	57.49	45.85	45.67	51.51	50.83
Ningxia	0.00	0.25	0.65	1.18	1.02	0.88
Qinghai	0.68	0.64	0.84	0.42	0.60	0.51
Shaanxi	2.05	10.35	20.60	25.41	37.53	61.91
Shandong	66.33	115.16	130.51	134.84	150.05	150.93
Shanxi	4.82	7.51	7.74	8.35	10.65	11.47
Sichuan	26.88	65.95	87.63	135.61	125.92	143.92
Xinjiang	1.16	1.18	1.71	1.04	1.66	3.46
Yunnan	1.18	1.24	2.00	1.97	6.26	6.34
Zhejiang	4.59	4.94	4.56	6.44	6.50	7.77
Total	497.56	859.21	1058.94	1212.97	1386.96	1760.66

Notes: For the little brick output, little coal output and no available data from references, the coal gangue consumption in Guangdong, Shanghai, Tianjin, Hainan, Hong Kong, Macao, Taiwan and Xizang are not included in this table.

Table S5
 Provincial clay consumption in brick plants in China (10⁴ t).

	2008	2009	2010	2011	2012	2013
Anhui	17.06	30.37	63.63	50.34	50.96	50.90
Beijing	4.41	5.19	3.67	1.03	0.37	0.11
Chongqing	11.42	22.95	31.99	14.59	16.67	18.22
Fujian	4.87	7.12	12.01	6.42	11.87	17.92
Gansu	0.68	16.19	0.74	0.20	3.75	2.83
Guangdong	12.13	14.82	15.52	11.85	13.28	17.75
Guangxi	21.47	32.82	48.85	40.88	40.14	38.74
Guizhou	5.27	6.43	8.32	8.16	16.32	20.82
Hebei	60.21	62.40	63.34	53.92	25.44	20.57
Heilongjiang	2.43	4.85	14.11	21.42	26.81	18.51
Henan	237.37	346.81	396.17	386.61	319.43	400.89
Hubei	46.20	80.83	87.54	82.48	82.38	84.96
Hunan	45.10	55.06	54.63	62.84	75.01	73.29
Inner Mongolia	8.98	9.98	11.93	13.21	12.16	12.45
Jiangsu	16.61	15.71	17.80	7.99	7.32	6.00
Jiangxi	11.16	14.41	16.96	11.27	9.29	7.58
Jilin	12.11	32.60	32.73	25.71	25.93	22.71
Liaoning	32.78	63.24	44.28	38.28	36.90	30.50
Ningxia	0.00	0.27	0.63	0.99	0.73	0.53
Qinghai	0.85	0.70	0.81	0.36	0.43	0.31
Shaanxi	2.55	11.39	19.90	21.30	23.89	27.14
Shandong	82.32	126.68	134.74	113.01	107.48	90.56
Shanghai	0.08	0.00	0.14	0.00	0.38	0.35
Shanxi	5.99	8.26	7.47	3.64	3.62	3.88
Sichuan	33.35	72.55	84.63	86.65	90.19	86.35
Tianjin	5.46	5.27	12.87	4.15	2.70	2.39
Xinjiang	3.92	4.27	4.55	0.87	1.19	2.08
Yunnan	1.46	1.36	1.93	1.65	4.48	3.80
Zhejiang	18.11	21.93	17.93	5.40	4.66	4.66
Total	704.36	1074.48	1209.84	1075.21	1013.77	1066.77

Table S6

Provincial distribution of average concentration of toxic elements in coals.

	Ash yield (wt. %)	As ($\mu\text{g/g}$)	Cd ($\mu\text{g/g}$)	Hg ($\mu\text{g/g}$)	Pb ($\mu\text{g/g}$)
Anhui	16.8	2.89	0.11	0.43	13.2
Beijing	10.1	4.02	0.66	0.17	26.7
Chongqing	25.5	5.66	1.22	0.31	30.4
Fujian	8.85	9.93	0.31	0.07	25.5
Gansu	7.43	4.14	0.08	0.27	8.35
Guangdong	8.60	8.30	0.25	0.07	24.4
Guangxi	8.81	16.9	0.41	0.33	29.9
Guizhou	8.63	6.68	0.79	0.39	23.8
Hebei	12.4	4.88	0.23	0.15	29.3
Heilongjiang	13.5	3.42	0.13	0.12	22.2
Henan	14.5	2.20	0.54	0.20	16.8
Hubei	7.91	5.30	0.36	0.20	47.4
Hunan	8.40	10.6	0.64	0.12	26.3
Inner Mongolia	6.36	5.77	0.10	0.22	26.7
Jiangsu	11.4	2.74	0.06	0.69	20.9
Jiangxi	7.55	7.41	0.56	0.16	19.3
Jilin	8.92	11.6	0.15	0.40	29.0
Liaoning	12.4	5.51	0.16	0.17	19.6
Ningxia	6.76	3.65	1.10	0.22	14.1
Qinghai	18.4	2.68	0.03	0.25	10.7
Shaanxi	7.62	3.87	0.75	0.21	35.2
Shandong	8.88	5.23	0.39	0.18	16.6
Shanghai	7.43	4.92	0.20	0.28	24.0
Shanxi	13.5	3.84	0.75	0.17	26.2
Sichuan	6.57	5.38	1.95	0.29	28.3
Tianjin	8.37	3.98	1.74	0.17	29.6
Xinjiang	11.5	2.97	0.12	0.06	2.68
Yunnan	6.91	8.82	0.80	0.36	42.5
Zhejiang	11.7	12.0	0.47	0.65	17.3

Table S7

The emission factors of toxic elements during coal combustion (%).

Element	Emission factor, controlling devices, and sources
As	0.78-1.1 / ESP (Ondov et al., 1979)
	12.5 / ESP (Brooks, 1989)
	0.1-2.8 /ESP (Szpunar, 1993)
	2.8 / ESP (Wang et al., 1995)
	3.9 / ESP (Heble, 2000)
	0.7-1.9 / ESP (Otero-Rey et al., 2003)
	1.5-2.1 / ESP (Reddy et al., 2005)
	0.85 / ESP (Goodarzi, 2006)
	1.7 / ESP, 0.41 / ESP+FGD (Meij and Te Winkel, 2007)
	1.6/ ESP + FGD (Ito et al., 2006)
	13. 8 / ESP (Tian et al., 2013)
Cd	6.3-11.5 / ESP (Ondov et al., 1979)
	25.4 / ESP (Brooks, 1989)
	2.7 / ESP (Szpunar, 1993)
	12.3-18.6 (Reddy et al., 2005)
	1.42 / ESP (Goodarzi, 2006)
	1.4 / ESP+FGD (Ito et al., 2006)
	1.5 / ESP, 0.29 / ESP+ FGD (Meij and Te Winkel, 2007)
	3.53 (Tian et al., 2013)
Hg	53.4-93.5 (Wang et al.,2000)
	68.3 / ESP (Zhu et al., 2002)
	71.2-80.3 / ESP (Otero-Rey et al., 2003)
	61-73 / ESP (Pavlish et al., 2003)
	72.6- 80.1 / ESP (Reddy et al., 2005)
	69.4 / ESP (Streets et al., 2005)
	56.5 /ESP (Goodarzi, 2006)
	83 / ESP (Guo et al., 2007)
	88.5 / ESP (Zhang et al., 2008)
	29.1 / ESP+FGD (Yokoyama et al., 2000)
	26.0 / ESP+FGD (USEPA, 2002)
	24.6 / ESP+FGD (Lee et al., 2006)
	27.6 / ESP+FGD (Ito et al., 2006)
	50.4 / ESP, 25.1 / ESP+FGD (Meij and Te Winkel, 2007)
	53.6-93.9 / ESP, 18.6-32.2 / ESP+FGD (Wang et al., 2010)
66.8 / ESP, 9.61 / ESP + FGD (Tian et al., 2013)	
Pb	3.7-5.5 / ESP (Ondov, 1979)
	1.8 / ESP (Szpunar, 1993)

Continued

Pb	0.4-0.5 /ESP (Reddy et al., 2005)
	0.38 / ESP (Goodarzi, 2006)
	1.2 / ESP +FGD (Ito et al., 2006)
	0.90 / ESP, 0.18 / ESP+FGD (Meij and Te Winkel, 2007)
	2.83 / ESP (Tian et al., 2013)

Table S8

Provincial distribution of average concentration of toxic element in coal ash ($\mu\text{g/g}$).

	As	Cd	Hg	Pb
Anhui	16.7	0.62	0.79	77.3
Beijing	38.6	6.22	0.52	259
Chongqing	21.5	4.55	0.38	117
Fujian	108	3.33	0.24	282
Gansu	54.0	1.02	1.12	110
Guangdong	93.5	2.76	0.25	278
Guangxi	186	4.43	1.16	333
Guizhou	75.0	8.71	1.40	271
Hebei	38.1	1.76	0.37	232
Heilongjiang	24.5	0.92	0.27	161
Henan	14.7	3.54	0.43	113
Hubei	64.9	4.33	0.78	587
Hunan	122	7.25	0.44	306
Inner Mongolia	87.9	1.50	1.07	411
Jiangsu	23.3	0.50	1.87	180
Jiangxi	95.1	7.05	0.65	251
Jilin	126	1.60	1.38	319
Liaoning	43.0	1.23	0.42	156
Ningxia	52.3	15.5	1.00	204
Qinghai	14.1	0.16	0.42	57.1
Shaanxi	49.2	9.36	0.85	453
Shandong	57.1	4.18	0.63	184
Shanghai	64.1	2.56	1.16	317
Shanxi	27.6	5.28	0.39	191
Sichuan	79.3	28.2	1.36	422
Tianjin	46.1	19.8	0.63	347
Xinjiang	25.0	0.99	0.16	22.8
Yunnan	124	11.0	1.61	603
Zhejiang	99.7	3.82	1.72	145

Table S9

Provincial concentration of As in coal gangue ($\mu\text{g/g}$).

	Min	Max	Ave	Amounts	References
Anhui	2.47	38.6	18.8	330	Cui et al., 2004; Cai et al., 2008; Chen et al., 2011; Zhou et al., 2014a,b
Beijing			1.62	3	Ren et al., 2006
Chongqing	0.40	9.60	3.08	21	Yang et al., 1983; Ren et al., 2006
Fujian	7.50	21.0	12.0	3	Lu et al., 1995; Cui and Chen, 1998; Ren et al., 2006
Gansu	3.49	9.58	3.47	2	Yang et al., 1983; Ren et al., 2006
Guangxi			3.84	1	Yang et al., 1983; Ren et al., 2006
Guizhou	2.89	3.15	3.02	2	Zhang, 2009
Hebei	0.50	7.20	2.38	9	Yang et al., 1983; Dai, 2002; Ren et al., 2006
Heilongjiang	2.20	11.1	6.00	5	Song, 2007
Henan	2.08	12.3	6.45	22	Cui et al., 2004; Jin et al., 2012
Hubei	9.6	24.3	17.3	3	Yang et al., 1983; Lu et al., 1995; Ren et al., 2006
Hunan	1.30	15.1	4.14	17	Yuan, 1999; Ren et al., 2006
Inner Mongolia	9.81	17.2	13.5	5	Ao, 2005; Sun et al., 2007
Jiangsu	0.40	8.00	2.04	12	Chen and Tang, 2002; Ren et al., 2006
Jiangxi	8.2	30.1	17.1	8	Zhou, 1991; Ren et al., 2006
Jilin	0.40	61.4	7.45	56	Wu et al., 2004; Ren et al., 2006
Liaoning	0.50	28.2	9.26	12	Zhao, 2007
Ningxia	0.25	9.05	0.97	11	Dai, 2002; Song, 2003; Ren et al., 2006
Qinghai	1.34	3.62	2.70	4	Ren et al., 2006
Shaanxi	1.00	3.00	1.90	5	Yang et al., 1983; Ren et al., 2006
Shandong	0.45	8.14	5.34	35	Liu et al., 2001; Xu et al., 2002; Yin et al., 2006; Wu et al., 2009
Shanxi	0.78	27.5	3.62	60	Ge, 1996; Zhang, 2012
Sichuan	1.54	31.8	10.7	6	Zhang et al., 1992; Yuan, 1999; Ren et al., 2006
Xinjiang	0.92	4.28	1.85	10	Chen and Tang, 2002; Ren et al., 2006
Yunnan	0.10	86.2	6.20	96	Zhou, 1998; Ren et al., 2006
Zhejiang	4.21	17.5	13.0	8	Yang et al., 1983; Li et al., 1993; Cui and Chen, 1998; Ren et al., 2006

Table S10

Provincial concentration of Cd in coal gangue ($\mu\text{g/g}$).

	Min	Max	Ave	Amounts	References
Anhui	0.02	0.54	0.07	330	Cui et al., 2004; Cai et al., 2008; Chen et al., 2011; Zhou et al., 2014a,b
Beijing			0.66	1	Tian et al., 2014
Chongqing	0.16	5.40	2.21	5	Ren et al., 2006
Fujian	0.03	0.61	0.19	5	Lu, 1995; Yue et al., 2005
Gansu			0.08	1	Ren et al., 2006
Guangxi			0.25	1	Lu, 1995
Guizhou	0.15	0.37	0.26	10	Ding et al., 2011
Hebei	0.09	0.93	0.21	30	Zhuang et al., 1999; Ren et al., 2006
Heilongjiang	0.02	0.25	0.17	9	Wang et al., 1996; Ren et al., 2006
Henan	0.05	1.47	0.69	22	Cui et al., 2004; Jin et al., 2012
Hubei	0.08	0.63	0.38	2	Lu, 1995; Ren et al., 2006
Hunan	0.7	1.20	0.95	10	Wang, 1994; Ren et al., 2006
Inner Mongolia	2.84	5.82	3.52	5	Ao, 2005; Sun et al., 2007
Jiangsu	n.d.	0.11	0.03	5	Tang and Zhao, 2002; Ren et al., 2006
Jiangxi	0.20	1.00	0.53	4	Zhuang et al., 2001; Ren et al., 2006
Jilin	n.d.	0.44	0.18	56	Wu et al., 2004; Ren et al., 2006
Liaoning	n.d.	0.80	0.17	14	Zhao, 2007
Ningxia	0.02	2.30	0.15	12	Dai, 2002; Song, 2003; Ren et al., 2006
Qinghai	0.01	0.04	0.03	4	Ren et al., 2006
Shaanxi			0.75	1	Tian et al., 2014
Shandong	0.42	1.06	0.76	21	Liu et al., 2001; Xu et al., 2002; Yin et al., 2006; Wu et al., 2009
Shanxi	0.11	1.70	0.23	60	Ge, 1996; Zhang, 2012
Sichuan	0.79	3.10	2.13	5	Ren et al., 2006
Xinjiang	0.04	0.32	0.12	5	Ren et al., 2006
Yunnan	0.50	2.90	0.59	42	Zhou, 1998; Ren et al., 2006
Zhejiang	0.35	0.59	0.51	2	Ren et al., 2006

Table S11

Provincial concentration of Pb in coal gangue ($\mu\text{g/g}$).

	Min	Max	Ave	Amounts	References
Anhui	1.09	32.2	28.7	330	Cui et al., 2004; Cai et al., 2008; Chen et al., 2011; Zhou et al., 2014a,b
Beijing			17.2	1	Ren et al., 2006
Chongqing	16.8	42.5	24.4	5	Ren et al., 2006
Fujian	4.98	42.2	32.3	5	Lu, 1995; Yue et al., 2005
Gansu	2.75	13.5	8.35	3	Ren et al., 2006
Guangxi	18.1	59.0	47.1	5	Lu, 1995; Ren et al., 2006
Guizhou	5.15	13.7	9.64	10	Ding et al., 2011
Hebei	4.50	37.8	18.7	5	Li, 2010; Ouyang et al., 2013
Heilongjiang	12.3	28.4	23.5	9	Song, 2007
Henan	7.52	52.8	36.1	22	Cui et al., 2004; Jin et al., 2012
Hubei	22.7	53.8	38.3	2	Lu, 1995; Ren et al., 2006
Hunan	26.5	43.9	35.2	2	Ren et al., 2006
Inner Mongolia	10.0	15.6	12.8	5	Ao, 2005; Sun et al., 2007
Jiangsu	2.30	50.6	17.8	4	Tang and Zhao, 2002; Ren et al., 2006
Jiangxi	8.50	18.0	12.4	4	Lu, 1995; Zhuang et al., 2001; Ren et al., 2006
Jilin	1.60	69.0	30.7	56	Wu et al., 2004; Ren et al., 2006
Liaoning	4.40	47.0	26.4	14	Zhao, 2007
Ningxia	3.80	16.2	8.54	7	Dai, 2002; Song, 2003
Qinghai	6.20	22.6	10.7	4	Ren et al., 2006
Shaanxi	16.2	28.7	24.5	11	Ren et al., 2006
Shandong	27.1	256	38.6	35	Liu et al., 2001; Xu et al., 2002; Yin et al., 2006; Wu et al., 2009
Shanxi	0.50	108	25.3	60	Ge, 1996; Zhang, 2012
Sichuan	6.50	49.7	29.7	4	Zhang et al., 1992; Ren et al., 2006
Xinjiang	1.20	9.90	5.28	4	Ren et al., 2006
Yunnan	10.5	19.3	15.2	3	Rong, 2003; Ren et al., 2006
Zhejiang	11.6	22.9	17.1	2	Ren et al., 2006

Table S12

Provincial concentration of Hg in coal gangue ($\mu\text{g/g}$).

	Min	Max	Ave	Amounts	References
Anhui	0.220	0.760	0.630	90	Cui et al., 2004; Cai et al., 2008
Beijing			0.100	1	Ren et al., 2006
Chongqing	0.500	0.616	0.553	4	Yao et al., 2004; Ren et al., 2006
Fujian			0.070		Tian et al., 2014
Gansu			1.350	1	Ren et al., 2006
Guangxi			0.330		Tian et al., 2014
Guizhou	0.076	0.377	0.137	29	Song and He, 2009
Hebei	0.031	0.800	0.163	24	Zhuang et al., 1999; Dai, 2002; Ren et al., 2006
Heilongjiang	0.012	0.069	0.035	5	Song, 2007
Henan	0.100	0.130	0.120	2	Jin et al., 2012
Hubei			0.230	1	Ren et al., 2006
Hunan	0.046	0.197	0.071	10	Wang 1994
Inner Mongolia	0.004	0.771	0.326	4	Sun et al., 2007
Jiangsu	0.022	0.300	0.177	9	Huang and Yang, 2002; Ren et al., 2006
Jiangxi			0.200	1	Ren et al., 2006
Jilin			0.430	1	Wang and Ma, 1997
Liaoning	n.d.	0.400	0.150	14	Zhao, 2007
Ningxia	0.106	0.220	0.154	6	Dai, 2002; Song, 2003
Qinghai	0.200	0.570	0.308	4	Ren et al., 2006
Shaanxi	0.100	0.400	0.300	3	Ren et al., 2006
Shandong	0.020	1.860	0.740	35	Liu et al., 2001; Xu et al., 2002; Yin et al., 2006; Wu et al., 2009
Shanxi	0.010	3.350	0.320	54	Ge, 1996
Sichuan	0.300	0.660	0.412	5	Ren et al., 2006
Xinjiang	0.018	0.280	0.092	6	Ren et al., 2006
Yunnan	0.015	3.800	0.380	42	Zhou, 1994
Zhejiang	0.240	1.260	0.750	2	Yang et al., 1983; Ren et al., 2006

Table S13

The concentration of toxic element in the selected coal, coal gangue, coal ash, clay samples and their combustion products.

	Ash yield (%)	Raw materials ($\mu\text{g/g}$)				Combustion residues ($\mu\text{g/g}$)				Flue gas ($\mu\text{g/m}^3$)			
		As	Cd	Hg	Pb	As	Cd	Hg	Pb	As	Cd	Hg	Pb
Coal -1	14.7	3.52	0.12	0.262	14.8	17.4	0.50	0.290	64.8	6.23	0.28	1.182	31.7
Coal -2	18.4	5.43	0.07	0.193	16.3	20.0	0.25	0.110	51.6	8.05	0.16	1.035	37.6
Coal -3	16.2	2.73	0.08	0.346	10.5	12.1	0.32	0.180	43.7	5.34	0.17	1.810	23.1
Coal gangue -1	57.6	24.4	0.04	0.317	23.6	32.1	0.04	0.175	29.3	37.3	0.09	1.299	45.8
Coal gangue -2	62.5	19.5	0.06	0.230	28.8	23.8	0.05	0.096	33.6	26.4	0.16	1.046	45.4
Coal gangue -3	55.3	25.7	0.04	0.174	24.9	34.0	0.04	0.073	30.9	38.4	0.10	0.757	43.1
Coal ash -1	96.7	16.9	0.56	0.325	66.5	14.2	0.42	0.310	52.5	20.4	0.93	0.108	86.2
Coal ash -2	98.5	17.4	0.68	0.284	72.3	13.6	0.49	0.269	59.0	19.3	1.20	0.116	84.1
Coal ash -3	97.3	15.5	0.63	0.168	53.4	12.9	0.48	0.156	43.1	21.1	0.97	0.056	73.0
Clay -1	92.8	15.2	0.04	0.022	12.5	14.9	0.04	0.011	12.5	8.39	0.03	0.067	8.03
Clay -2	94.6	8.39	0.02	0.043	18.9	8.06	0.02	0.023	17.7	4.83	0.02	0.136	14.2
Clay -3	95.6	12.6	0.08	0.076	16.6	11.9	0.07	0.040	15.2	6.35	0.06	0.220	9.76

Table S14

The mass balance and distribution characterization of toxic element.

	Combustion residues % total				Flue gas % total				Mass balance %			
	As	Cd	Hg	Pb	As	Cd	Hg	Pb	As	Cd	Hg	Pb
Coal -1	70.5	61.5	24.8	64.3	29.5	38.5	75.2	35.7	78.4	61.5	109.2	78.6
Coal -2	75.3	62.4	10.6	61.5	24.7	37.6	89.4	38.5	74.2	54.8	114.8	68.3
Coal -3	67.4	65.6	12.8	63.4	32.6	34.4	87.2	36.6	69.3	50.7	112.6	73.9
Coal gangue -1	74.6	61.5	31.7	67.6	25.4	38.5	68.3	32.4	73.6	58.6	117.5	82.1
Coal gangue -2	77.4	54.8	24.2	73.7	22.6	45.2	75.8	26.3	68.7	48.5	123.6	79.5
Coal gangue -3	75.1	57.0	27.5	71.1	24.9	43.0	72.5	28.9	82.3	56.9	108.3	69.4
Coal ash -1	79.8	72.3	94.5	78.4	20.2	27.7	5.52	21.6	65.6	64.4	121.4	74.4
Coal ash -2	81.5	70.5	93.2	80.6	18.5	29.5	6.83	19.4	73.7	53.2	113.6	79.6
Coal ash -3	77.3	74.3	94.5	77.2	22.7	25.7	5.54	22.8	77.4	56.4	116.5	69.3
Clay -1	90.8	87.6	49.5	89.3	9.20	12.4	50.5	10.7	65.8	47.6	115.3	64.7
Clay -2	90.4	86.3	47.4	87.4	9.60	13.7	52.6	12.6	81.7	57.2	117.2	68.9
Clay -3	91.6	87.5	51.7	90.2	8.40	12.5	48.3	9.80	72.4	56.5	120.5	76.2

Table S15

The concentration of toxic element in flue gas at the inlet/outlet of wet flue gas desulfurization systems and removal efficiency.

	Inlet of desulfurization system ($\mu\text{g}/\text{m}^3$)				Outlet of desulfurization system ($\mu\text{g}/\text{m}^3$)				Removal efficiency (%)			
	As	Cd	Hg	Pb	As	Cd	Hg	Pb	As	Cd	Hg	Pb
Sample-1	47.6	1.56	2.32	67.8	41.22	1.41	2.20	60.61	13.4	9.47	5.35	10.6
Sample-2	56.4	1.74	1.96	75.6	46.92	1.54	1.87	69.23	16.8	11.5	4.65	8.43
Sample-3	53.9	1.36	2.46	78.5	46.03	1.25	2.30	69.16	14.6	8.43	6.43	11.9

Table S16

Uncertainties in the emissions of As, Cd, Hg, and Pb by different raw materials in China in 2013 (t) at a 95% confidence interval around the central estimate.

Raw materials	As	Cd	Hg	Pb
Coal	28.66 (-6%, 18%)	4.03 (-9%, 23%)	3.80 (-16%, 27%)	171.45 (-7%, 14%)
Coal ash	566.02 (-53%, 46%)	84.99 (-35, 59%)	1.98 (-19%, 26%)	2891.38 (-37%, 52%)
Coal gangue	38.38 (-14%, 35%)	5.82 (-9%, 16%)	3.57 (-8%, 22%)	177.28 (-14%, 43%)
Clay	10.99 (-98%, 85%)	0.12 (-72%, 63%)	0.36 (-68%, 89%)	29.68 (-122%, 76%)
Total	644.05 (-22%, 37%)	94.96 (-28%, 45%)	9.71 (-15%, 23%)	3269.79 (-32%, 43%)

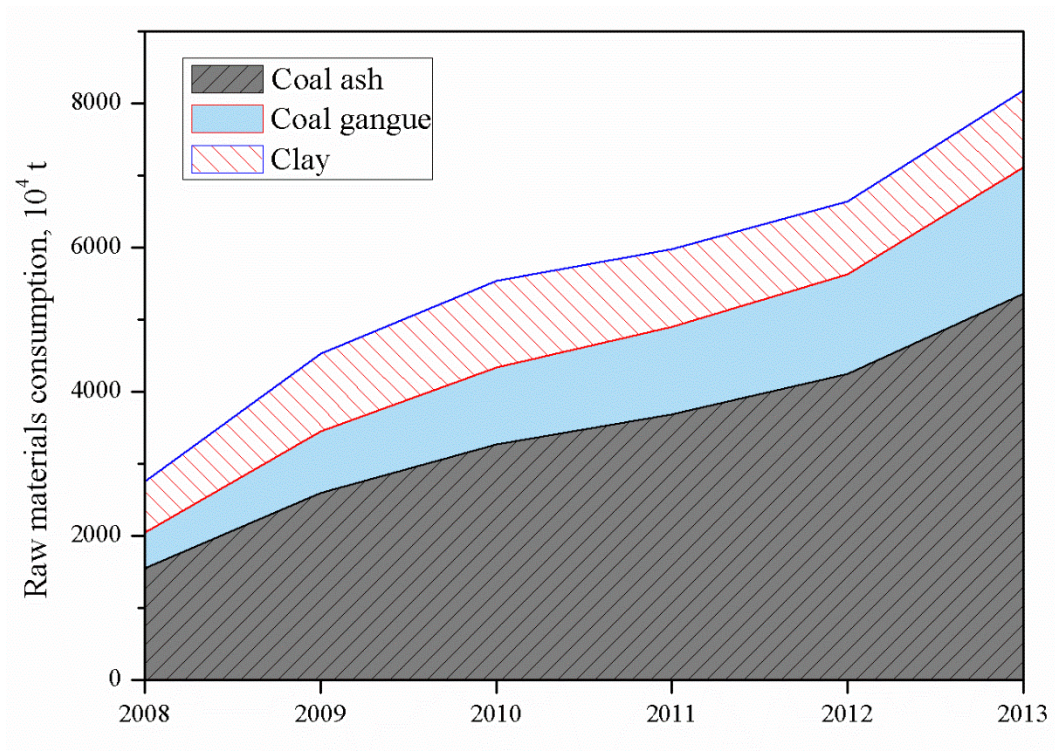


Figure S1. Trend of raw materials consumption in China, 2008-2013.

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